Alabama Power

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July 11, 2019

Mr. Eric L. Sanderson, P. E., Chief
Solid Waste Branch
Alabama Department of Environmental Management
1400 Coliseum Boulevard
Montgomery, Alabama 36110-2400

Re: Assessment of Corrective Measures for the Plant Barry Ash Pond

Dear Mr. Sanderson:

Alabama Power Company is the owner and operator of the Plant Barry Ash Pond, located at Bucks, Alabama. Pursuant to 40 CFR § 257.96, rule 335-13-15-.06(7) of the regulations of the Alabama Department of Environmental Management (ADEM), and Paragraph C of ADEM Administrative Order No. 18-094-GW, please find enclosed an Assessment of Corrective Measures (ACM) for the Plant Barry Ash Pond.

The ACM is the first step in developing a long-term corrective action plan to address exceedances of groundwater protection standards (GWPS) identified at the site. As part of the ACM, potential groundwater corrective measures were identified and evaluated based on the criteria outlined in § 257.96(c) and r. 335-13-15-.06(7)(c). The closure plan for the Plant Barry Ash Pond, as reflected in the permit application package filed at ADEM in December 2018, was also considered because source control activities are integral to the long-term corrective action plan and will influence corrective measures performance at the site.

As proposed in the December permit application and the updated package to be submitted on July 15, 2019, Alabama Power plans to close the Plant Barry Ash Pond by dewatering, excavating, consolidating, and capping the ash within an impermeable composite cover system to prevent infiltration. In addition, Alabama Power will use other advanced engineering technologies beyond the minimum requirements of the CCR rule to accelerate water removal, provide additional redundancy in the dike, seal off horizontal access with a barrier wall, and seal off vertical access with an impermeable cap.

Dewatering will consist of removing the free liquids from the pond, which will reduce the volume of water available to potentially migrate from the ash pond during closure and minimize the hydraulic head within the pond, thereby reducing pressure to cause any migration from the pond. As part of ash consolidation, the closure plan proposes to excavate ash and move it back from the river by at least 100 and up to 750 yards. Construction will require the movement of approximately 8 million cubic yards of ash within the unit (out of a total volume of some 21 million cubic yards of material). The process will reduce the footprint of the area covered by ash from approximately 597 acres to 330 acres. The area of consolidation will be protected by the existing perimeter berms and an advanced engineering feature of an additional dike around the contained ash, providing redundant flood protection. The redundant dike system will be protective of inundation from a 500-year flood event with a hypothetical condition of a 1-meter sea level rise. Ongoing groundwater monitoring will provide important information that will ensure the remediation goals of the long-term corrective action plan are being met.

Alabama Power will take advantage of a geological feature that is specific to Plant Barry. Below the entire area of consolidation is a natural clay layer ranging in depth from 4 to 28 feet which creates separation from the aquifer confined beneath it. This clay layer is shown to have a measured permeability of as low as 10^{-7} cm/sec. The natural clay layer will work with enhanced engineering technologies that are built into the closure plan to provide robust source control. Additionally, we have designed a subsurface barrier wall that extends downward from the interior of the inner dike and ties into the clay layer. It has the effect of locking the subsurface of the containment area in place. An internal drainage system will be installed inside the internal dike and barrier wall on top of the clay to accelerate removal of water within the CCR and provide the ability to remove any residual water that may remain post closure.

To meet the requirements of Part C of the Administrative Order, and after a thorough consideration of available corrective measures, Alabama Power is proposing a remedial system that consists of combined source control and monitored natural attenuation at the site. The dewatering and enhanced closure design of the Plant Barry Ash Pond are expected to reduce the source contribution to groundwater such that the attenuation may be all that is needed to achieve the GWPS in a reasonable timeframe. However, using an adaptive site management process, site conditions will be monitored and necessary adjustments will be made, leading to continuous improvements in the corrective measures performance. The closure configuration includes space between the capped area and the outer dike, should Alabama Power identify a need for further action in that area.

Thank you for your consideration. Please feel free to contact me if Alabama Power can provide additional information or answer any questions.

