Big Sandy Power Plant
Fly Ash Pond
Alternative Source Demonstration

The Big Sandy Fly Ash Pond initiated an assessment monitoring program in accordance with 40 CFR 257.95 on April 13, 2018. Groundwater protection standards (GWPS) were set in accordance with 257.95(d)(2) and a statistical evaluation of the assessment monitoring data was conducted. This statistical evaluation revealed an exceedance of the GWPS for beryllium, cobalt, and lithium at Monitoring Well MW-1603 on February 3, 2021. A successful alternative source demonstration (ASD) was completed per 257.95(g)(3), therefore, the Big Sandy Fly Ash Pond will remain in assessment monitoring. An alternative source demonstration is documentation that shows a source other than the CCR unit was responsible for causing the statistics to exceed the GWPS. The ASD document will explain the alternate cause of the GWPS exceedances. The successful ASD is attached.

Alternative Source Demonstration Addendum Report for the October 2020 Monitoring Data

Big Sandy Fly Ash Pond
Louisa, Kentucky

Prepared for:

American Electric Power

Prepared by:

EHS Support℠

April 2021

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Acronyms

µg/L	micrograms per liter
AEP	American Electric Power
ASD	alternative source demonstration
bgs	below ground surface
BSFAP	Big Sandy Fly Ash Pond
CCR	coal combustion residual
CFR	Code of Federal Regulations
EPRI	Electric Power Research Institute
ft	foot/feet
GWPS	Groundwater Protection Standards
KGS	Kentucky Geological Survey
LCL	lower confidence level
mg/L	milligrams per liter
msl	mean sea level
MDL	method detection limit
ORP	oxidation-reduction potential
pCi/L	picocuries per liter
ppm	parts per million
SSL	statistically significant level
S.U.	standard units (pH)
TDS	total dissolved solids
UCL	upper confidence level
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Certification by Qualified Professional Engineer

I certify that the alternative source demonstration (ASD) conducted and presented within this report is accurate and appropriate for evaluating the groundwater monitoring data for the Big Sandy Fly Ash Pond Coal Combustion Residual (CCR) management area associated with the Big Sandy Power Plant located in Louisa, Kentucky. This ASD meets the requirements of the United States Environmental Protection Agency CCR Rule defined at 40 Code of Federal Regulations 257.95(g)(3)(ii).

Jonathan Patrick Waddell
Printed Name of Licensed Professional Engineer

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1 Introduction

EHS Support LLC ("EHS Support") was retained by American Electric Power (AEP) – Kentucky Power Company in December 2018 to conduct an alternative source demonstration (ASD) investigation for coal combustion residual (CCR) constituents in groundwater near the Big Sandy Fly Ash Pond (BSFAP). The BSFAP is associated with the Big Sandy Power Plant located in Louisa, Kentucky (EHS Support, 2019a). The ASD determined that groundwater in the vicinity of the BSFAP was not being impacted by CCR constituents from the BSFAP. The statistically significant levels (SSLs) of beryllium, cobalt, and lithium concentrations present in excess of the Groundwater Protection Standards (GWPS), which triggered the ASD investigation, were determined to be a result of the oxidation of coal seams that were intersected by the borehole and well screen for well MW-1603.

Since the initial ASD investigation was completed (incorporating data from September 2016 to October 2018), the following ASD investigations have been conducted:

- The second ASD investigation was conducted after the March 2019 groundwater monitoring data indicated continued SSLs of beryllium, cobalt, and lithium exceeding the GWPS at MW-1603 (EHS Support, 2019b).
- The third ASD investigation was conducted following continued detections of beryllium, cobalt, and lithium at SSLs above the GWPS in MW-1603 during the August 2019 sampling event (EHS Support, 2020). In addition, an SSL of radium 226 combined with radium 228 (hereafter radium 226/228) above its GWPS was measured for the first time in MW-1603 during the August 2019 sampling event (EHS Support, 2020).
- The fourth ASD investigation was conducted following continued detections of the four constituents (beryllium, cobalt, lithium, and radium 226/228) at SSLs above the GWPS in MW-1603 In March and June 2020 (EHS Support, 2021).

In October 2020, three constituents (beryllium, cobalt, and lithium) were detected at SSLs above the GWPS in MW-1603, thus requiring the ASD addendum investigation presented in this report. This ASD addendum investigation has been prepared per the requirements of the United States Environmental Protection Agency (USEPA) CCR Rule (40 Code of Federal Regulations [CFR] §257.95). The concentrations of beryllium, cobalt, and lithium in MW-1603 groundwater were determined herein to result from Type IV natural variations in groundwater (ASD types are discussed in **Section 3.1**). This conclusion was reached by examining analytical results for compounds detected at SSLs in the context of the broader list of CCR constituents analyzed at the Site.

1.1 Objectives

The objective of this ASD investigation is to assess groundwater monitoring data collected in compliance with the CCR Rule, as allowed under paragraph 40 CFR §257.95(g)(3)(ii) of the CCR Rule. This part of the CCR Rule allows AEP to determine whether the source(s) for SSLs of beryllium, cobalt, and lithium exceeding the GWPSs, as reported in groundwater monitoring well MW-1603, are associated with the CCR unit; or alternatively if the SSL resulted from an error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality.

1.2 Lines of Evidence

This fifth ASD investigation for the BSFAP has been conducted to further evaluate potential alternate sources or reasons for the continuing detection of SSLs of beryllium, cobalt, and lithium in groundwater samples from monitoring well MW-1603.

A potential alternate source was previously identified in the prior four ASD investigations (EHS Support, 2019a, 2019b, 2020, and 2021), based on the following lines of evidence:

- A lack of exceedances and increasing trends of primary indicators of CCR.
- Constituent concentrations in BSFAP water lower than those of the corresponding constituent observed in groundwater from MW-1603.
- Major ion chemistry was not indicative of mixing between BSFAP water and groundwater.

For the purposes of this ASD addendum investigation, constituents were identified that would serve as a primary indicator for CCR. A primary indicator must meet **both** of the following criteria:

1. Constituent typically has a high concentration in CCR leachate, relative to background, such that it is expected to have an elevated concentration in the event of a release.
2. Constituent is unreactive and has high mobility in groundwater, such that it is expected to be at the leading edge of the plume. Consequently, the constituent will have elevated concentrations relative to background across the entire area of the plume.

As boron and sulfate are primary indicators for CCR (Electric Power Research Institute [EPRI], 2012) and have previously been evaluated, they have been re-evaluated herein as primary indicators for this ASD investigation. In addition, chloride is used as a primary indicator for this ASD. Other potential indicators that were evaluated in this ASD investigation include potassium, sodium, fluoride, molybdenum, and bromide.

2 Project Background

A detailed description of Site location, history, and geology was previously provided in the *Alternative Source Demonstration Report for Beryllium, Cobalt and Lithium, Big Sandy Fly Ash Pond, Louisa, Kentucky* (EHS Support, 2019a). Attached **Figure 1** and **Figure 2** show the Site layout and groundwater monitoring network, respectively.

To support and provide context to this ASD addendum investigation, the following sections describe the groundwater monitoring network and groundwater monitoring.

2.1 Groundwater Monitoring Network Evaluation

On behalf of AEP, Geosyntec Consultants, Inc. ("Geosyntec") conducted an assessment of the groundwater monitoring network in the uppermost aquifer associated with the BSFAP (Geosyntec, 2016). Geosyntec determined that the hydrostratigraphy in the vicinity of the BSFAP is characterized by an interconnected water-bearing system comprised of Pennsylvanian-aged bedrock (of the Breathitt Group, Conemaugh Formation) and Quaternary alluvium. The Conemaugh Formation and Breathitt Group consists of sandstones, siltstones, shale, and coal that may grade laterally and vertically into one another. The overlying Quaternary alluvium deposits include sandy lean clay to silty sand and gravel at the bottom of the Horseford Creek valley and the floodplain of Blaine Creek. Based on these hydrogeologic conditions, Geosyntec defined the interconnected water-bearing system of the fractured bedrock and alluvium as the uppermost aquifer for the BSFAP CCR unit. This determination was based on the presence of groundwater in numerous monitoring wells screened in the water-bearing units (fractured bedrock and alluvium), the recovery of these wells during pumping and development, and a potentiometric surface generally consistent with Site topography and surface water elevations.

To assess the upper water-bearing aquifer (fractured bedrock and alluvium), Geosyntec defined the groundwater detection monitoring network with 10 groundwater monitoring wells (Geosyntec, 2016). Of these, six monitoring wells (MW-1011, MW-1012, MW-1203, MW-1601, MW-1602, and MW-1603) are screened in fractured sandstone and shale layers of the Breathitt formation. The remaining four monitoring wells (MW-1604 through MW-1607) are screened in the alluvium. The location of each groundwater monitoring well within the uppermost aquifer is shown in **Figure 2**.

Three of the monitoring wells (MW-1011, MW-1012, and MW-1203) screened in bedrock were installed on the hillside slopes upgradient of the BSFAP to support background monitoring. Three monitoring wells (MW-1601, MW-1602, and MW-1603) were installed in bedrock located downgradient of the BSFAP and used for compliance monitoring. Two monitoring wells (MW-1604 and MW-1605) were screened in alluvium and are used for background monitoring; while the remaining two monitoring wells (MW-1606 and MW-1607), screened in alluvium and located below the Main Dam, are used for compliance monitoring.

As bedrock monitoring well MW-1603 is the focus of this ASD, the boring log was reviewed (EHS Support, 2019a). The boring log descriptions show alternating sequences of yellowish-brown sandstones and bluish-gray to black shales (beginning at 13 feet below ground surface [ft bgs] and extending to the bottom of the boring at 39.5 ft bgs) that are indicative of the upper portion of the Princess Formation (uppermost formation in the Breathitt Group [Rice and Hiett, 1994]). Within the screened interval (22 to

32 ft bgs), the shale at a depth of 24 to 25 ft bgs was described as "intensely fractured, black, wet, nearly all organic matter; slight coaly texture." This depth (24 to 25 ft bgs) corresponds with the measurements by the Kentucky Geological Survey (KGS) of the elevation of the Princess Number 8 coal, which is present within the Princess Formation of the Breathitt Group (EHS Support, 2019a). Coal or "organic material" was also visually identified during soil boring logging in three other monitoring wells (MW-1608, MW-1609, and MW-1610) in the network (**Table 2-1**) at the same approximate elevation, between 630 and 650 feet, that matches the KGS measurements. No coal was documented in this section in three monitoring wells (MW-1601, MW-1602, and MW-1611). Four monitoring wells (MW-1604, MW-1605, MW-1606, and MW-1607) were installed below this coal layer in the sedimentary sequence.

Table 2-1 Screened Interval of Monitoring Wells

Well/Boring	Surface Elevation (ft msl)	Screened Interval (ft msl)	Coal or "Organics" Description at ~632-650 ft
MW-1601	713.8	646.8-636.8	No coal logged
MW-1602	711.6	632.1-622.1	No coal logged
MW-1603	673.2	651.2-641.2	Yes, at a depth of ~25 ft (Elevation of 648 ft)
MW-1604	553.1	513.1-503.1	---
MW-1605	554.4	538.9-528.9	---
MW-1606	551	513.1-503.1	---
MW-1607	542.2	518.7-508.7	---
MW-1608	716.2	606.6-596.6	Yes, at depths of ~74 ft (Elevation of 642 ft), ~ 75.3 to 76.6 ft (Elevation of 641 to 640 ft), and ~ 83.5 to 84 ft (Elevation of 633 to 632 ft)
MW-1609	~728	---	Yes, at a depth of ~79 ft (Elevation of 649 ft)
MW-1610	~716	---	Yes, at a depth of ~81 ft (Elevation of 635 ft)
MW-1611	~711	606-596	No coal logged

--- = Boring advanced below the coal interval
~ = Approximate
ft = feet
msl = mean sea level

Geosyntec determined that the groundwater monitoring well network described above meets the requirements of 40 CFR §257.91, as it consists of a sufficient number of wells installed at the appropriate locations and depths to yield groundwater samples from the uppermost aquifer, which accurately represents the quality of background groundwater and groundwater passing the waste boundary of the BSFAP.

2.2 Groundwater Monitoring

AEP has conducted groundwater monitoring of the uppermost aquifer to meet the requirements of the CCR Rules. Groundwater monitoring generally included the following activities:

- Collection of groundwater samples and analysis for Appendix III and Appendix IV constituents, as specified in 40 CFR §257.94 *et seq.* and AEP's *Groundwater Sampling and Analysis Plan* (AEP and EHS Support, October 2016).
- Completion of validation tests for groundwater data, including tests for completeness, valid values, transcription errors, and consistent units.
- Establishment of background data for each Appendix III and Appendix IV constituent.
- Initiation of detection monitoring sampling and analysis.
- Evaluation of the groundwater data using a statistical process per 40 CFR §257.93, which was prepared, certified, and posted to AEP's CCR website in April 2017 in AEP's *Statistical Analysis Plan* (Geosyntec, 2017); the statistical process was guided by USEPA's *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* ("Unified Guidance"; USEPA, 2009).
- Initiation of assessment monitoring sampling and analysis.
- Completion of statistical data evaluation and determination of GWPS.