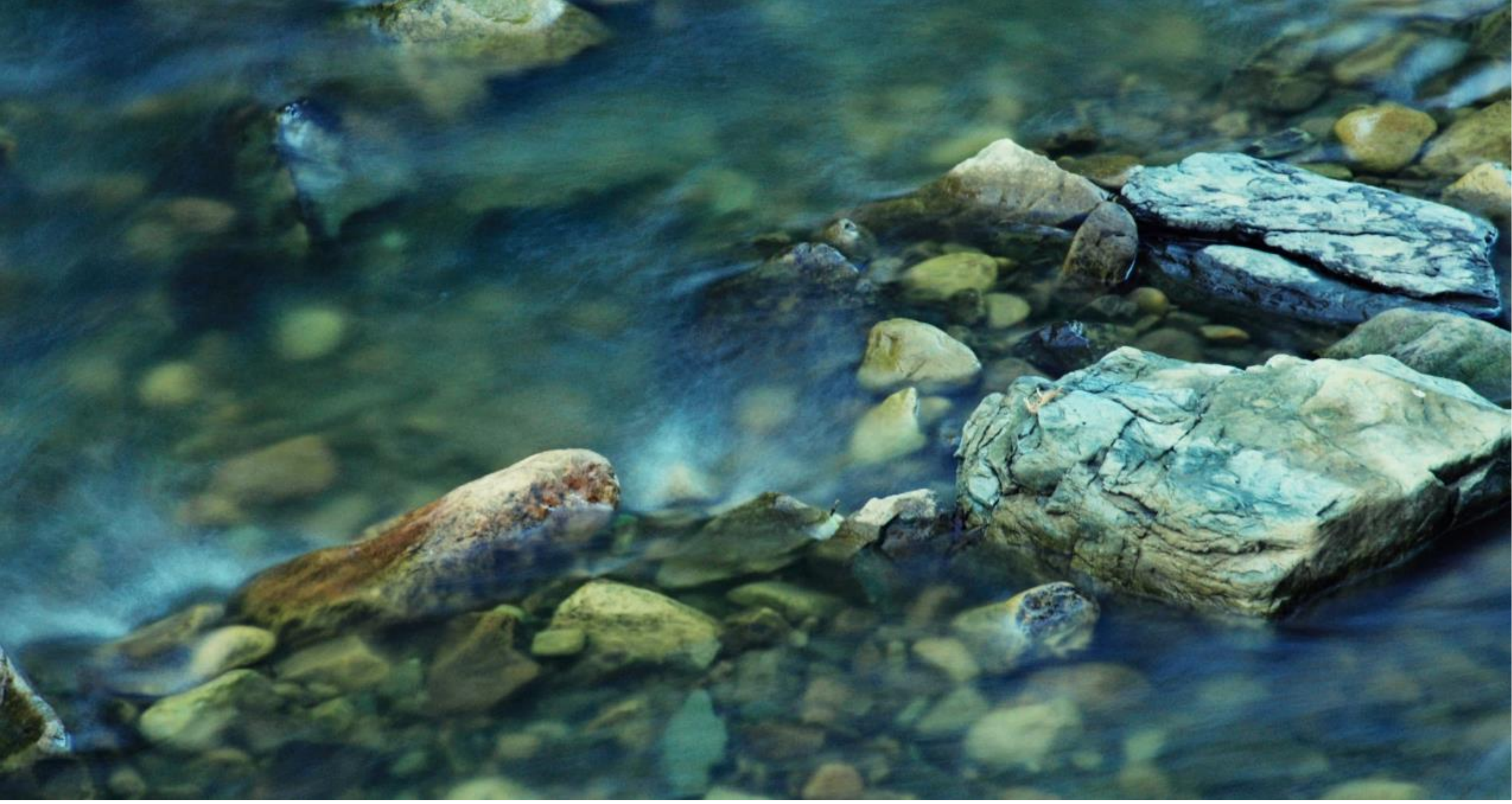
Sincerely,

Susan B. Comensky

Susan B. Comensky

Enclosures

cc w/enc.: Heather Jones
Scott Story



June 2019
Plant Barry

ANCHOR QEA

Assessment of Corrective Measures
Plant Barry Ash Pond

Prepared for Alabama Power Company

June 2019
Plant Barry

Assessment of Corrective Measures
Plant Barry Ash Pond

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ABBREVIATIONS

ACM	Assessment of Corrective Measures
ADEM	Alabama Department of Environmental Management
Admin. Code	Administrative Code
APT	aquifer performance test
CCR	coal combustion residuals
CCR rule	80 Federal Register 21302 (April 17, 2015); "Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities"
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act, or Superfund
CFR	Code of Federal Regulations
cm/sec	centimeters per second
CMS	Corrective Measures Study
CSM	conceptual site model
EPRI	Electric Power Research Institute
FeS_2	pyrite
ft^2/day	foot squared per day
GWPS	groundwater protection standard
mg/L	milligram per liter
MNA	monitored natural attenuation
MSL	mean sea level
O&M	operation and maintenance
PRB	permeable reactive barrier
RCRA	Resource Conservation and Recovery Act
RCRA FIRST Toolbox	*Resource Conservation and Recovery Act Facilities Investigation Remedy Selection Track: A Toolbox for Corrective Action*
SSI	statistically significant increase
SSL	statistically significant level
USGS	U.S. Geological Survey
USEPA	U.S. Environmental Protection Agency

1 Introduction

This Assessment of Corrective Measures (ACM) has been prepared pursuant to the U.S. Environmental Protection Agency (USEPA) coal combustion residuals (CCR) rule (40 Code of Federal Regulations [CFR] Part 257 Subpart D), the Alabama Department of Environmental Management's (ADEM's) Administrative Code (Admin. Code) r. 335-13-15, and an Administrative Order issued by ADEM (AO 18-094-GW) to evaluate potential groundwater corrective measures for the occurrence of arsenic and cobalt in groundwater at statistically significant levels (SSLs) at the Ash Pond at Plant Barry (Site).

Specifically, this ACM is prepared pursuant to 40 CFR 257.96, ADEM Admin. Code r. 335-13-15-.06(7), and Part C of the Administrative Order. Pursuant to the requirements of Part C of the Administrative Order, this ACM also "include(s) the remedy proposed to the Department for approval."

This ACM was initiated within 90 days of identifying the SSLs on January 13, 2019; a 60-day extension until June 12, 2019, for completion of the ACM was documented on April 12, 2019.

This ACM is the first step in developing a long-term corrective action plan to address exceedances of groundwater protection standards (GWPS) identified at the Site. Based on the results of the ACM, further evaluation will be performed, site-specific studies completed, and a final long-term corrective action plan developed and implemented pursuant to 40 CFR 257.97–98 and ADEM Admin. Code r. 335-13-15-.06(8) and (9).

In addition to the corrective measures discussed in this ACM, APC will close the Ash Pond by excavation and consolidation of the unit's CCR material into a smaller area located within the current footprint of the Ash Pond. A final cover system will be installed that is designed to minimize infiltration and erosion. A summary of the Closure Plan was published to APC's CCR compliance webpage in November 2016.

Completing a final long-term corrective action frequently takes several years. Therefore, corrective measures presented herein can be applied as warranted based on site conditions during closure and while implementing a long-term corrective action strategy to meet remedial objectives at the Site.

1.1 Purpose and Approach

The purpose of this ACM is to begin the process of selecting corrective measure(s). This process may be composed of multiple components to analyze the effectiveness of corrective measures and to address the potential prior migration of CCR constituents to groundwater at the Site.

The CCR rule (40 CFR 257 Subpart D), ADEM Admin. Code (r. 335-13-15), and ADEM AO 18-094-GW provide requirements for an ACM. In addition, the subsequent 2016 USEPA report entitled *Resource Conservation and Recovery Act Facilities Investigation Remedy Selection Track: A Toolbox for Corrective Action* (RCRA FIRST Toolbox; USEPA 2016) provides general guidance for conducting a Corrective Measures Study (CMS) at Resource Conservation and Recovery Act (RCRA) facilities. Because a CMS is equivalent to an ACM, ACM will be used in this report for consistency with the CCR rule terminology. The RCRA FIRST Toolbox (USEPA 2016) describes three approaches for assessing the need for, or performing, an ACM at RCRA facilities:

1. **No ACM:** "This is a likely outcome when interim measures are suitable for the final remedy, when post-closure will include provisions for corrective action, or when the only additional requirements are institutional controls" (USEPA 2016). Examples where an ACM is not likely to be needed include the following:
   a. Low risk facilities
   b. Excavation/removal remedies
   c. Presumptive remedies/proven effective remedies in similar cases
2. **Limited ACM:** In some cases, the final remedy may be obvious, but additional field work, bench-scale testing, or pilot testing may be required to support the final decision. The RCRA FIRST Toolbox includes a path for additional study without requiring a full ACM.
3. **Full ACM:** USEPA recommends that a full ACM be used only when more than one viable alternative exists to meet site cleanup and other criteria. USEPA discourages creating alternatives (such as No Action) for comparison purposes only.

According to the RCRA FIRST Toolbox (USEPA 2016), a full ACM is not required in every case, and determining the appropriate level of study is the first step in an ACM. Because two Appendix IV constituents (arsenic and cobalt) were identified at the Site and several technologies are available for addressing the constituents, a full and thorough ACM was performed for the Site.

Per USEPA (2016) guidance, corrective measures that were clearly not viable were not evaluated. Initial steps in the ACM included analyzing existing Site information and developing a conceptual site model (CSM). Closure and source control plans were also considered because those activities are integral to the long-term strategy and will influence groundwater corrective measures performance. Potential groundwater correction measures were then identified and evaluated against the applicable criteria.

Frequently used technologies that are unlikely to perform satisfactorily or reliably at the Site, or that are technically impractical to implement, were not thoroughly evaluated as part of this ACM. A brief explanation is provided for each remedy not thoroughly evaluated. Though several technologies and combinations of these technologies appear viable for the Site, further evaluation of the technologies is needed to identify a remedy (or remedies) that may be implemented as part of a long-term corrective action plan.

1.2 Remedy Evaluation Criteria

Once potential remedies were identified, they were evaluated using the criteria outlined in 40 CFR 257.96 and ADEM Admin. Code r. 335-13-15-.06(7), which state that the ACM should include an analysis of the effectiveness of potential corrective measures that considers the following:

- Performance
- Reliability
- Ease of implementation
- Potential impacts of the remedy (including safety, cross-media impacts, and exposure)
- The time required to begin and complete the remedy
- Any institutional requirements (e.g., permitting or environmental and public health requirements) that could affect implementation of the remedy

These evaluation criteria, discussed in more detail in the following sections, were considered for each potential remedy.

1.2.1 Performance

Factors taken into consideration when determining the performance of a remedy include the degree to which the remedy removes released Appendix IV constituents from the environment and the ability of the remedy to achieve GWPS at compliance boundaries.

1.2.2 Reliability

Reliability includes the type and degree of long-term management (e.g., monitoring, operations, and maintenance) of a remedy, the reliability of the engineering and institutional controls to maintain the effectiveness of the remedy, potential need for replacement, or any other operational reliability issues that may arise for the remedy that will limit its use or effectiveness in meeting the corrective action objectives.

1.2.3 Ease of Implementation

Ease of implementation includes the degree of difficulty associated with installing or constructing a remedy due to Site conditions, including the need to obtain necessary approvals and/or permits from other agencies, the availability of necessary equipment and/or specialists to implement the remedy, and the available capacity and location of treatment, storage, or disposal services, if needed.

1.2.4 Potential Impacts of the Remedy

Potential impacts of a remedy include the short-term risks that might be posed to the community or the environment during implementation of the remedy (e.g., due to excavation, transportation, disposal, or containment of CCR material), potential for exposure of humans and environmental receptors to remaining CCR material following implementation of the remedy, and cross-media impacts due to the remedy.

1.2.5 Time Required to Begin and Complete the Remedy

The time required to begin and complete a remedy considers the amount of time needed to completely design and implement (i.e., begin) the remedy as well as the time it will take the implemented remedy to achieve applicable GWPS at compliance points.

1.2.6 Institutional, Environmental, or Public Health Requirements

Institutional requirements can vary from site to site and technology to technology. Any state, local, or site-specific requirements (e.g., permits), or other environmental or public health requirements, that could substantially affect construction or implementation of the remedy are considered.

2 Site Background and Characteristics

2.1 Location

Alabama Power Company’s James M. Barry Electric Generating Plant is located in northeastern Mobile County, Alabama, approximately 23 miles north of Mobile, Alabama, and 1 mile east of the city of Bucks, Alabama. The physical address is 15300 U.S. Highway 43 North, Bucks, Alabama 36512. Plant Barry lies in Section 36 of Township 1 North, Range 1 West, Sections 31 and 32 of Township 1 North, Range 1 East, Section 1 of Township 1 South, Range 1 West, and Sections 5 and 6 of Township 1 South, Range 1 East. Section/Township/Range data are based on visual inspection of U.S. Geological Survey (USGS) topographic quadrangle maps and GIS maps (USGS 1980, 1982a, 1982b, 1983).

The Ash Pond is located east-southeast of the main plant, between the Mobile River and the Site barge canal. Figure 1 depicts the location of the Site with respect to the surrounding area. The Ash Pond was originally constructed in 1965, and the area designated for ash storage and disposal currently includes about 594 acres. As described in Section 2.5, ash will be consolidated into an area of approximately one-half to one-third of the initial size.

2.2 Site History

The Site is an electricity generating facility that includes coal-fired units. The Ash Pond received and stored CCR produced during the coal-fired electricity generating process. It also served as a low-volume waste treatment pond for the plant, receiving process water and stormwater from various plant sources, sluiced ash, and decant water from the gypsum pond. As of April 15, 2019, the Ash Pond ceased receipt of all CCR and non-CCR wastestreams. Per ADEM Admin Code r. 335-13-15-.09, Alabama Power Company submitted a closure plan for the Ash Pond to ADEM for review and approval, as part of the permitting package.

The Ash Pond was built on land located south of the generating units in an area having a bottom elevation of about 3 feet above mean sea level (MSL). The soils underlying the impoundment are made up of naturally occurring deposits of predominately low-permeability clays. The fill utilized to form the original embankments is of varied composition but can generally be classified as a mixture of silty and sandy clays, clayey fine sands, and sands underlain by soft organic silts and clays.

The Ash Pond was originally constructed in 1965. The pond was formed by the construction of dikes on the east, south, and west sides of the impoundment. The north side of the impoundment is natural ground that ties into the east and west dikes. Per ADEM Admin. Code

r. 335-13-15-.09, Alabama Power Company submitted a closure plan for the Ash Pond to ADEM for review and approval, as part of the permitting package.

2.3 Hydrogeological Conceptual Site Model and Groundwater Flow

The major components of the hydrogeological CSM include (Alabama Power 2018a):

- Geologic Units 1 and 2 (Figure 2)—Predominantly low permeability clays with interbedded sands in Unit 2; combined thickness generally between 20 and 35 feet; vertical hydraulic conductivities ranging from 1.1×10^{-7} centimeters per second (cm/sec) to 7.08×10^{-9} cm/sec; provide upper confining or leaky confining conditions for the uppermost aquifer, the Watercourse Aquifer (Unit 3 Sand)
- Uppermost Aquifer (Unit 3 Sand)—Described locally as the Watercourse Aquifer; located 45 to 70 feet beneath the top of the dike or 20 to 45 feet beneath top of natural ground; 50 to 60 feet in thickness; composed of silty sand with clay lenses in upper sections and fine gravel towards the base; may be separated (confined) from deeper aquifers by underlying low permeability clay (Unit 4) at depth
- An aquifer performance test (APT) was completed in the southwestern portion of the Ash Pond within the CCR and the underlying Watercourse Aquifer (Unit 3 Sand) (Geosyntec Consultants 2018):
  - Watercourse Aquifer (Unit 3 Sand):
    - Leaky confined aquifer with an incompressible aquitard and a potential infinite-source recharge boundary (i.e., the canal located 200 feet to the west of the APT area)
    - Hydraulic conductivity (K) ranged from 3.2×10^{-3} to 3.4×10^{-2} cm/sec
    - Transmissivity (T) ranged from 452 to 474 feet squared per day (ft^2/day)
    - Storativity (S) ranged from 6.2×10^{-4} to 1.4×10^{-3}
  - CCR Material:
    - K ranged from 3.5×10^{-4} to 9.2×10^{-4} cm/sec
    - T ranged from 23.4 to 58.9 ft^2/day
    - S ranged from 1.8×10^{-2} to 6.8×10^{-2}
- Six slug tests were performed at 6 of the 16 monitoring wells to estimate the horizontal hydraulic conductivity of the Watercourse Aquifer:
  - K ranged from 3.5×10^{-3} to 2.1×10^{-2} cm/sec
- Vertical K values were obtained from Shelby tube permeameter testing:
  - Unit 1 (clay and silt): K ranged from 1.15×10^{-8} to 1.40×10^{-7} cm/sec
  - Unit 1 (interbedded sand and clay): K ranged from 7.08×10^{-9} to 3.82×10^{-7} cm/sec
  - Unit 4 (clay): K ranged from 3.78×10^{-8} to 2.13×10^{-7} cm/sec

- Groundwater flow characteristics:
  - Groundwater flow occurs via porous (Darcy) flow mechanics with potential for preferential movement along more conductive sand and gravel lenses or channels.
  - Vertical groundwater flow in upper strata is likely retarded by low permeability clays.
  - Groundwater recharge is likely occurring from the barge canal and outcropping connected sand units to the west.
  - Groundwater flows horizontally from west to east towards the Mobile River in an arcuate pattern matching the geometry of the river with some components of northerly and southerly groundwater flow.
  - Horizontal hydraulic conductivity values in the uppermost aquifer average 3.3×10^{-3} cm/sec (9.4 feet per day), as determined from pump testing.
  - Groundwater flow velocity is calculated at a relatively slow rate of 0.008 foot per day and is influenced heavily by low hydraulic gradients across the Site.