Assessment monitoring for the BSFAP has been conducted on a semi-annual basis since April 2018. The groundwater data collected up until and including the October 2020 monitoring events have been used for this ASD addendum investigation. Assessment monitoring data for well MW-1603 in October 2020 is provided in **Table 2-2**.

Table 2-2 MW-1603 October 2020 Groundwater Quality

Analyte	Unit	October 2020 Value
Antimony	µg/L	<0.02
Arsenic	µg/L	1.12
Barium	µg/L	14.6
Beryllium	µg/L	17.5
Boron	mg/L	0.05
Bromide	mg/L	<0.04
Cadmium	µg/L	0.87
Calcium	mg/L	94.5
Chloride	mg/L	4.1
Chromium	µg/L	0.743
Cobalt	µg/L	90.5
Fluoride	mg/L	0.47
Lead	µg/L	4.85
Lithium	mg/L	0.165

Analyte	Unit	October 2020 Value
Mercury	µg/L	<0.002
Molybdenum	µg/L	<0.4
pH	S.U.	4.09
Potassium	mg/L	4.29
Radium 226/228	pCi/L	2.681
Residue, Filterable, TDS	mg/L	1,020
Selenium	µg/L	5.8
Sodium	mg/L	21.1
Sulfate	mg/L	794
Thallium	µg/L	1.82

< = non detect at method detection limit (MDL)
µg/L = micrograms per liter
mg/L = milligrams per liter
NA = constituent not analyzed
pCi/L = picocuries per liter
S.U. = standard units
TDS = total dissolved solids

AEP submitted the October 2020 monitoring data to Groundwater Stats Consulting, LLC for statistical analysis. A GWPS was established for each of the Appendix IV parameters. Confidence intervals, including lower confidence levels (LCLs) and upper confidence levels (UCLs), were calculated for Appendix IV parameters at the compliance wells to assess whether Appendix IV parameters were present at an SSL above the GWPS. Based on this statistical analysis evaluating the October 2020 data, the following SSLs were identified at the BSFAP in MW-1603 (no other monitoring well had constituents exceeding a GWPS):

- LCL for beryllium exceeded the GWPS of 0.004 milligrams per liter (mg/L) at MW-1603 (0.0167 mg/L).
- LCL for cobalt exceeded the GWPS of 0.006 mg/L at MW-1603 (0.087 mg/L).
- LCL for lithium exceeded the GWPS of 0.04 mg/L at MW-1603 (0.194 mg/L).

3 Alternative Source Demonstration Requirements

3.1 Alternative Source Demonstration

Potential causes that may support an ASD include, but are not limited to, sampling causes (ASD Type I), laboratory causes (ASD Type II), statistical evaluation causes (ASD Type III), and/or natural variation causes (ASD Type IV). This ASD for the BSFAP is focused on assessing whether Type IV natural variations in groundwater could be the cause of the SSLs of beryllium, cobalt, and lithium reported for groundwater collected from monitoring well MW-1603 during the October 2020 sampling.

Historical groundwater monitoring data for MW-1603 is provided in **Table 1**(attached).

3.2 Assessment of Groundwater Monitoring Results

The following constituents will typically provide the information required for a complete ASD:

- Primary indicators (boron and sulfate) are evaluated for potential BSFAP leachate.
- Major ion concentrations (alkalinity, chloride, sulfate, calcium, magnesium, potassium, and sodium) in leachate and groundwater are used to evaluate whether downgradient groundwater chemistry remains representative of background groundwater chemistry. Major ion chemistry can also be used to evaluate natural variability due to seasonal changes or other causes.
- Field turbidity of groundwater is used as an indicator of the presence of suspended solids that may contribute to elevated concentrations of constituents monitored in unfiltered samples under the CCR Rule.
- pH of leachate and groundwater provides information on chemical reactions and potential mobility of constituents in groundwater.
- Dissolved oxygen, oxidation-reduction potential (ORP), iron, and manganese in groundwater are used as indicators of redox conditions. Redox changes can affect the chemical state and solubility of sulfate, in addition to trace elements including arsenic and selenium. For example, under strongly reduced conditions (ORP less than –200 millivolts at pH 7), sulfate can be reduced to form hydrogen sulfide or it can precipitate as iron sulfide, arsenic reduces to the more mobile arsenite species, and selenium reduces to the low-mobility selenite species.

Groundwater monitored at a CCR unit for compliance with the CCR Rule is a compilation of the history of all sources of water comingling at that particular monitoring well. Different sources may contribute to the presence and detection of some of the same constituents, making source identification challenging. The identification and use of water quality “signatures” can be used as a tool for deciphering the similarity between potential sources and the water quality at a specific monitoring point.

4 Alternative Source Demonstration Assessment

As stated within **Section 1.2**, the primary indicators for CCR leachate impacts to groundwater are boron and sulfate. In addition to these two constituents, chloride is also used as a primary indicator for this ASD. Other potential indicators that have been evaluated include potassium, sodium, fluoride, molybdenum, and bromide.

As identified in **Section 1.1**, SSLs of beryllium, cobalt, and lithium have been reported in groundwater samples above the GWPS from monitoring well MW-1603 in October 2020. The water quality signatures for well MW-1603 are discussed in **Section 4.3** and compared to the water quality of the BSFAP.

EPRI (2012) defines three tiers of investigation for evaluation of water quality signatures to determine if elevated concentrations represent a release from a CCR facility:

- Tier I: Trend Analysis and Statistics
- Tier II: Advanced Geochemical Evaluation Methods
- Tier III: Isotopic Analyses

Conversely, these tools can also be used to evaluate whether or not sources other than CCR are contributing to groundwater quality degradation.

The CCR Rule requires statistical analysis under assessment monitoring for the determination of SSLs above the GWPS. Many of the primary and potential indicator constituents listed for CCR (EPRI, 2017) are included in AEP's constituent list for the BSFAP groundwater monitoring programs, including primary constituents boron and sulfate. If there is an SSL without a corresponding increase in a primary indicator constituent (boron and usually sulfate for CCR), then this is a key line of evidence for an ASD.

4.1 Groundwater Data Analysis

Temporal plots are provided in the following subsections for well MW-1603. Each of the plots uses the following color-coding system:

- Red – indicates a concentration reported above the reporting limit.
- Orange – indicates a concentration reported below the reporting limit but greater than the method detection limit (MDL) (denoted as estimated "J" values).
- Green – indicates a concentration not detected at or above the MDL (denoted as "U"); results were conservatively plotted as the MDL.

The October 19, 2017 data for the BSFAP water is presented for comparison. The BSFAP water signature is plotted as a constant concentration in **Figure 4-1** to **Figure 4-12**. As the BSFAP accepted fly ash before 1970, it is probable that BSFAP water quality has historically varied over time. However, since the BSFAP ceased accepting fly ash before 2016, the water quality is anticipated to be more stable; therefore, the October 19, 2017 data provides a reasonable representation of current BSFAP conditions.

Groundwater quality for well MW-1603 is plotted on the primary y-axis and BSFAP water quality is plotted on the secondary y-axis, due to the differences in concentration between the groundwater quality in the vicinity of MW-1603 and the BSFAP water, as labeled in **Figure 4-1** to **Figure 4-12**

4.1.1 Primary Indicators

Temporal plots for primary indicators boron, sulfate, and chloride reported in groundwater monitoring well MW-1603 are provided in **Figure 4-1** to **Figure 4-3**, respectively.