Groundwater elevations fluctuate in response to rainfall and Mobile River stage. Seasonal variations of 5 to 7 feet are typical at the Site. These fluctuations are consistent in monitoring wells across the Site, indicating a relatively uniform response to rainfall events and fluctuations of the discharge canal and Mobile River. A typical potentiometric surface map is presented in Figure 3. Groundwater elevation data indicates that water levels tend to be higher in the early spring and lower during the fall and winter seasons. Table 1 provides a summary of historical groundwater elevation data for the Site.

2.4 Delineation of Appendix IV Constituents

The groundwater monitoring network is composed of 16 monitoring wells installed around the Ash Pond (Figure 3 and Table 2): 3 upgradient and 13 downgradient. Monitoring well locations MW-2 through MW-4 serve as upgradient locations for the Ash Pond, as determined by water level monitoring and potentiometric surface maps constructed for the Site. Upgradient wells are screened within the same uppermost aquifer as downgradient locations and are representative of background groundwater quality at the Site. Monitoring well locations MW-1 and MW-5 through MW-16 are utilized as downgradient locations for the Ash Pond, as determined by water level monitoring and potentiometric surface maps constructed for the Site.

Background sampling occurred between March 2016 and June 2017. Compliance detection sampling began following completion of background sampling, with sampling occurring in September 2017. Statistically significant increases (SSIs) of Appendix III constituents were noted during the September 2017 compliance detection sampling event, as described in the *2017 Annual Groundwater Monitoring and Corrective Action Report* (Alabama Power 2018b). The

Appendix III SSIs triggered assessment sampling for Appendix IV constituents, with sampling events occurring in January, May, and November 2018. Appendix III and IV Maximum Contaminant Level and CCR-rule-specified GWPS values are shown in Table 3. The May and November 2018 sampling events noted Appendix IV constituents arsenic and cobalt at SSLs above GWPS. SSLs above the GWPS for arsenic (0.01 milligram per liter [mg/L]) and cobalt (0.006 mg/L) from the May and November 2018 sampling events are summarized as follows:

- Arsenic was reported at SSLs above the GWPS at the following monitoring wells: BY-AP-MW-1, BY-AP-MW-5, and BY-AP-MW-7 through BY-AP-MW-15 for both May and November 2018 sampling events.
- Cobalt was reported at SSLs above the GWPS at monitoring wells BY-AP-MW-7, BY-AP-MW-15, and BY-AP-MW-16 during the May 2018 sampling event. Only one downgradient well, BY-AP-MW-15, was reported at SSLs above the GWPS during the November 2018 sampling event.

Note that while arsenic and cobalt concentrations did exceed the GWPS at some wells during the May and November 2018 sampling event, concentrations were generally only slightly above the GWPS. Detected concentrations ranged from approximately 0.001 to 0.08 mg/L for arsenic and 0.003 to 0.03 mg/L for cobalt (Tables 4 and 5). One upgradient monitoring well, BY-AP-MW-2, also exceeded the GWPS for cobalt in November 2018.

To delineate groundwater impacts, additional monitoring wells consisting of seven vertical delineation wells and six horizontal delineation wells have been planned and or installed at locations downgradient of monitoring wells where Appendix IV SSIs were observed. To date, the installation of six vertical delineation wells, three horizontal delineation wells, and three ash pore-water piezometers have been completed. The remaining scope could not be completed during the wet season as areas where horizontal delineation wells were planned were not accessible to drill rigs due to wet and unsafe field conditions. These locations will be re-attempted during the relatively drier months of June, July, or August of 2019. Vertical delineation wells were installed at the base of Unit 3 Sands between depths of 100 and 115 feet below ground surface and generally screened just above the Unit 4 Clay. The remaining horizontal delineation wells will be installed in the upper and middle portions of Unit 3 along the eastern and southern waste boundaries.

To discern the nature of source, pore water samples from three locations within the Ash Pond were collected and analyzed for Appendix III and IV constituents. The results indicate that cobalt is either not present or remains in the in-place solid material. Therefore, an alternate source demonstration for cobalt is under consideration for the Site.

2.5 Pond Closure and Source Control

Closure of the Plant Barry Ash Pond will be accomplished by dewatering, consolidating and capping the ash with a final cover system. Dewatering is estimated to last several years. The mechanical treatment system will be adjusted to 1) control Ash Pond drawdown at a rate to ensure structural integrity of the impoundment is maintained as determined by the Dam Safety Engineer, and 2) manage fluctuating site conditions due to the decrease of the Ash Pond volume as well as the addition of rainfall. This will effectively control the source of CCR constituents to groundwater by removing free liquid from the ash, reducing the area of ash, and preventing further infiltration through the ash. The Plant Barry Ash Pond will be closed by leaving CCR in place and consolidating the current site footprint of approximately 597 acres to an area of approximately 330 acres. The current closure plan estimates that dewatering, consolidation and capping will be completed in 2031.

As part of the ash consolidation, the Ash Pond will be dewatered sufficiently to remove the free liquids. Removing free liquids will reduce the volume of water available to migrate from the Ash Pond during closure and minimize hydraulic head within the pond, thereby reducing pressure to cause migration from the Ash Pond. A reduction of hydrodynamic forces that lead to outward or downward migration will also allow the natural, low permeability clay directly underlying the Ash Pond to more effectively confine vertical seepage. CCR will be consolidated into a smaller footprint and graded to create a subgrade for the final cover system. Excavation will include removing all visible ash and over excavating into the subgrade soils. Additionally, an internal toe drain system will be installed near the perimeter of the consolidated footprint at an approximate elevation of 1 feet above mean sea level during closure and left in place post-closure. This internal toe drain will be used during closure and through post-closure to aid dewatering activities and collect residual pore water. Collected pore water will be conveyed to the water treatment plant.

The final cover will be constructed to control, minimize or eliminate, to the maximum extent feasible, post closure infiltration of liquids into the waste and potential releases of CCR from the unit. This will be prevented by providing sufficient grades and slopes to: 1) preclude the probability of future impoundment of water, slurry, or sediment; 2) ensure slope and cover system stability; 3) minimize the need for further maintenance; and, 4) be completed in the shortest amount of time consistent with recognized and generally accepted good engineering practices.

The final cover system will be designed to minimize infiltration and erosion. The current design for the cover system is the synthetic ClosureTurf® cover system that utilizes a 50-mil LLDPE geomembrane overlain by an engineered synthetic turf. The synthetic turf will contain a minimum ½ inch sand infill. The permeability of the final cover system will be significantly less than the permeability of the natural subsoils beneath the surface impoundment. Final design will ensure the disruption of the integrity of the final cover system is minimized through a design that accommodates settlement and subsidence, in addition to providing an upper component for protection from wind or water erosion.

3 Groundwater Corrective Measures Alternatives

3.1 Objectives of the Corrective Measures

Following 40 CFR 257.97(b) and ADEM Admin. Code r. 335-13-15-.06(8)(b), the following summarizes the criteria that must be met by the remedy:

- Protect human health and the environment.
- Attain applicable GWPS.
- Control the source of the release so as to reduce or eliminate, to the maximum extent feasible, further releases of Appendix IV constituents to the environment.
- Remove from the environment as much of the material released from the CCR unit as is feasible, considering factors such as avoiding inappropriate disturbances of sensitive ecosystems.
- Comply with any relevant standards (i.e., all applicable RCRA requirements) for management of wastes generated by the remedial actions.

All corrective measures selected for evaluation for potential use at the Site are anticipated to satisfy the above performance criteria to varying degrees of effectiveness.

3.2 Potential Groundwater Corrective Measures

The following presents a summary of potential groundwater corrective measures evaluated as part of this ACM. Based on Site-specific information and knowledge of corrective alternatives, the following remedies—or combination of remedies—are being considered using the evaluation criteria specified in 40 CFR 257.96(c) and ADEM Admin. Code r. 335-13-15-.06(7)(c):

- Monitored natural attenuation (MNA)
- Hydraulic containment (pump-and-treat)
- Permeable reactive barriers (PRBs)
- Subsurface barrier walls
- Geochemical manipulation (in situ injection)

Two frequently considered remedies, 1) phytoremediation and 2) in situ grouting, were not considered viable at the Site. Conventional phytoremediation for inorganic constituents may be effective for impacts at or near the ground surface. Appendix IV SSLs occur in groundwater at depths below 10 to 20 feet and phytoremediation would not be effective at those depths. The TreeWell phytoremediation technology may be effective to depths of 50 feet (possibly more), but trees do not bioaccumulate arsenic and cobalt and would not transpire a sufficient amount of water to achieve hydraulic containment in the hydrogeologic conditions at the Site.

In situ grouting was not considered because the grain size is too fine and the low permeability of the Unit 3 sand will impede the horizontal distribution of the grout, thus rendering it impractical.

3.2.1 Monitored Natural Attenuation

MNA has been a component of corrective action at RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) sites since the 1990s. MNA describes a range of physical and biological processes in the environment that reduce the concentration, toxicity, or mobility of constituents in groundwater. For inorganic constituents, the mechanisms of natural attenuation include biostabilization, sorption, dispersion, and precipitation (USEPA 1999, 2007a, 2007b). MNA as a remedial alternative depends on a good understanding of localized hydrogeologic conditions and may require considerable information and monitoring over an extended period of time. MNA is not an approach that will lead to rapid closure of a site and is frequently used in combination with other remedies at a site.

Where site conditions are conducive to MNA, it has the potential to provide a more sustainable, lower-cost alternative to aggressive remediation technologies such as pump-and-treat. The Electric Power Research Institute (EPRI) has prepared a document describing implementation of MNA for 24 inorganic constituents (EPRI 2015a).

USEPA defines MNA as follows (USEPA 1999, 2015):

> The reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a timeframe that is reasonable compared to that offered by other more active methods. The "natural remediation processes" that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater.

When properly implemented, MNA removes constituents from groundwater and immobilizes them onto aquifer solids. Decisions to utilize MNA as a remedy or remedy component should be thoroughly supported by site-specific data and analysis (USEPA 1999, 2015).

According to USEPA (2015) guidance, a four-phase approach should be used to establish whether MNA can be successfully implemented at a given site. The phases (also referred to as "steps" or "tiers") include the following (USEPA 1999, 2007a):

1. Demonstrate that the extent of groundwater impacts is stable.
2. Determine the mechanisms and rates of attenuation.
3. Determine if the capacity of the aquifer is sufficient to attenuate the mass of constituents in groundwater and that the immobilized constituents are stable and will not remobilize.
4. Design a performance monitoring program based on the mechanisms of attenuation and establish contingency remedies (tailored to site-specific conditions) should MNA not perform adequately.

Based on MNA case histories for inorganic constituents, MNA timeframes range from a few years to decades (EPRI 2015a). Because pond closure activities (consolidation and capping) at the Site are projected to take approximately 12.5 years, the timeframe for MNA is compatible with the closure period.

Attenuation mechanisms can be placed in two broad categories, physical and chemical. Physical mechanisms include dilution, dispersion, flushing, and related processes. All constituents are subject to physical attenuation mechanisms, so physical processes should be considered in MNA evaluations. In its most recent guidance, USEPA (2015) discourages using dilution and dispersion as primary MNA mechanisms, as these mechanisms disperse contaminant mass rather than immobilize it. Further, USEPA (2015) advises that dilution and dispersion may be appropriate as a polishing step (e.g., at the boundaries of a plume, when source control is complete, an active remedy is being used at the Site, and appropriate land use and groundwater controls are in place).

Common chemical mechanisms of attenuation for inorganic constituents include adsorption to, or coprecipitation with, oxides and hydrous oxides (oxyhydroxides) of iron and manganese; coprecipitation with, and adsorption to, iron sulfides such as pyrite (FeS_2); and precipitation as carbonates, sulfides, sulfates, and/or phosphates (USEPA 2007b).

Arsenic and cobalt are subject to physical attenuation mechanisms and are also chemically attenuated (e.g., by sorption to naturally occurring oxyhydroxides of iron and other metals, and by coprecipitating with common minerals such as iron sulfides). Therefore, MNA is a potentially viable corrective measure for groundwater at the Site.

3.2.2 Hydraulic Containment (Pump-and-Treat)

Hydraulic containment utilizes pumping wells (and sometimes injection wells, trenches, galleries, and/or trees) to contain and prevent the expansion of impacted groundwater. Effective hydraulic containment uses pumping wells or other subsurface hydraulic mechanisms to create a horizontal and vertical capture zone or a hydraulic barrier. After pumping, the water may be reused in beneficial applications or treated, discharged, or reinjected. Hydraulic containment is one of the most mature corrective action technologies, and it is described in *Pump-and-Treat Ground-Water Remediation: A Guide for Decision Makers and Practitioners* (USEPA 1996) and *Groundwater Contamination, Optimal Capture and Containment* (Gorelick et al. 1993).