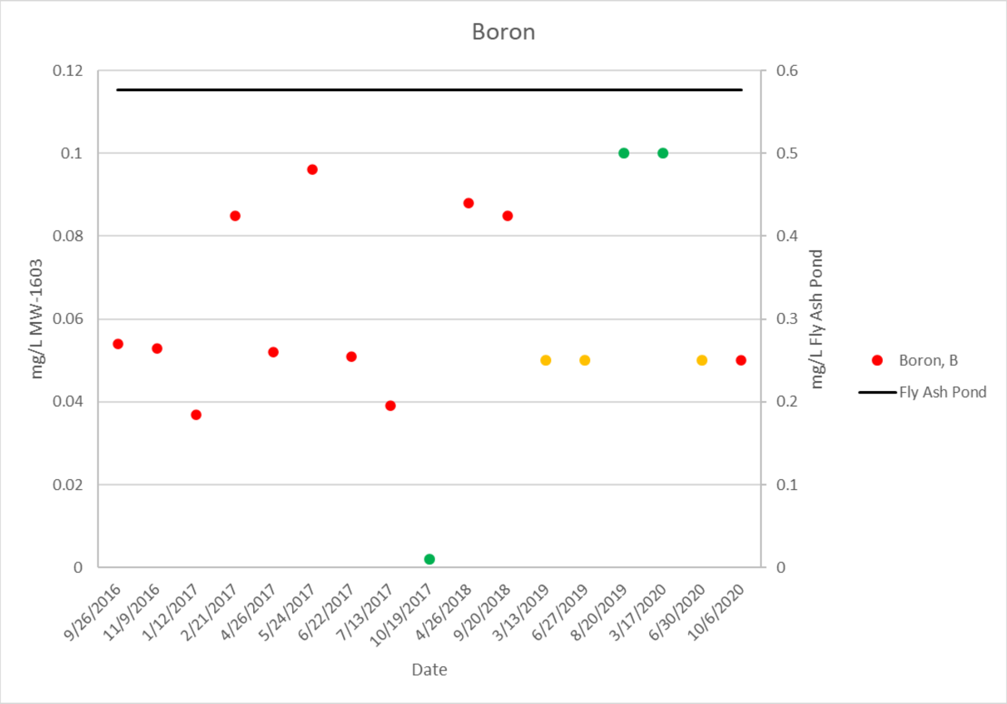

Figure 4-1 MW-1603 Boron Concentrations

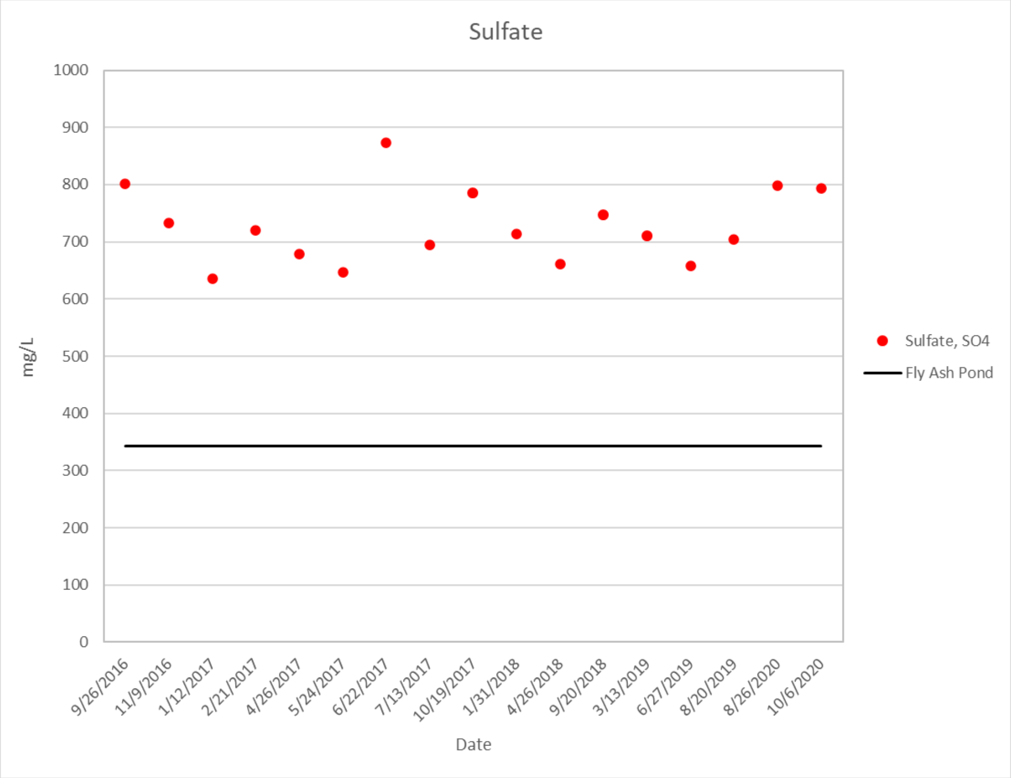

Figure 4-2 **MW-1603 Sulfate Concentrations**

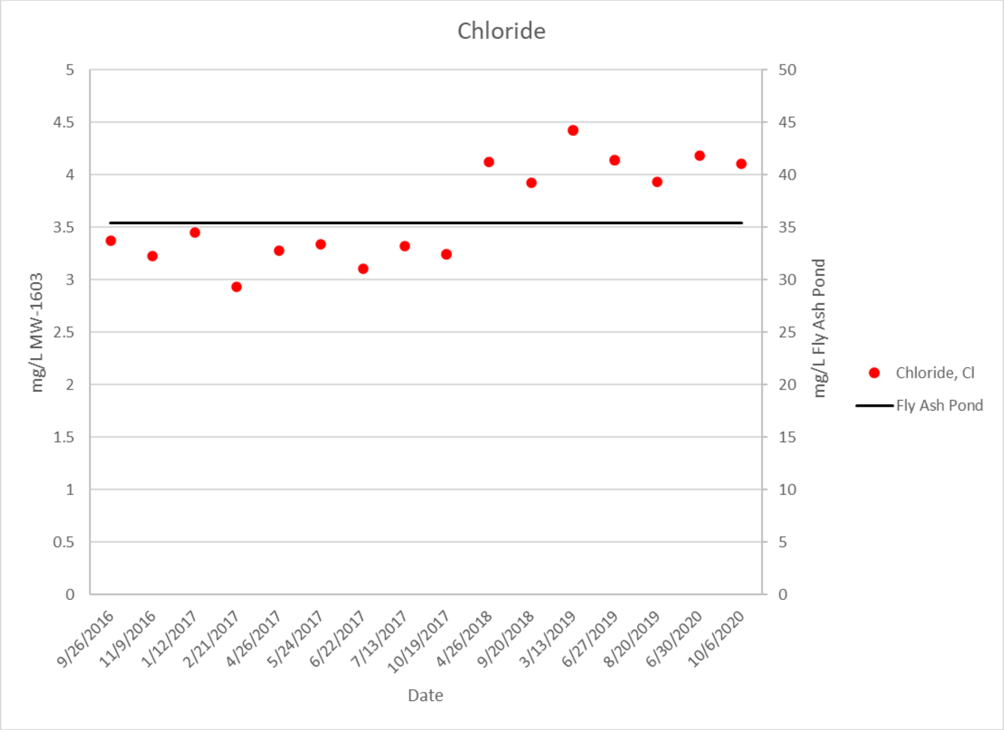

Figure 4-3 **MW-1603 Chloride Concentrations**

Boron and sulfate concentrations in MW-1603 have remained relatively stable within the same order of magnitude, with minor variability over the monitoring period (September 2016 through October 2020). Chloride concentrations in MW-1603 remained relatively stable between 2.93 and 3.24 mg/L until April 2018, after which a slight increase is observed that has remained stable between 3.92 and 4.42 mg/L. Boron and chloride in water from the BSFAP are present at higher concentrations than in groundwater at MW-1603, whereas sulfate is present at higher concentrations in groundwater at MW-1603 than in water from the BSFAP.

In summary, there were negligible changes in primary indicator concentrations since the last review in January 2021.

4.1.2 Potential Indicators

Temporal plots for potential indicators (bromide, fluoride, molybdenum, potassium, and sodium) reported in groundwater monitoring well MW-1603 are provided in **Figure 4-4** to **Figure 4-8**, respectively.

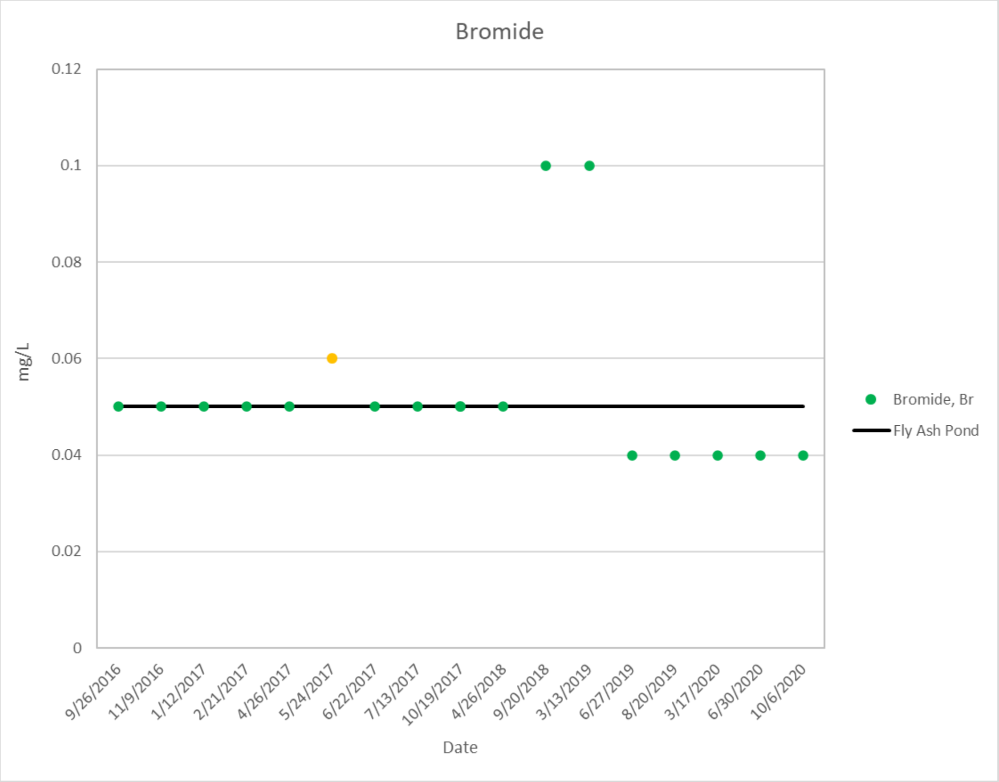

Figure 4-4 MW-1603 Bromide Concentrations[1]

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[1] Bromide is below the level of reporting for the BSFAP water, with an MDL of less than 0.05 mg/L for this sample result.