Due to the Unit 3 Sand (Watercourse Aquifer) hydraulic characteristics established during the aquifer performance testing, hydraulic containment could be implemented within the Unit 3 Sand. Because arsenic and cobalt are treatable by commonly used technologies, pump-and-treat is a potentially viable corrective measure for groundwater at the Site.

3.2.3 Permeable Reactive Barrier Walls

A PRB wall is the emplacement of chemically reactive materials in the subsurface to intercept impacted groundwater, provide a flow path through the reactive media, and capture or transform the constituents in groundwater to achieve GWPS downgradient of the PRB (Powell et al. 1998).

EPRI (2006) provides an overview of PRBs and possible PRB reactive media for constituents from CCR. The PRB is an in situ technology that allows impacted water to flow through the media and provides a barrier to constituents rather than to groundwater flow. PRBs can be used to treat groundwater impacted with metals and metalloids, chlorinated volatile organic compounds, petroleum hydrocarbons, and radionuclides. The main processes by which a PRB is used to remediate groundwater are transformation and immobilization. Transformation, or conversion, involves transforming a constituent to a less toxic form such as chemical reduction of chromium (VI) to chromium (III). Immobilization is of the most interest with respect to inorganic constituents such as those from CCR sites. Immobilization of constituents takes place through precipitation from the dissolved state or through sorption to reactive media in the PRB (Powell et al. 2002; EPRI 2006).

There are two design configurations for PRB walls (ITRC 2005; EPRI 2006):

- Continuous PRBs are ones in which the reactive media extend across the entire path of the plume. These should have minimal impact on groundwater flow and do not necessarily have to be tied to a low hydraulic conductivity unit, although that would be dependent on the depth of impacts and would safeguard against constituents flowing under the PRB if permeability of the reactive media was reduced.

- Funnel-and-gate systems incorporate barrier walls to control and direct flow to the reactive gate. The funnels can be constructed of sheetpiles, bentonite, or other barrier wall material. Similar to barrier walls used for containment, funnels must be tied into a confining bed or low hydraulic conductivity unit to avoid having impacted water flow under the wall. Funnels can also be placed in zones of greatest contaminant mass flux through the aquifer, to maximize efficiency of treatment. The use of a funnel can cause a significant increase in groundwater flow velocity, which must be considered in designing the reactive portion of the wall for residence time. The funnel must be designed to extend beyond the extent of the plume to avoid end-around flow.

Groundwater residence time through the gate needs to be sufficient to allow capture of the constituents as groundwater moves through the reactive media.

Site characterization is especially important with PRBs to allow proper design where groundwater flows naturally through the reactive media. An understanding of the following site and constituent characteristics is crucial to the success of the system (Powell et al. 1998; EPRI 2006):

- The permeability of the reactive zone, which must be kept greater than or equal to the aquifer to avoid diverting flow away from the PRB
- An understanding of the groundwater impact area boundaries and flow paths
  - The reactive media and funnel system, if used, must be properly designed and placed such that the groundwater will not bypass or be diverted around or under the system.
  - Excessive depth and fractured rock are difficult for placement of media.
- The geochemistry of the constituents and how they will interact with the reactive media
- Determination of how quickly groundwater will move through the reactive media to calculate residence time of the impacted groundwater
- The ability of the reactive media to remove constituents from groundwater yet remain reactive for an extended period

Major considerations in selecting reactive media for PRBs include the following (Gavaskar et al. 1998; EPRI 2006):

- Reactivity: The media should have adequate reactivity to immobilize a constituent within the residence time of the design.

- Hydraulic performance: The media should facilitate adequate flow through the PRB, which usually means it has a greater particle size than the surrounding aquifer media. Alternatively, gravel may be placed upgradient of PRBs to direct flow through them.
- Stability: The media should remain reactive for an amount of time that makes its use economically viable compared to other technologies.
- Environmentally compatible by-products: The media should not release by-products that are not environmentally acceptable in the aquifer environment. For example, media should not produce excess alkalinity (or acidity) such that pH is raised (or lowered) to unacceptable levels.
- Availability and price: The media should be easy to obtain in large quantities at a price that makes the PRB economically feasible.

Inorganic constituents have been shown to be amenable to remediation using PRB technology when using the appropriate reactive media. These include arsenic, chromium, sulfate, selenium, nickel, lead, uranium, technetium, iron, manganese, copper, cobalt, cadmium, zinc, molybdenum, nitrate, and phosphate (McGregor et al. 2002; EPRI 2006; EPRI 2015a; Dugan 2017).

A PRB can be installed through trenching, or soil excavation, in a similar manner as a slurry wall. A biopolymer slurry is used to stabilize the trench walls during excavation. The biopolymer is usually guar gum-based to allow microbial breakdown of residual slurry after placement of the reactive media. The reactive media is placed through the slurry by tremie. The depths are limited to about 90 feet, or the depth a trench can be kept open (ITRC 2005).

Due to the hydraulic characteristics of the Unit 3 Sand (Watercourse Aquifer), the presence of a laterally extensive lower confining bed (Unit 4 Clay), and the availability of reactive media for inorganic constituents, the PRB wall is a potentially viable corrective measure for groundwater at the Site. The depth required at the Site, however, is approaching the limit for a PRB wall.

3.2.4 Vertical Barrier Walls

Vertical barrier walls are used to stop the flow of groundwater and any constituents that groundwater contains. Though effective, vertical barrier walls may serve as groundwater dams, so hydraulic containment to address mounding of groundwater behind barrier walls or flow of groundwater around the ends of barrier walls should be considered.

Bentonite slurry walls have been used for decades to control the flow of groundwater in both environmental applications as well as general foundation construction. Soil-bentonite walls are constructed by excavating a narrow vertical trench and injecting bentonite slurry to support the trench walls. The bentonite slurry used to support the trench walls is generally a mixture of pulverized bentonite in water. Water from the slurry bleeds into the trench wall, leaving behind a mat of particles known as filter cake, which along with the hydrostatic force of the slurry, holds the trench open. Once the trench reaches final grade, the trench is backfilled with a mixture of soil from the excavation, slurry, and soil from other sources, as necessary, to achieve the desired properties of strength and hydraulic conductivity. The backfill is generally placed with a tremie, clamshell, and/or a bulldozer, displacing the trench support slurry. The filter cake remains in place and, along with the gradation of the backfill used in the wall, is a function of the hydraulic conductivity of the final wall. Installation of soil-bentonite barrier walls can require significant amounts of space for mixing backfill (Bliss 2014). At CCR facilities, berms may be constructed to provide the working space for barrier wall emplacement.

Cement-bentonite barrier walls are similar to soil-bentonite walls except that the stabilizing fluid used during excavation is a cement-bentonite water mix. The slurry remains in place to form the wall, so a separate operation to mix the backfill and displace the slurry is not necessary. Because the excavated material is not used in the backfill mix, significant amounts of spoil are generated with this type of barrier wall. Also, due to the method of excavation with the slurry, there can be a significant amount of slurry waste (up to 40% of the total trench/panel volume) during excavation (EPRI 2015b).

Barrier walls used alone at the Site could produce groundwater mounding, with possible rise of groundwater to the surface, and could produce groundwater flow around the end of the barrier walls. However, barrier walls could be used to improve the subsurface hydraulic (flow) conditions for PRB walls and pump-and-treat. For example, barrier walls could form the impermeable portions of a funnel-and-gate PRB wall to direct groundwater to the treatment gates containing reactive media and could be used in a similar way to direct groundwater toward pumping wells in a pump-and-treat system. Because they could be part of PRB or hydraulic containment (pump-and-treat) systems, barriers walls are potentially viable corrective measures at the Site. Note that to be effective for environmental applications, barrier walls should be tied into a continuous, relatively impermeable layer such as the Unit 4 Clay at the Site.

3.2.5 Geochemical Manipulation (In Situ Injection)

Geochemical manipulation usually via subsurface injections, is an emerging remediation technology for inorganic constituents in groundwater. Geochemical manipulation for inorganic constituents may be applied in three modes: redox manipulation; adsorption to iron or other metal oxyhydroxides under oxidizing groundwater conditions; and adsorption to, or coprecipitation with, iron or other metal sulfides under reducing conditions (sequestration in sulfides).

Redox manipulation has been applied to metals such as chromium since the 1990s, where reducing compounds are injected to chemically reduce chromium (VI) to the more benign chromium (III) (USEPA 2000; Ludwig et al. 2007). Geochemical processes such as adsorption and coprecipitation are applicable to arsenic and cobalt. In adsorption under oxidizing conditions, an iron source (such as ferrous sulfate) is injected into the subsurface and oxidizes to iron oxyhydroxides (ferrihydrite) to which contaminants adsorb (Pugh et al. 2012; Redwine et al. 2004). Due to the generally mildly reducing conditions at the Site, sequestration in sulfides is potentially the most viable of the geochemical manipulation technologies.

In the sequestration-in-sulfides technology, soluble sources of organic carbon, ferrous iron, and sulfate are injected into the subsurface to optimize conditions for sulfate-reducing bacteria growth (Saunders 1998). Sulfate-reducing bacteria produce sulfide minerals as a by-product of their metabolism, and constituents are removed from groundwater and immobilized by the sulfide minerals. Trace constituents substitute for other elements in the sulfide mineral structure and are adsorbed to sulfide mineral surfaces. In recent successful applications for arsenic, a treatment solution containing molasses, ferrous sulfate heptahydrate, and small amounts of commercial fertilizer dissolved in unchlorinated water were injected to significantly decrease arsenic concentrations in groundwater.

The following inorganic constituents may be removed from groundwater by sulfide mineral formation: antimony, arsenic, cadmium, cobalt, copper, mercury, lead, molybdenum, nickel, selenium, thallium, and zinc, in addition to some rarer elements (Abraitis et al. 2004; EPRI 2015b). The most common sulfide minerals include the iron sulfide family (FeS, FeS_2), though many other sulfide minerals are documented.

Because of the generally mildly reducing groundwater conditions at the Site, and effectiveness for arsenic and cobalt, sequestration in sulfide minerals is a potentially viable for corrective action at the Site. Because the technology has not yet been demonstrated for large areas, its optimum application may be treatment of isolated areas (e.g., in the vicinity of a few impacted wells).

3.3 Potential Remedy Evaluation

3.3.1 Introduction

The following remedies are considered potentially viable for corrective measures for groundwater at the Site:

- MNA
- Hydraulic containment (pump-and-treat)

- Funnel-and-gate PRB wall
- Vertical barrier walls as components of other corrective measures
- Geochemical manipulation (injections), particularly sequestration in sulfide minerals

Although these technologies are potentially feasible remedies, further data collection and evaluation are required to: 1) verify the feasibility of each; and 2) provide sufficient information to design a corrective action system that meets the criteria specified in 40 CFR 257.97(b) and ADEM Admin. Code r. 335-13-15-.06(8)(b). Table 6 provides a summary of these technologies compared to the evaluation criteria discussed in Section 1 as applied to Site conditions. Table 7 discusses advantages and disadvantages of each technology that should be considered.

3.3.2 MNA

MNA is compatible with the other groundwater corrective actions that are potentially viable for the Site. At a minimum, MNA can serve as a polishing step (USEPA 2015), which may be all that is needed at the Site due to source control and the small reduction in constituent concentrations required to meet GWPS.

The performance of MNA requires further investigation, especially related to the identification of attenuating mechanisms, capacity of Unit 3 for attenuation, and time to achieve GWPS. Because Unit 3 is a sandy aquifer, the capacity for attenuation may not be as high as in an aquifer that contains more fines (silt and clay) or organic material. Therefore, MNA performance is considered medium in the absence of additional data. Dewatering, consolidation, and capping of the Ash Pond, however, will likely reduce the source contribution to groundwater such that the attenuation capacity of Unit 3 may be sufficient to achieve GWPS in a reasonable timeframe.

Implementation of MNA at the Site will be relatively easy. Most of the wells for MNA are already in place, though a few additional wells may need to be installed to monitor progress in critical areas. Solid (e.g., aquifer) samples will need to be collected to identify attenuating mechanisms and to test capacity, permanence, and help determine the time required to achieve GWPS.

Reliability of MNA will be relatively high because MNA requires almost no operation and maintenance (O&M). Potential impacts of the remedy will be negligible because MNA is non-intrusive and produces no effluents or emissions.

Implementation of MNA would require some geochemical studies and possibly the installation of some new wells. Because MNA does not require design and construction of infrastructure other than new monitoring wells, it can be initiated within 6 months to a year. At least 1 year of groundwater monitoring data is recommended before implementation of MNA is considered complete. The additional data would be needed for statistical analysis and to determine if additional monitoring wells need to be installed. Therefore, complete implementation of MNA would take about 18 to 24 months.

Time for MNA to achieve GWPS is currently unknown and would require additional studies. Published and unpublished case histories for arsenic, and by inference cobalt, suggest that MNA would take 2 decades or more to achieve GWPS. However, the timeframe at the Site may be less because of the source control measures (dewatering, consolidation, and capping) and the fact that groundwater monitoring data for arsenic and cobalt are only slightly above the GWPS.

3.3.3 Hydraulic Containment (Pump-and-Treat)

Hydraulic containment via pump-and-treat has been used for groundwater corrective action for decades. When the pump-and-treat system is online, the performance is considered high: arsenic and cobalt are readily treated, and if the system subsurface hydraulics are designed properly, the area of impact will stabilize or shrink. Because these systems require substantial O&M, the reliability is considered not quite as high as some other technologies. In other words, pumps, piping, and the water treatment system must be maintained and will be offline occasionally for various reasons.

Similarly, hydraulic containment is not as easy to implement as some other technologies (e.g., MNA or geochemical manipulation), due to design, and installation of wells, pumps, and piping. An on-site water treatment plant would be required to accommodate both the quantity and constituents in the pumped groundwater. Because the quantity of water requiring treatment cannot be ascertained without further study, the design parameters of the treatment system would also need to be verified through additional investigations.

Hydraulic containment could probably be designed and installed within 1 to 2 years. Based on published and unpublished case histories, time to achieve GWPS could take a decade or more due to the slow desorption kinetics of arsenic and cobalt from the Unit 3 aquifer, though both the planned source control and MNA should accelerate this process.