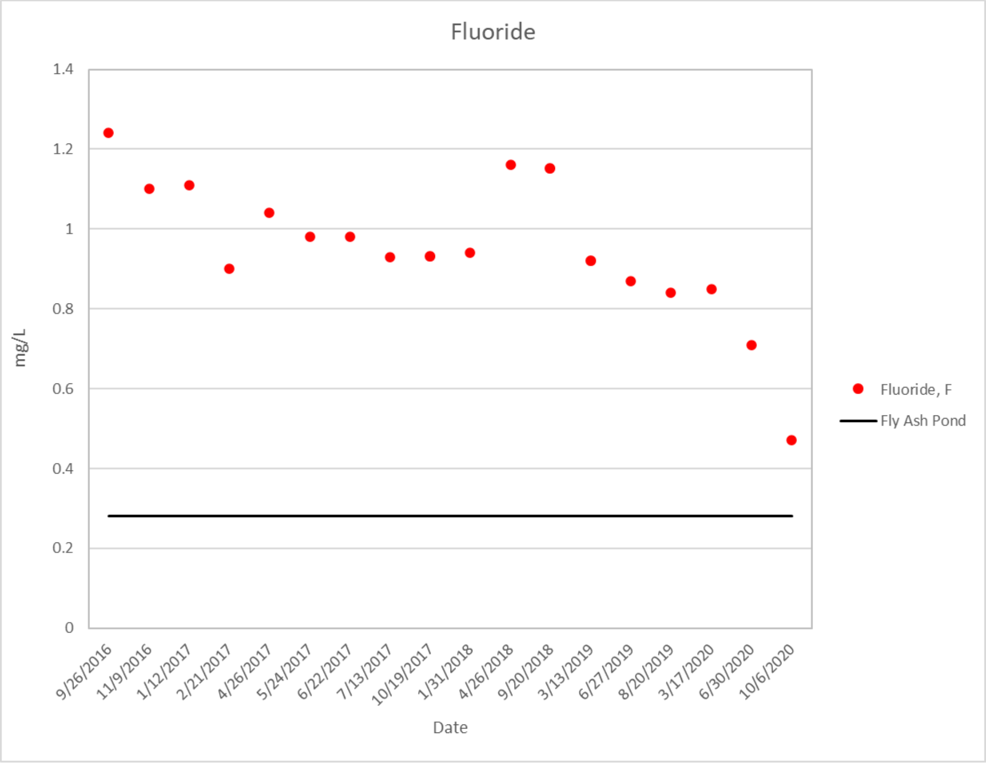

Figure 4-5 MW-1603 Fluoride Concentrations

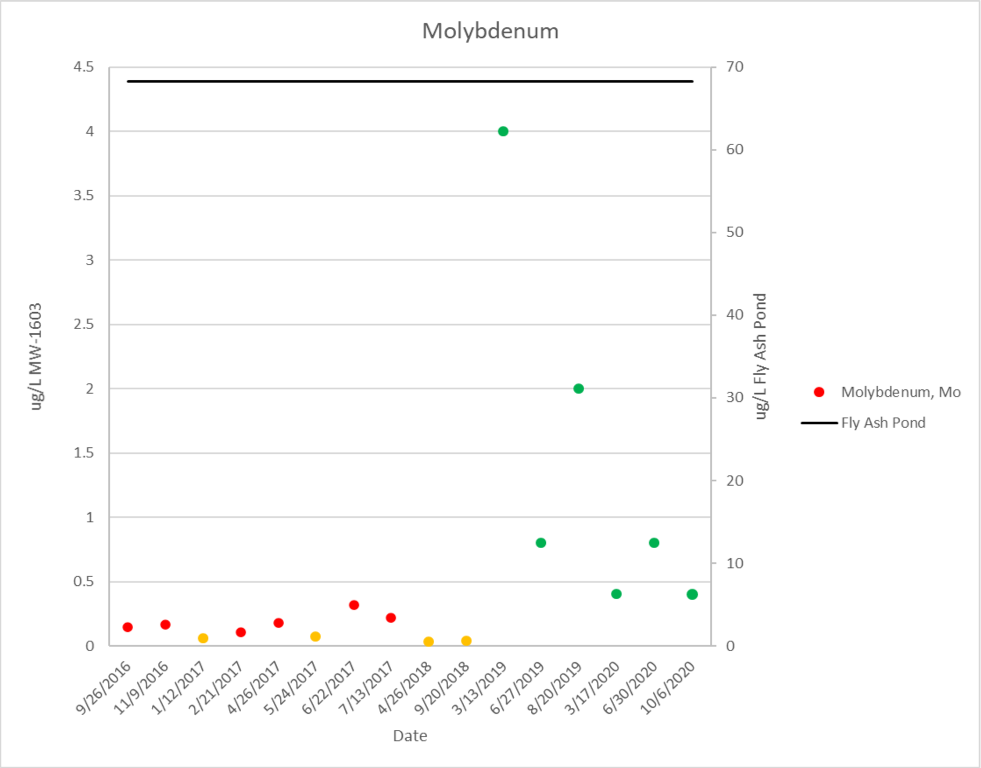

Figure 4-6 MW-1603 Molybdenum Concentrations

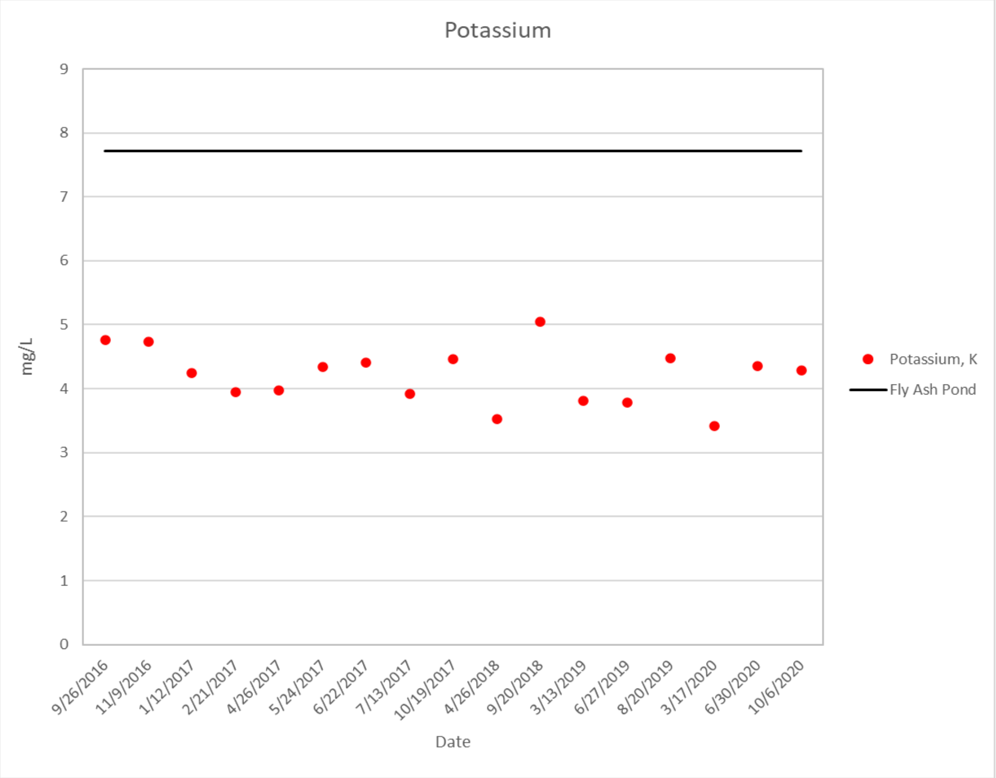

Figure 4-7 **MW-1603 Potassium Concentrations**

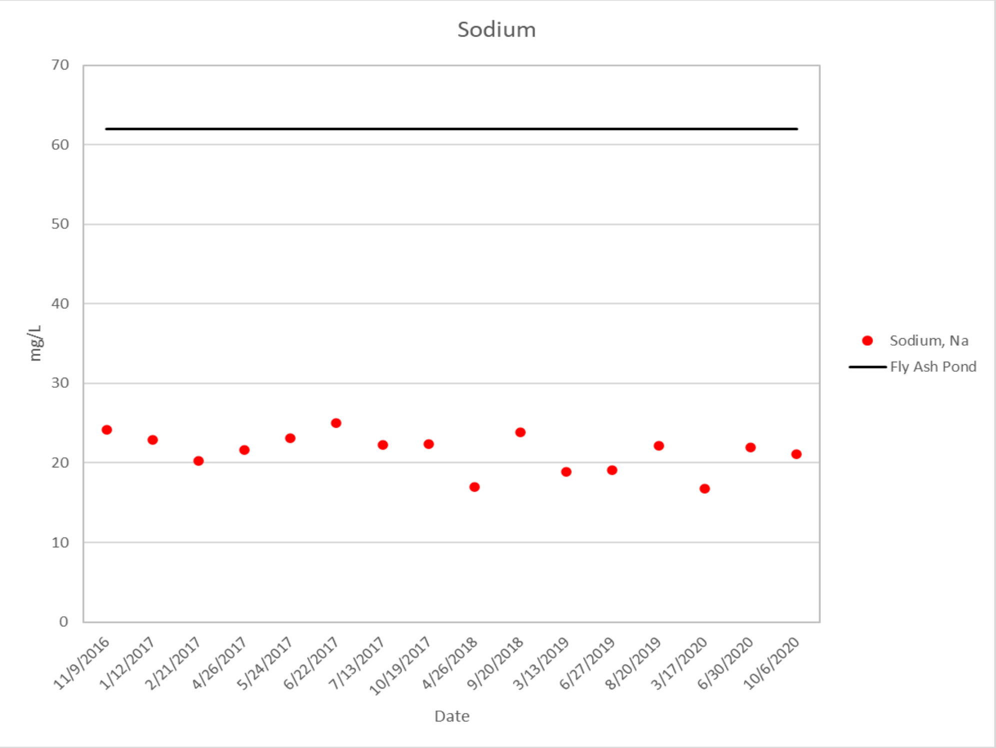

Figure 4-8 **MW-1603 Sodium Concentrations**

Molybdenum, potassium, and sodium concentrations in groundwater from MW-1603 have consistently been lower than water from the BSFAP. As seen in **Figure 4-6**, molybdenum was last detected above MDL in MW-1603 in September 2018. The recent variation in molybdenum concentrations, as shown in green, is due to variable MDLs achieved via laboratory analysis. Fluoride concentrations in groundwater from MW-1603 have consistently been higher than water from the BSFAP but have been at historical low concentrations for the past two sampling events in 2020, following an overall declining concentration trend with time. Bromide concentrations in groundwater from MW-1603 have been mostly below the MDL. Bromide was detected only once since the initial background monitoring events. When bromide was detected (May 2017) it was 0.06 mg/L, or slightly above the less than 0.05 mg/L reported for BSFAP water in May 2017.

A comparison of the pH of BSFAP water and groundwater from MW-1603 is provided in **Figure 4-9**. The figure illustrates the substantial difference in pH between the pond water and groundwater of approximately three to five standard units. This is using the standard (logarithmic) pH scale which converts to a factor of 1,000 to 100,000 difference in the hydrogen ion concentration between the BSFAP and MW-1603. The pH in MW-1603 is acidic with values generally between 3 and 4 standard pH units, whereas the BSFAP water is alkaline at a pH of approximately 8 standard units.

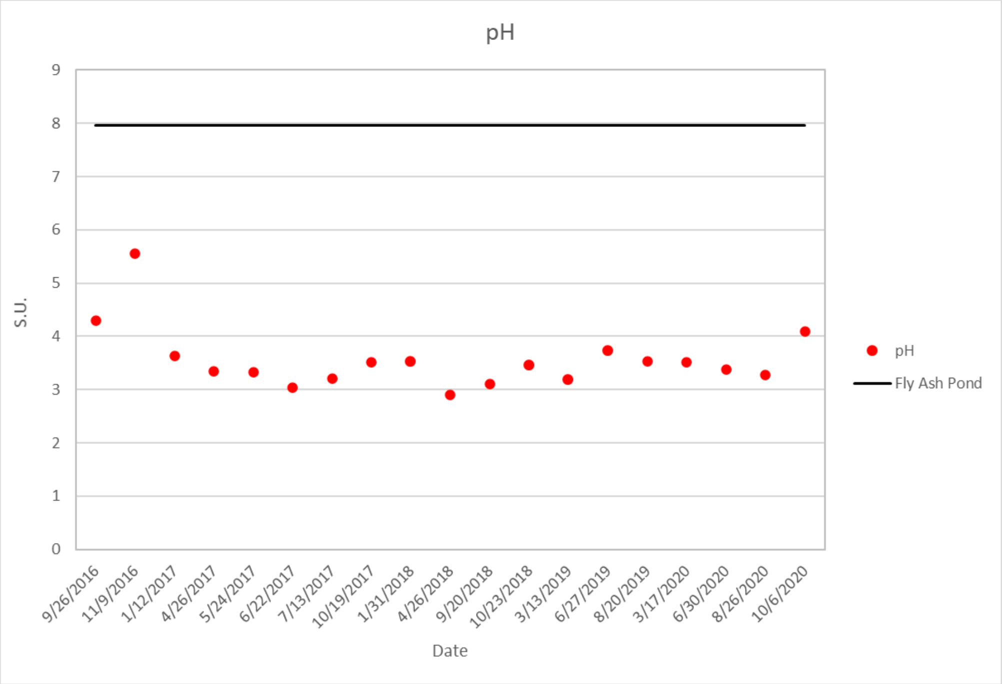

Figure 4-9 MW-1603 pH Values

In summary, there were negligible changes in potential indicator concentrations since the last review in January 2020.

4.1.3 ASD Constituent Trends

Temporal plots for the ASD constituents, beryllium, cobalt, and lithium reported in groundwater monitoring well MW-1603 are provided in **Figure 4-10** to **Figure 4-12**, respectively.

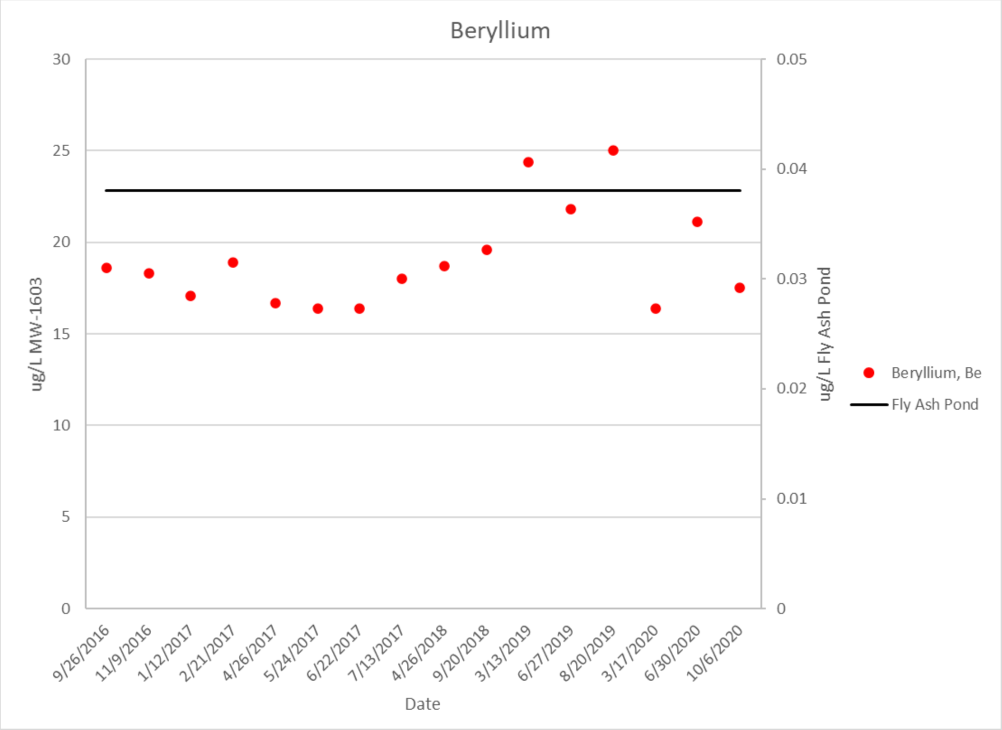

Figure 4-10 MW-1603 Beryllium Concentrations

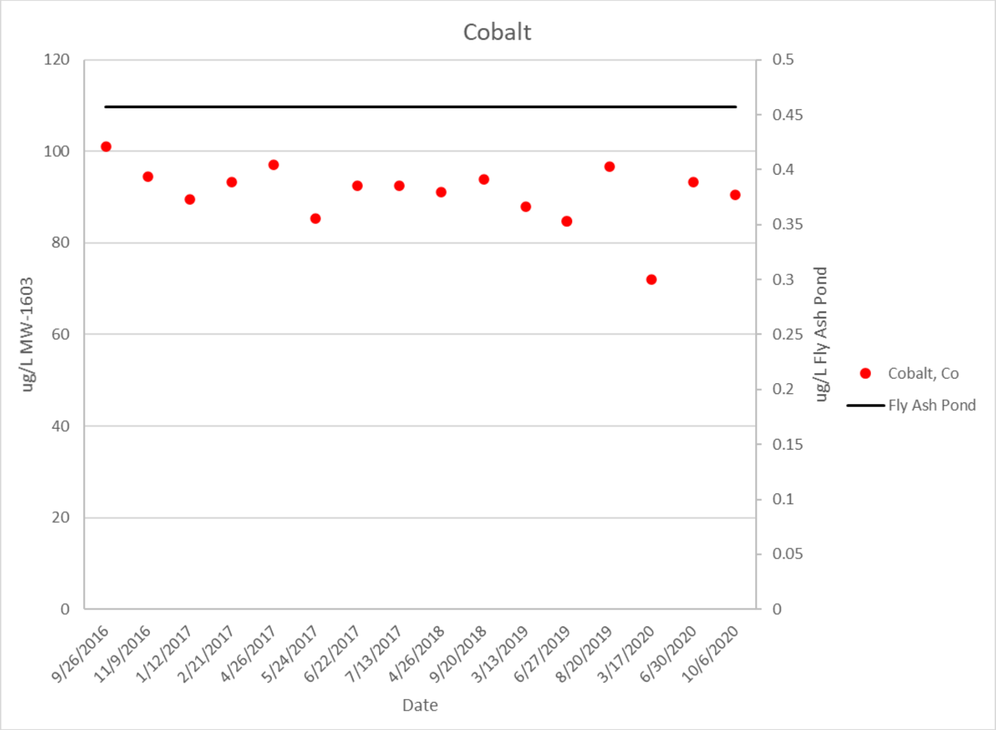

Figure 4-11 MW-1603 Cobalt Concentrations

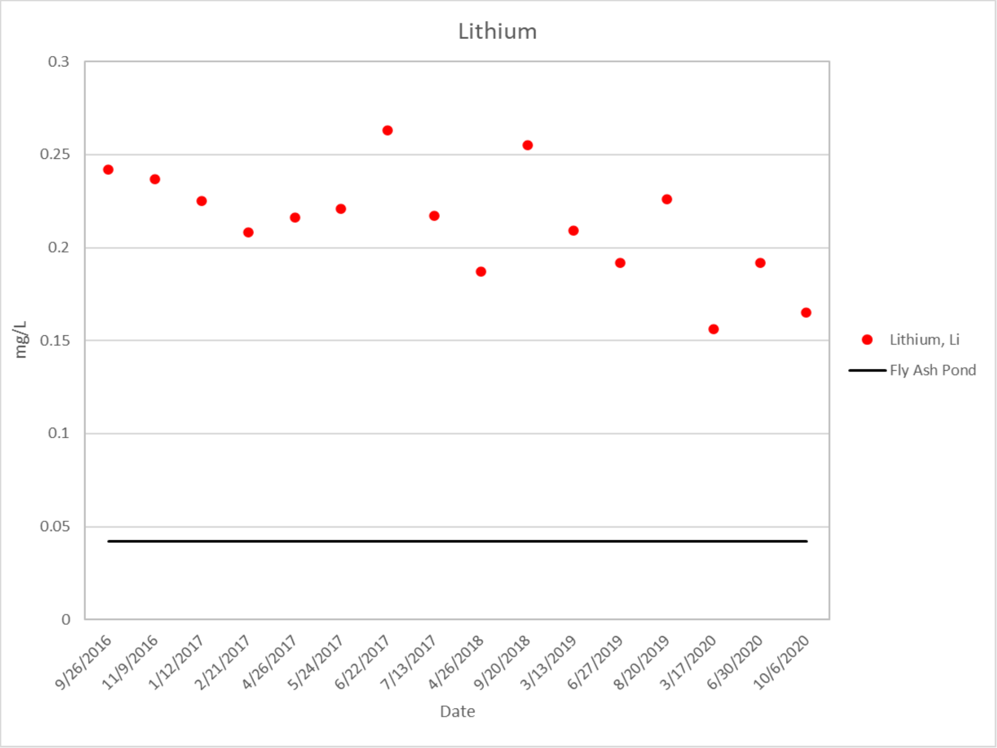

Figure 4-12 MW-1603 Lithium Concentrations

Beryllium, cobalt, and lithium concentrations are higher in groundwater from MW-1603 compared to BSFAP water, indicating that the source of beryllium, cobalt, and lithium is not associated with the BSFAP.

4.1.4 Indicator Analysis Findings

Based on the temporal plots for primary indicators, potential indicators, and ASD constituents, it is considered unlikely that CCR constituents from the BSFAP are influencing the chemistry of surrounding groundwater. This is based on the primary indicator sulfate, potential indicators fluoride and bromide, and the ASD constituent's beryllium, cobalt, and lithium all being present at higher concentrations in surrounding groundwater in comparison to the BSFAP water (EHS Support, 2019a). As the concentrations of these constituents in surrounding groundwater are higher, it is unlikely that there is a concentration gradient extending from the BSFAP into groundwater. It is more likely that an alternate source is contributing to the higher concentrations observed in groundwater.

In summary, based on the analyses presented above, no trends in the MW-1603 groundwater dataset suggest that CCR constituents are migrating from the BSFAP into groundwater.

4.2 Tier I Evaluation - Statistical Evaluation

Statistical evaluations of analytes have been conducted previously (EHS Support, 2019a, 2019b, 2020, and 2021). The evaluations concluded that groundwater in the vicinity of MW-1603 is statistically the same as that which the United States Geological Survey (USGS) reported for regional background (Ruppert et al., 2000) for arsenic, boron, calcium, chloride, chromium, fluoride, molybdenum, potassium, sodium, and strontium. The box plots from the earlier ASD investigation (EHS Support, 2019a) also show a difference between well MW-1603, BSFAP water, and/or the regional background for pH, alkalinity, barium, cobalt, lead, lithium, magnesium, selenium, and sulfate. No background values were provided by the USGS for beryllium, chromium, lead, lithium, molybdenum, and selenium.

Updated box and whisker plots for constituents reported in MW-1603 groundwater are provided in **Appendix A**. Plots for pH, fluoride, and cobalt exhibit outliers which are calculated to be outside the range of distribution (refer to Figure A-8, Figure A-4, and Figure A-10 of **Appendix A**, respectively).

It is likely that the acidic pH conditions identified at MW-1603, relative to regional background, are driving the observed SSLs. The geochemical conditions within well MW-1603, including a strongly acidic pH, low alkalinity, and high sulfate, are indicative of conditions similar to those observed at acid mine drainage sites. At MW-1603, the geochemical conditions have developed due to the presence of the sulfide-bearing Princess coal seams being intersected by the screened interval of the monitoring well (discussed in EHS Support, 2019a). The combination of the well installation and effects of well sampling have resulted in development of aerobic and water-saturated conditions within the coal seams. These conditions have led to a lowering of the pH through oxidation of sulfides present in the coal which has subsequently enhanced rock dissolution. Enhanced host rock dissolution at MW-1603 is evident from the much higher total dissolved solids (TDS) values at this location in comparison to groundwater samples from the other Site wells, including water from the BSFAP. In addition to an abundance of sulfides, rock and coal samples from the Princess Formation in Kentucky have been shown to contain parts per million (ppm) levels of beryllium, cobalt, and lithium (Hood et al., 2020), thereby, providing a viable source for the observed SSLs.

For context, studies have demonstrated that the pH of groundwater in contact with fly ash is maintained alkaline (pH 7 to 10) for decades due to buffering by reactions with carbonates and amorphous aluminum silicates in the fly ash (Twardowska et al., 2003). The BSFAP water is consistent with this range, with a pH of 7.97. Consequently, the acidic pH of groundwater identified at MW-1603 is compelling evidence that groundwater at this location has not mixed with and is not representative of water from the BSFAP.

4.3 Tier II Evaluation - Geochemical Evaluation

A simple analysis of primary and potential indicator constituents (as performed in **Section 4.1**) may not provide the lines of evidence required for a robust ASD investigation. It is recognized that naturally occurring indicator constituents and upgradient sources may have an additional influence on groundwater quality. Spatially across a Site, groundwater quality may be observed to change due to chemical interactions with the aquifer matrix. EPRI (2012) recommended the use of more sophisticated methods for multiple parameters over multiple locations, such as ion ratios and ternary plots.

4.3.1 Ion Ratios

The development of ion ratios involves first selecting two non-competing, non-sorbing constituents (boron and chloride). The ratios of these constituents are then compared spatially across the Site and a judgment is made as to whether the hydraulically downgradient groundwater is similar to the background groundwater quality.

The calculation of ion ratios was conducted using median concentrations of the indicator species. The median concentrations of boron, chloride, and sulfate over the monitoring period (September 2016 through October 2020) are provided in **Table 4-1**. These three constituents were selected based on the EPRI (2017) recommended indicator species. Whereas bromide is also a recommended indicator species, it was not included in the assessment as it was non-detect in the BSFAP water, indicating its presence in groundwater was either naturally derived or from an off-site source. The median concentrations for sulfate, boron, and chloride show minimal change since January 2019.

Table 4-1 Median Concentrations of Boron, Chloride, and Sulfate

		Median Concentrations September 2016 to October 2020		
Location	**Location ID**	**Boron (mg/L)**	**Chloride (mg/L)**	**Sulfate (mg/L)**
Source	**Fly Ash Pond**	0.58	35.4	342
Downgradient	**MW-1603**	0.052 ±0.026	3.41 ±0.47	714 ±65

mg/L = milligrams per liter

Ion ratios have been calculated using boron, chloride, and sulfate as recommended in EPRI (2017) and are provided in **Table 4-2**. The ion ratios show little change since the last evaluation in January 2021.

Table 4-2 Ion Ratios

		Median Concentrations September 2016 to October 2020		
Location	**Location ID**	**Boron/Sulfate (x1000)**	**Boron/Chloride**	**Chloride/Sulfate**
Source	**Fly Ash Pond**	1.68	0.002	0.10
Downgradient	**MW-1603**	0.07 ±0.03	0.02 ±0.01	0.005 ±0.001

Based on the previous and current ion ratio analysis, the conclusion that MW-1603 is not impacted by CCR constituents from the BSFAP is unchanged.

4.3.2 Ternary Plots

Ternary plots are used to identify changes in major or minor ion distributions over time. A ternary plot using calcium, chloride, and sulfate measured in the vicinity of MW-1603 is provided in **Figure 4-13**. The close grouping of ratios from all events on the ternary plot shows that the major ion groundwater ratios have not changed during the three-year period of groundwater quality monitoring at well MW-1603 and that the ratios are distinct from the BSFAP.

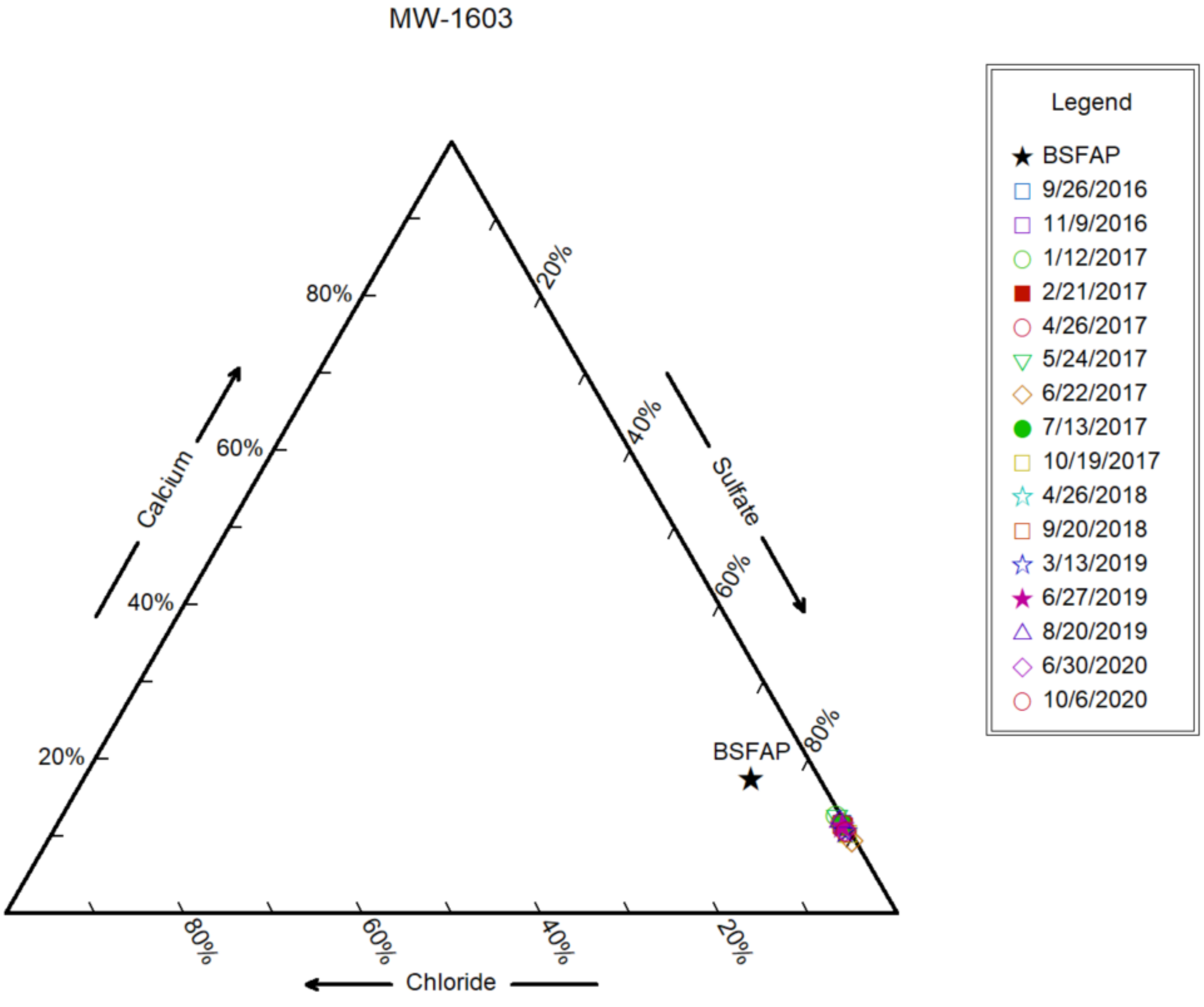

Figure 4-13 Ternary Plot MW-1603

4.3.3 Summary

In summary, based on the previous geochemical evaluation and the updated review presented in this ASD investigation, there is insufficient evidence to support the presence of CCR constituents (beryllium, cobalt, and lithium), as derived from the BSFAP, in groundwater sampled at MW-1603. The ternary plot does not support temporal changes of MW-1603 groundwater quality. The boron, chloride, and sulfate ion ratios remain unchanged since September 2019. Therefore, it is unlikely that beryllium, cobalt, and lithium detected within MW-1603 groundwater are sourced from the BSFAP. It is likely that beryllium, cobalt, and lithium are sourced from the lithologies in which this monitoring well is screened across, which includes the Princess coal seams.

5 Summary and Conclusions

Using the EPRI (2017) guidance for ASD investigations, the conclusions based on the lines of evidence presented and discussed within **Sections 3** and **4** indicate that groundwater in the vicinity of the BSFAP is not being impacted by CCR constituents from the BSFAP. The elevated beryllium, cobalt, and lithium concentrations that triggered the ASD investigation are due to the oxidation of sulfide minerals present in coal seams that have been intersected by well MW-1603, including organic material within the screened interval that is identified as having “a slight coaly texture.” This is supported by the visual evidence recorded during the logging of the core from this location (refer to EHS Support, 2019a), the low pH reported in groundwater, and the subsequent mobilization and leaching of trace metals (beryllium, cobalt, and lithium) into groundwater by the elevated acidity.

The elevated pH in the BSFAP water and the corresponding lower concentrations of minor ions in the BSFAP also support the unlikely influence of the BSFAP on groundwater. Therefore, it is concluded that the elevated signatures of beryllium, cobalt, and lithium in MW-1603, as noted in the October 2020 groundwater monitoring data, are related to the dissolution of naturally occurring, coal seam-derived constituents within the shale layers of the Breathitt Group, as supported by the discussion of local and regional geology in **Section 2.1** and EHS Support (2019a).

In conclusion, this ASD addendum for the BSFAP has determined that Type IV natural variations in groundwater resulted in SSLs of beryllium, cobalt, and lithium detected at MW-1603.

6 References

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Tables

Table 1
MW-1603 Historical Groundwater Data September 2016 to October 2020
Big Sandy Fly Ash Pond Groundwater Monitoring,
American Electric Power, Kentucky Power Company, Louisa, Kentucky

Analytes	Units	9/26/2016	11/9/2016	1/12/2017	2/21/2017	4/26/2017	5/24/2017	6/22/2017	7/13/2017	10/19/2017	1/31/2018	4/26/2018	9/20/2018	10/23/2018	3/13/2019	6/27/2019	8/20/2019	3/17/2020	6/30/2020	8/26/2020	10/6/2020
Antimony, Sb	µg/L	0.01 J	< 0.01	< 0.01	< 0.01	0.01 J	< 0.01	< 0.01	< 0.01	NA	NA	0.04 J	0.02 J	NA	< 0.2	< 0.04	< 0.1	< 0.02	< 0.04	NA	< 0.02
Arsenic, As	µg/L	1.51	1.19	1.4	1.26	1.3	1.34	1.29	0.89	NA	NA	1.6	1.4	NA	1.26	1.36	1.39	0.83	1.12	NA	1.12
Barium, Ba	µg/L	13.4	15.4	11.4	10.3	12.4	11.5	11.4	11.3	NA	NA	10.5	11.4	NA	12	11	13.6	9.92	12.2	NA	14.6
Beryllium, Be	µg/L	18.6	18.3	17.1	18.9	16.7	16.4	16.4	18	NA	NA	18.7	19.6	NA	24.4	21.8	25	16.4	21.1	NA	17.5
Boron, B	mg/L	0.054	0.053	0.037	0.085	0.052	0.096	0.051	0.039	< 0.002	NA	0.088	0.085	NA	0.05 J	0.05 J	< 0.1	< 0.1	0.05 J	NA	0.05
Bromide	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.06 J	< 0.05	< 0.05	< 0.05	NA	< 0.05	< 0.1	NA	< 0.1	< 0.04	< 0.04	< 0.04	< 0.04	NA	< 0.04
Cadmium, Cd	µg/L	0.84	0.93	0.79	0.75	0.87	0.77	0.86	0.8	NA	NA	0.74	0.83	NA	0.78	0.7	0.89	0.64	0.85	NA	0.87
Calcium, Ca	mg/L	105	94.7	92.7	91.9	90.5	93.9	90.6	90.2	91	82.2	83.6	97.5	NA	84.6	83.3	95.8	NA	96.6	NA	94.5
Chloride, Cl	mg/L	3.37	3.22	3.45	2.93	3.28	3.34	3.1	3.32	3.24	NA	4.12	3.92	NA	4.42	4.13	3.93	NA	4.18	NA	4.1
Chromium, Cr	µg/L	1.1	1.12	0.731	0.771	0.829	0.62	0.821	0.485	NA	NA	0.771	0.713	NA	1 J	0.618	0.8	0.56	0.694	NA	0.743
Cobalt, Co	µg/L	101	94.4	89.6	93.2	97.1	85.3	92.4	92.5	NA	NA	91.1	93.8	NA	87.9	84.7	96.6	72	93.2	NA	90.5
Comb. Radium 226/228	pCi/L	6.04	6.6	5.86	4.03	5.72	6.4	6	6.36	NA	NA	5.09	6.75	NA	4.8	7.149	10.92	7.19	6.22	NA	2.681
Fluoride, F	mg/L	1.24	1.1	1.11	0.9	1.04	0.98	0.98	0.93	0.93	0.94	1.16	1.15	NA	0.92	0.87	0.84	0.85	0.71	NA	0.47
Lead, Pb	µg/L	9.75	8.18	6.11	6.3	6.41	4.96	6.47	3.72	NA	NA	5.27	4.39	NA	4.28	3.68	4.17	3.95	4.67	NA	4.85
Lithium, Li	mg/L	0.242	0.237	0.225	0.208	0.216	0.221	0.263	0.217	NA	NA	0.187	0.255	NA	0.209	0.192	0.226	0.156	0.192	NA	0.165
Mercury, Hg	µg/L	< 0.002	< 0.002	< 0.002	< 0.002	0.002 J	< 0.002	< 0.002	< 0.002	NA	NA	< 0.002	NA	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	NA	< 0.002
Molybdenum, Mo	µg/L	0.15	0.17	0.06 J	0.11	0.18	0.07 J	0.32	0.22	NA	NA	0.03 J	0.04 J	NA	< 4	< 0.8	< 2	< 0.4	< 0.8	NA	< 0.4
pH	S.U.	4.29	5.56	3.64	4.51	3.34	3.32	3.04	3.20	3.52	3.52	2.91	3.10	3.46	3.19	3.73	3.54	3.52	3.38	3.27	4.09
Potassium, K	mg/L	4.76	4.73	4.25	3.95	3.98	4.34	4.41	3.92	4.46	NA	3.53	5.05	NA	3.81	3.78	4.48	3.42	4.36	NA	4.29
Residue, Filterable, TDS	mg/L	1,060	1,010	948	1,020	994	936	1,040	1,000	962	915	926	974	NA	896	954	1,010	NA	NA	1,040	1,020
Selenium, Se	µg/L	5.4	4.8	5.6	4.9	6.1	6.3	6.1	2.7	NA	NA	8.1	6.3	NA	4	4.9	5.6	4	6.2	NA	5.8
Sodium, Na	mg/L	NA	24.2	22.9	20.3	21.6	23.1	25	22.3	22.4	NA	17	23.9	NA	18.9	19.1	22.2	16.8	21.9	NA	21.1
Sulfate, SO4	mg/L	801	733	636	720	678	646	873	694	784	714	661	747	NA	709	658	704	NA	NA	798	794
Thallium, Tl	µg/L	1.29	1.55	1.39	1.2	1.41	1.35	1.43	1.43	NA	NA	1.39	1.7	NA	1 J	1.4	2 J	1.34	1.57	NA	1.82

Notes:

< = not detected at or above the method detection limit

µg/L = Micrograms per liter

J = Estimated value. Analyte detected at a level less than the reporting limit but greater than the method detection limit.

mg/L = Milligrams per liter

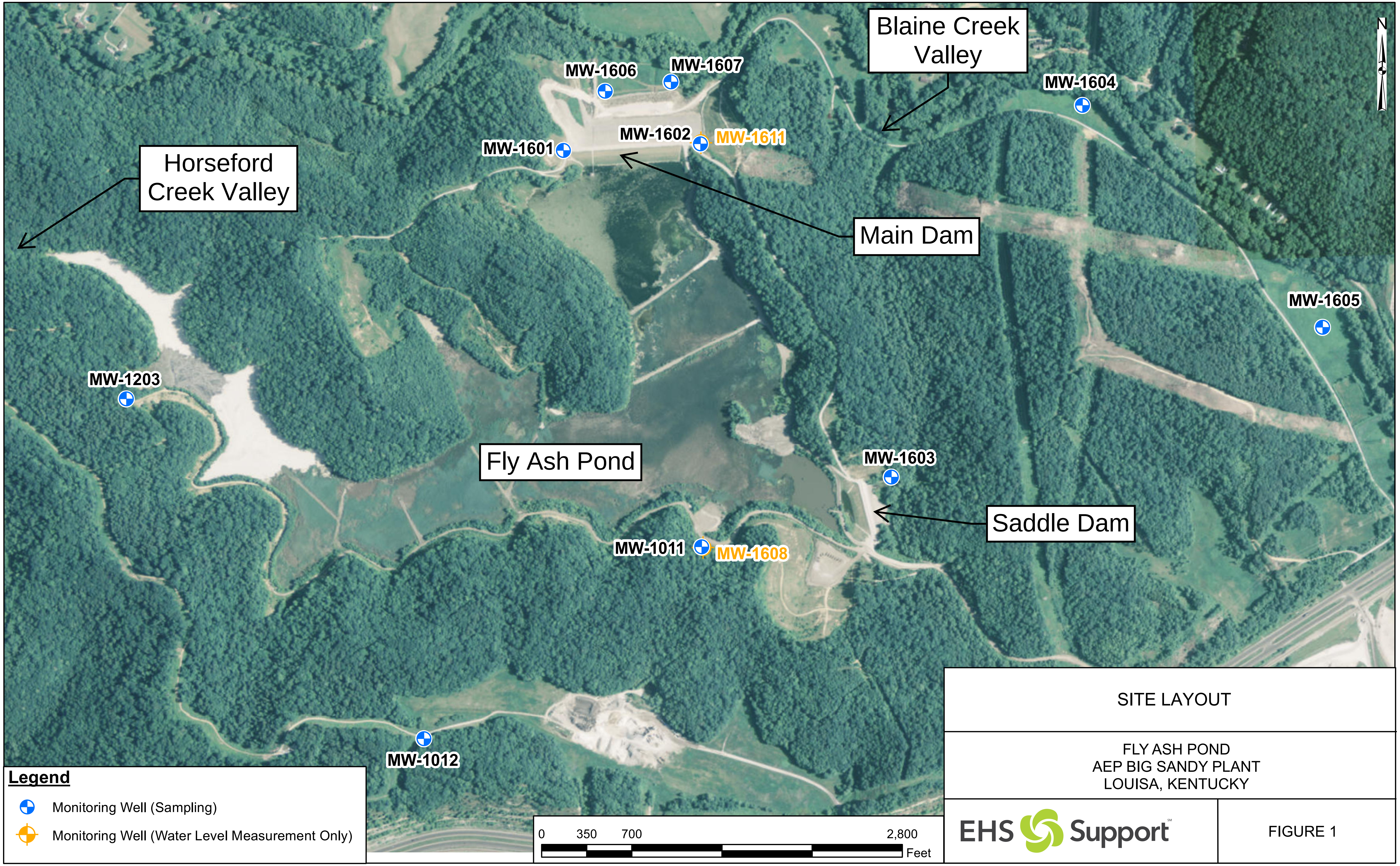
NA = Not analyzed

pCi/L = Picocuries per liter

S.U. = Standard Units

TDS = Total Dissolved Solids

Figures

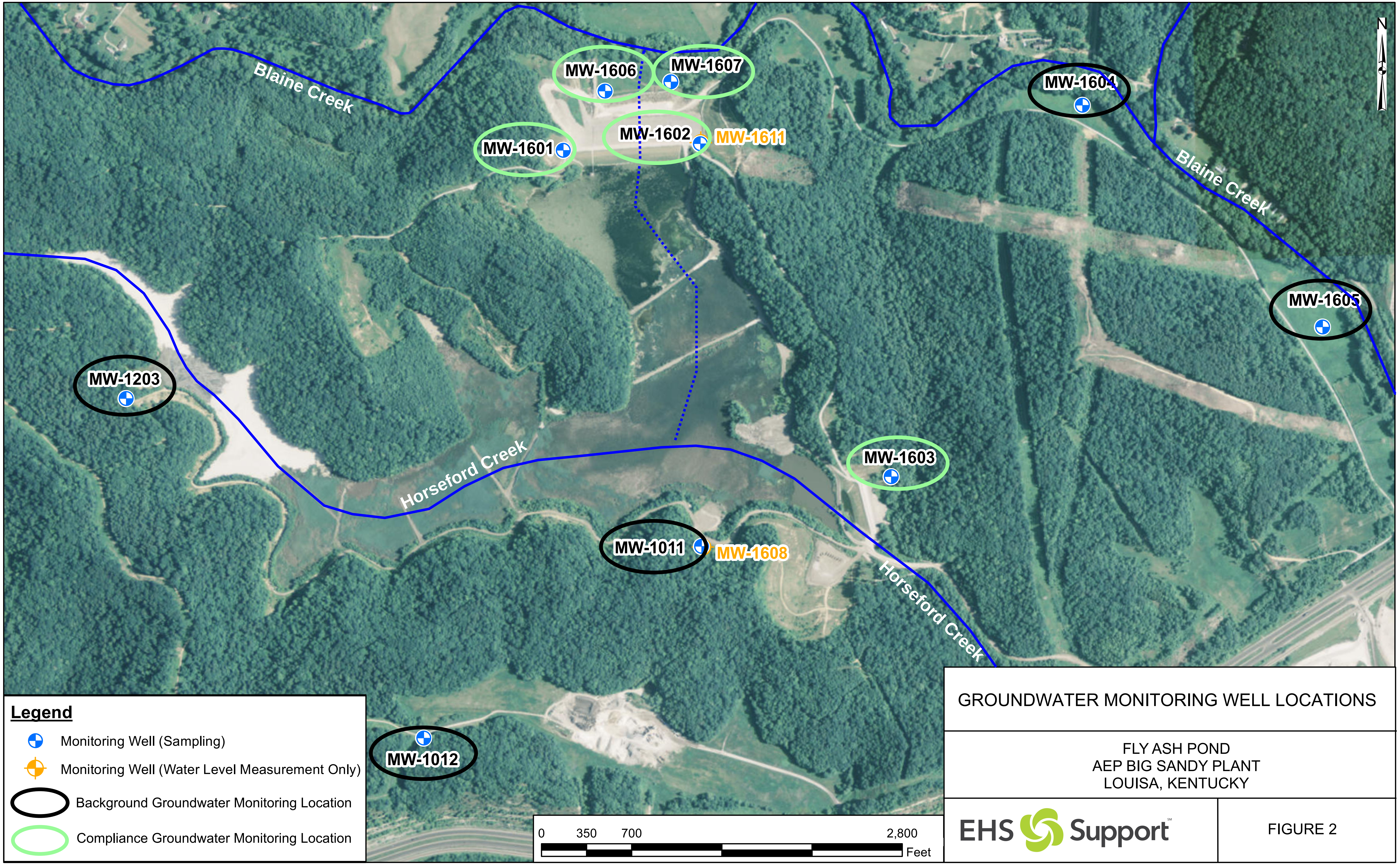


SITE LAYOUT

FLY ASH POND
AEP BIG SANDY PLANT
LOUISA, KENTUCKY

EHS Support

FIGURE 1



GROUNDWATER MONITORING WELL LOCATIONS

FLY ASH POND
AEP BIG SANDY PLANT
LOUISA, KENTUCKY

EHS Support

FIGURE 2

Appendix A Box Plots

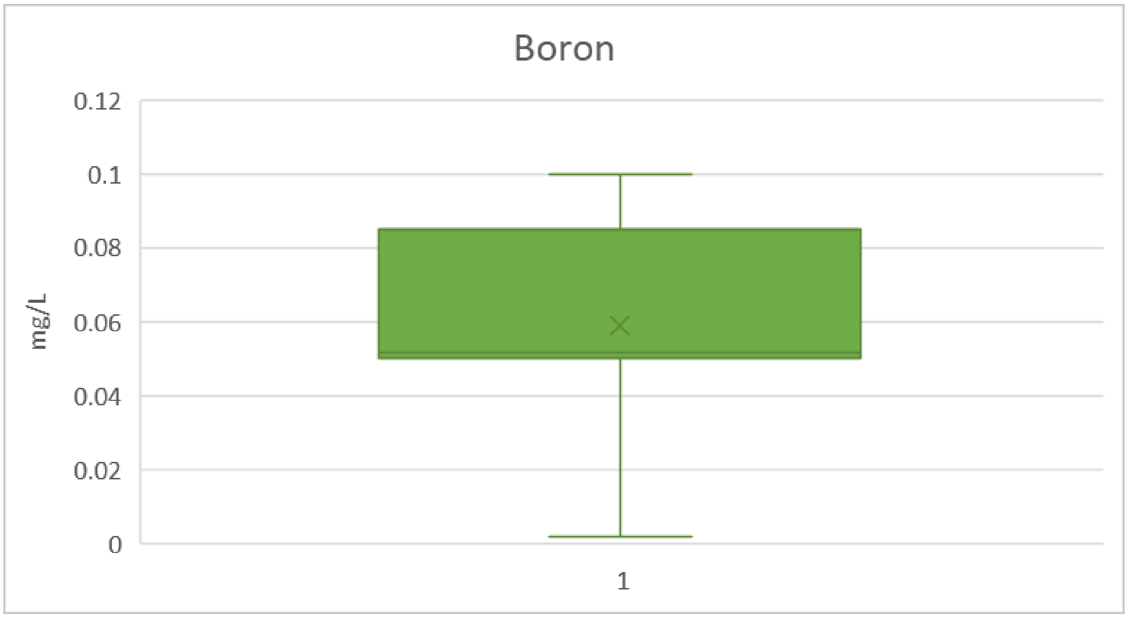


Figure A-1 **Boron Box Plot**

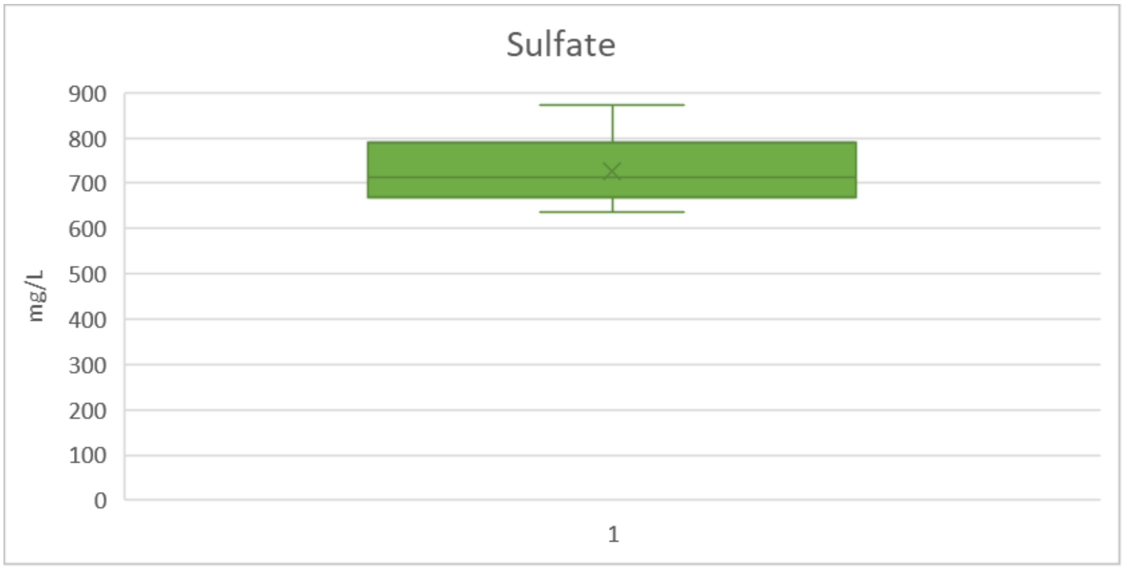


Figure A-2 **Sulfate Box Plot**

Figure A-3 Chloride Box Plot

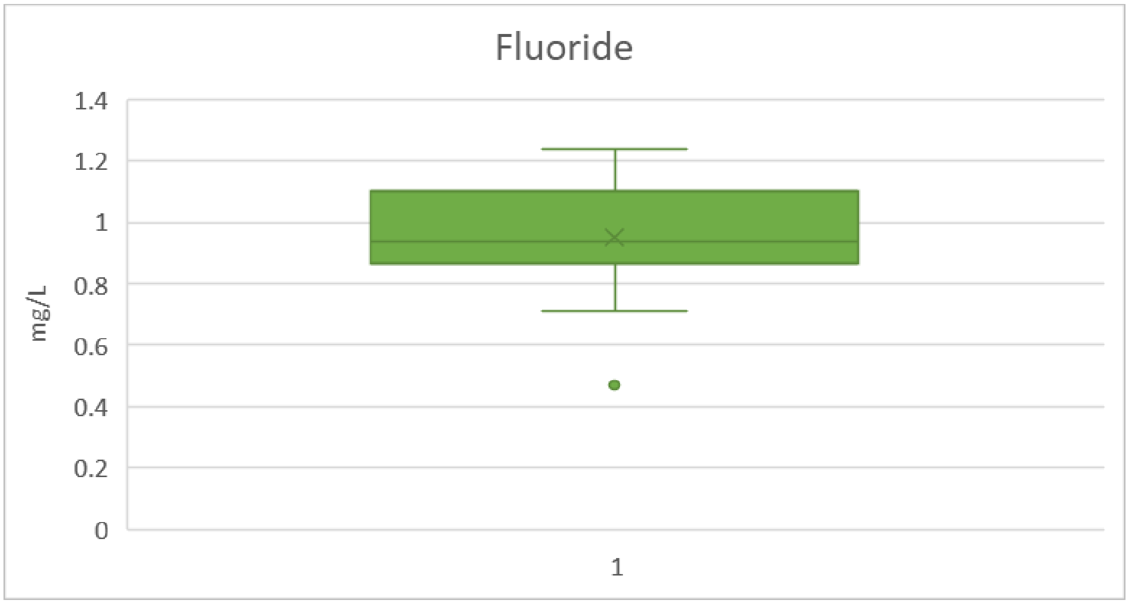


Figure A-4 Fluoride Box Plot

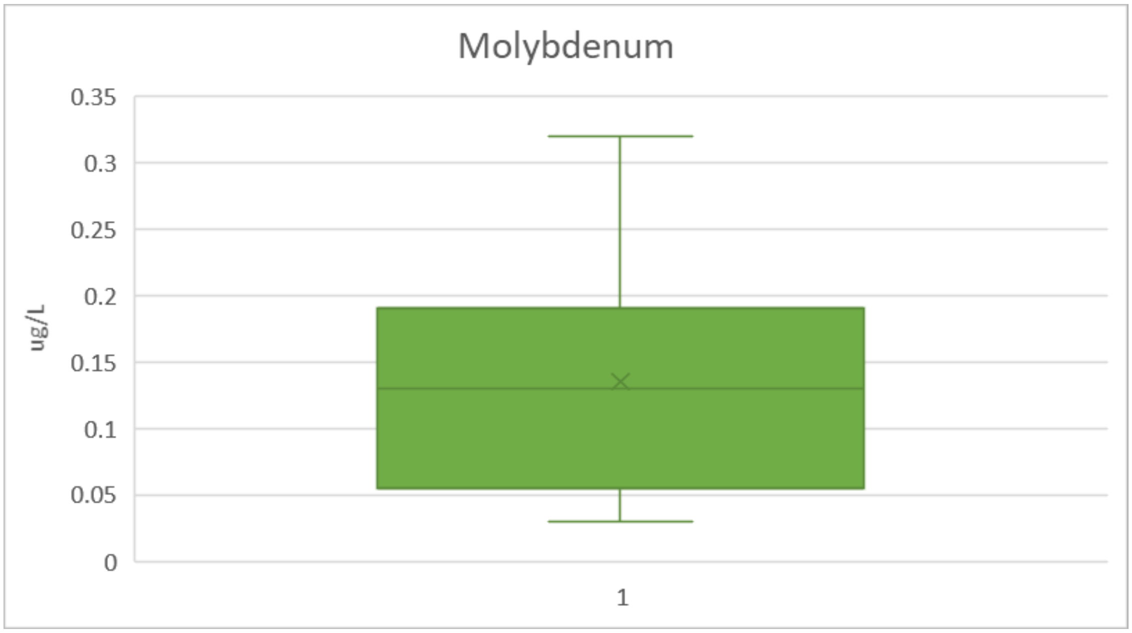


Figure A-5 **Molybdenum Box Plot**

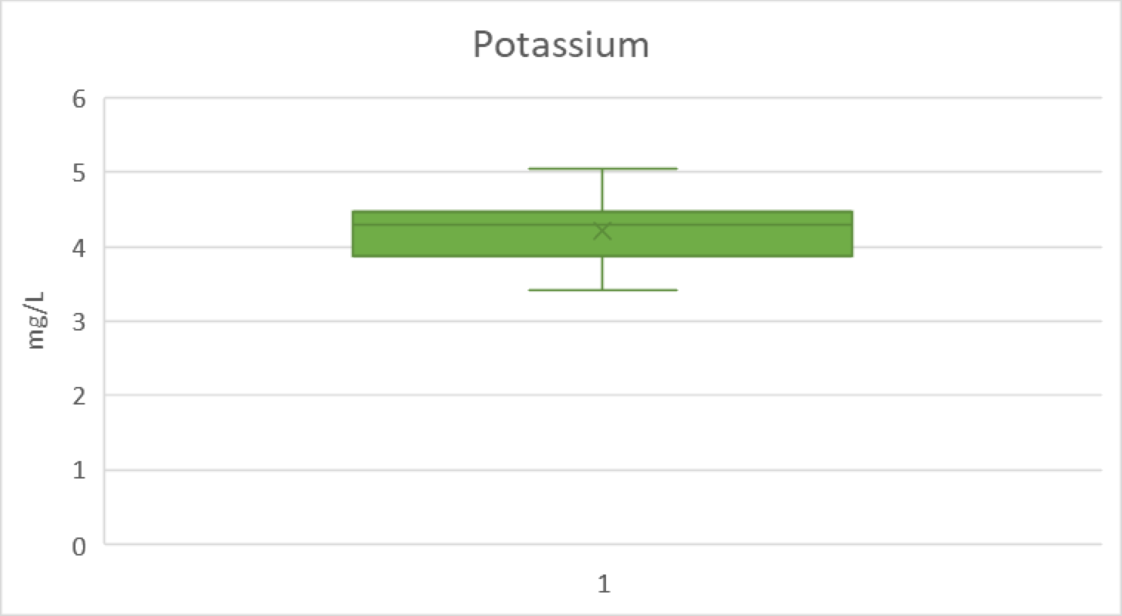


Figure A-6 **Potassium Box Plot**

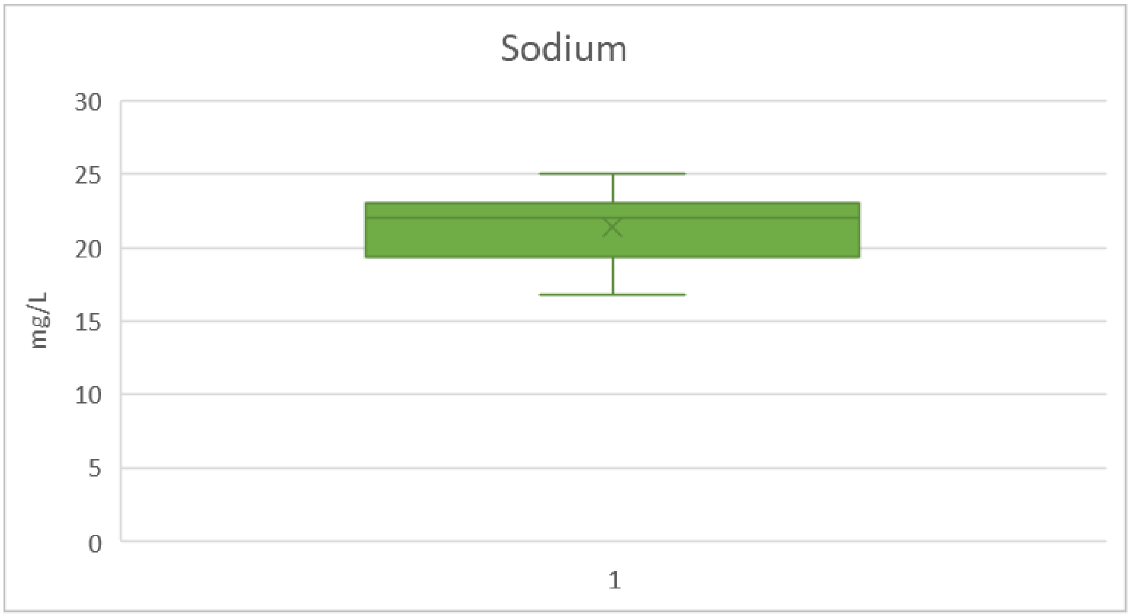
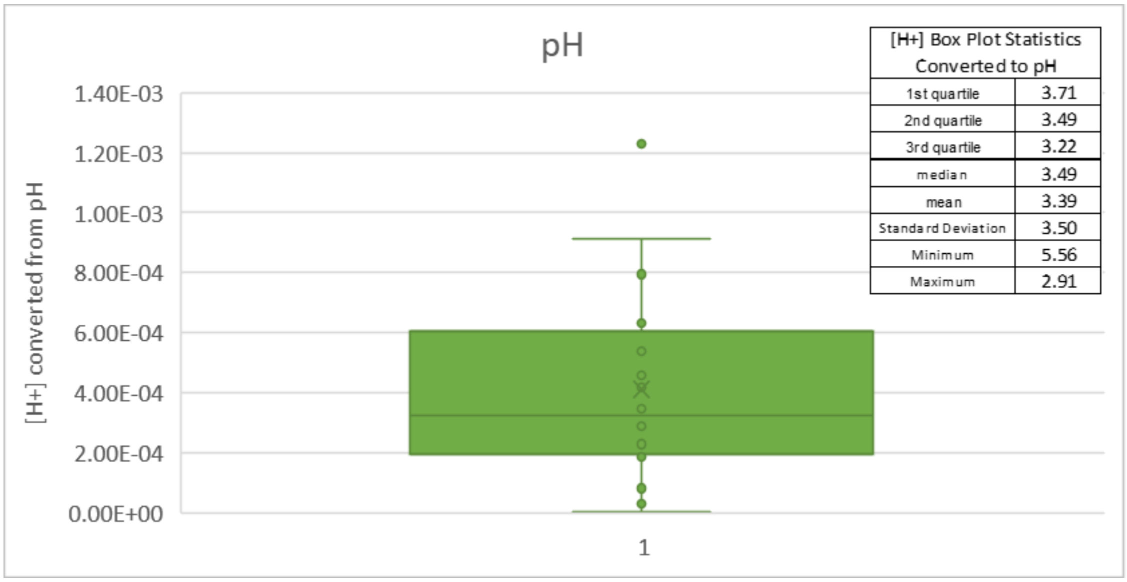


Figure A-7 Sodium Box Plot



[H+] Box Plot Statistics Converted to pH	
1st quartile	3.71
2nd quartile	3.49
3rd quartile	3.22
median	3.49
mean	3.39
Standard Deviation	3.50
Minimum	5.56
Maximum	2.91

Figure A-8 pH Box Plot

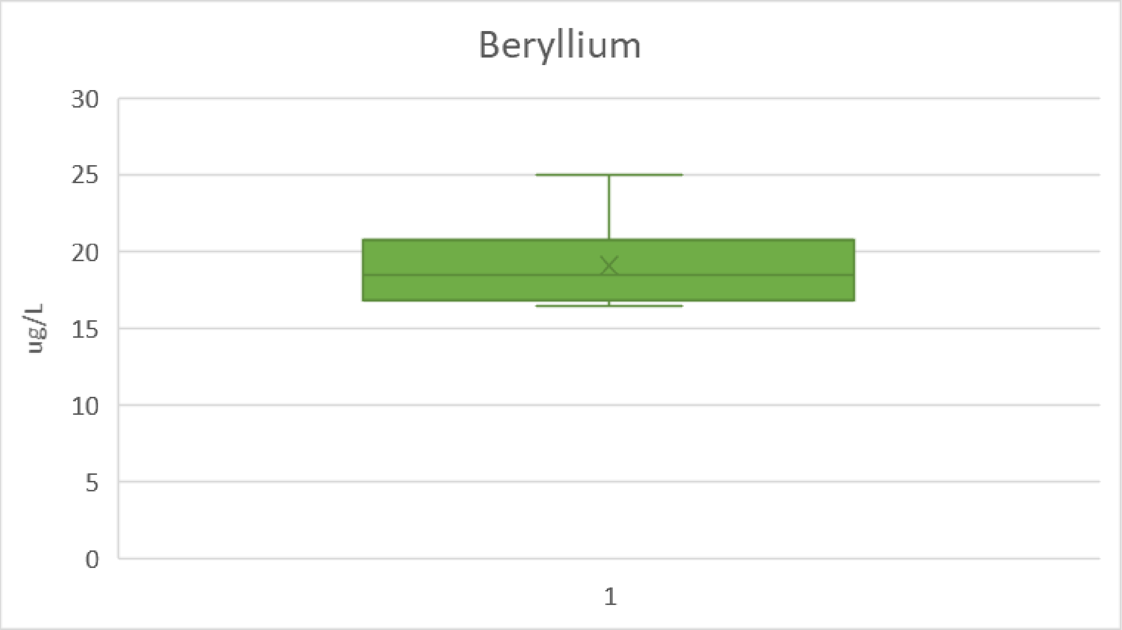


Figure A-9 **Beryllium Box Plot**

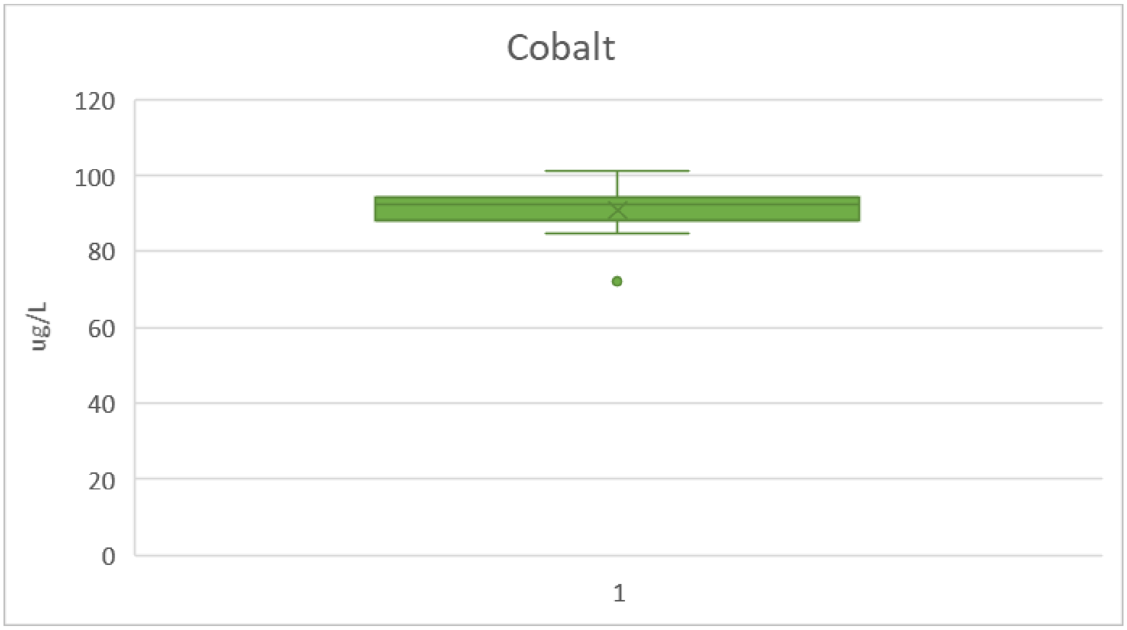


Figure A-10 **Cobalt Box Plot**

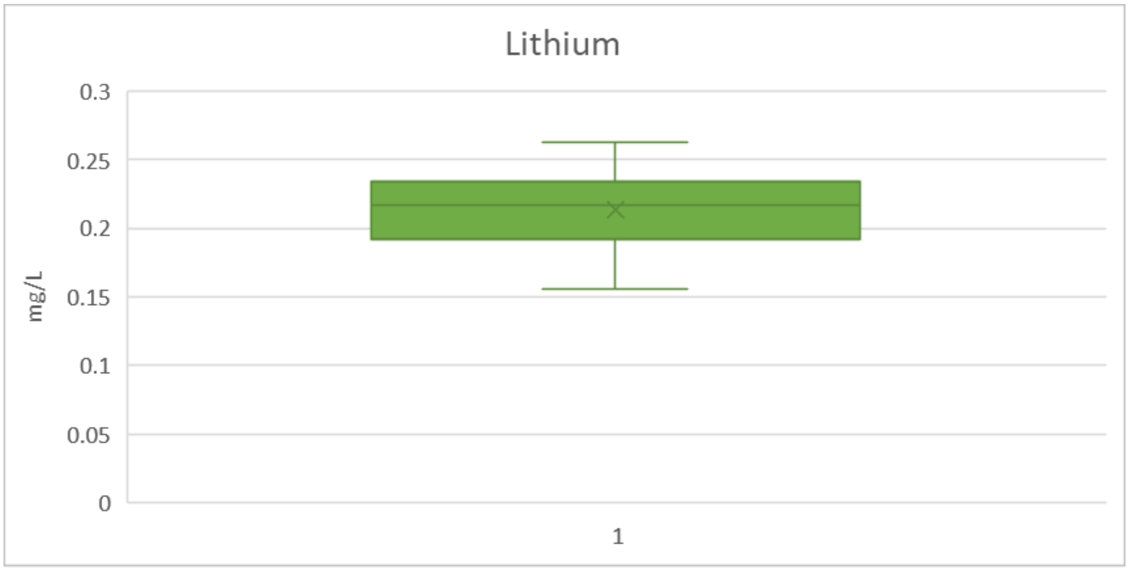


Figure A-11 Lithium Box Plot