Regulatory requirements and institutional controls may be greater for hydraulic containment than some of the other technologies. For example, permits may be required for the withdrawal and re-injection (if used) of water, and the chemistry of the effluent after treatment would need to be compatible with the National Pollutant Discharge Elimination System permit.

Active technologies such as hydraulic containment (pump-and-treat) may offer few or no advantages over MNA. For example, pump-and-treat for arsenic, cobalt, and other inorganic constituents may reach a point of diminishing returns relatively quickly (few months to a few years), as the concentration decreases and the subsequent reduction in concentration changes very little through time (EPRI 2018). The diminishing rate of concentration reduction is likely due to the slow desorption kinetics of constituents from aquifer solids (Bethke and Brady 2000; USEPA 2000). Due to the slow desorption kinetics, pump-and-treat may take a decade or more to achieve GWPS, such that it offers no time advantage over MNA (EPRI 2018).

3.3.4 Permeable Reactive Barrier Walls

PRB walls may be installed with continuous reactive media or with impermeable sections punctuated by reactive treatment gates (funnel-and-gate configuration). The funnel-and-gate configuration directs flow through the reactive gates, thereby improving treatment efficiency. Because of the large area to be treated, and increased efficiency of the system, the funnel-and-gate configuration is envisioned for the Site.

When working effectively in suitable conditions, PRB walls can reduce constituents to GWPS downgradient of the walls. However, because of site-specific uncertainties associated with the reactive media and subsurface hydraulics, performance is considered medium to high. Similarly, because the reactive media is expended and may clog through time, and will need to be replaced at some point, reliability is considered to be medium. Further technology-specific evaluation is required to more definitively determine the feasibility of implementing a PRB at the Site.

Due to the required depth of the PRB at the Site (approaching the maximum depth limit), and that mixed media may be required to treat the constituents, implementation may be moderately difficult. Alteration of subsurface hydraulics (flow) may be a potential impact of this remedy. Because of required laboratory treatability studies on the reactive media, and depth of the wall, time to implement the remedy is estimated to be 2 to 4 years. Time to achieve GWPS is estimated to be at least a decade or more, though a groundwater model could help to better define this period.

3.3.5 Vertical Barrier Walls

Vertical barrier walls, such as slurry walls, would not be applied alone at the Site due to the potential for groundwater rise to the surface and flow of impacted groundwater around the ends of walls. Impermeable barrier walls could be used to enhance the subsurface hydraulics for other treatments, for example, as impermeable sections between pumping zones, or impermeable sections between reactive gates in a funnel-and-gate PRB wall.

Subsurface vertical barrier walls are a widely used and accepted technology, with relatively high performance and reliability. Implementation at the Site could be moderately difficult due to the depth of the wall. Potential impacts of the remedy include alteration of subsurface hydraulics (flow).

Due to the depth of the wall, time to implement the remedy (construct the wall) could be 1 to 2 years, and time to achieve GWPS would be the same length of time as the companion technology (i.e., hydraulic containment or PRBs).

3.3.6 Geochemical Manipulation (In Situ Injection)

Geochemical manipulation (injection) is an emerging technology for inorganic constituents. The permanence of geochemical manipulation has not yet been demonstrated, due to its short history of application; therefore, performance is not considered high at present. Similarly, reliability is considered medium or moderate because Site geochemical conditions should not change beyond the tolerance of the treatment. The most effective use of this technology at the Site is probably for smaller isolated areas, where performance can be readily monitored and re-treatment applied if needed.

Geochemical manipulation is relatively easy to moderate to implement, particularly in small areas. The main infrastructure required are injection wells, though the treatment solution may be injected through direct-push drill rigs. Even though infrastructure requirements are minimal, some laboratory and/or field pilot test work will need to be done, and a state underground injection control permit may be required, so geochemical manipulation is estimated to require a few years to implement. Because the longevity of this technology has not yet been demonstrated and multiple injections may be required, up to a decade or more may be needed to achieve GWPS.

4 Remedy Selection

Pursuant to 40 CFR 257.97 and ADEM Admin. Code r. 335-13-15-.06(8), after completing this ACM, the Site must select a remedy as soon as feasible. In contrast, Part C of the Administrative Order states that this ACM must include the remedy proposed to the Department for approval.

To meet the requirement of Part C, the Site remedy is proposed to consist of the following:

1. Source control by dewatering the Ash Pond, consolidating the CCR material, and capping it with a low-permeability cover system to prevent infiltration
2. MNA with routine evaluation of system performance to ensure that remediation goals are being met
3. Adaptive site management and remediation system enhancement or modification to ensure that remediation performance goals are met

40 CFR 257.97(b) and ADEM Admin. Code r. 335-13-15-.06(8)(b) specify the following criteria that must be met by the remedy:

- Protect human health and the environment
- Attain applicable GWPS
- Control the source of the release so as to reduce or eliminate, to the maximum extent feasible, further releases of Appendix IV constituents to the environment
- Remove from the environment as much of the material released from the CCR unit as is feasible, considering factors such as avoiding inappropriate disturbances of sensitive ecosystems
- Comply with any relevant standards (i.e., all applicable RCRA requirements) for management of wastes generated by the remedial actions

Combined closure/source control and MNA are anticipated to meet the requirements of 40 CFR 257.97(b) and ADEM Admin. Code r. 335-13-15-.06(8)(b). In an adaptive site management process, system performance is monitored, and one or more technologies identified in this ACM will be used to supplement the remedy as soon as feasible if the system is not performing as intended or corrective action goals are not met.

Using adaptive site management, a remedial approach will be implemented, conditions monitored, and results interpreted. The framework for future decision-making is as follows. Based on monitoring data, adjustments will be made to the corrective measures as necessary, leading to continuous improvements in Site knowledge and corrective measures performance. Specifically, potential changes in Site conditions associated with pond closure may require periodic changes to the corrective measure system. Moreover, Site conditions may require the implementation of more than one corrective measure technology to meet remediation goals over the life of the project.

At the Site, Appendix IV SSLs have been identified and pond closure is underway but not complete. As soon as practical, MNA will be implemented to address the SSLs based on the current Site conditions. Using an adaptive site management approach, a remediation approach will be used whereby: 1) the corrective measures system will be implemented to address current conditions; 2) the performance of the system will be monitored and evaluated semi-annually; 3) the Site conceptual model will be updated as more data are collected; and 4) adjustment and augmentation will be made to the corrective action system to ensure that performance criteria are met.

4.1 Additional Data Needs

Additional data and analysis will be required to perform a thorough site-specific evaluation and supplemental design of groundwater corrective actions for the Site. The following provides a summary of typical additional data needed to evaluate and select a remedy system:

- Geochemical studies of groundwater and aquifer media and geochemical modeling as needed
- Subsurface hydraulic calculations or models
- Laboratory treatability studies on groundwater, aquifer media, reactive media, and potential treatment solutions for injection
- Field pilot studies based on results of laboratory treatability studies

4.2 Schedule

Table 8 provides a generalized conceptual schedule for evaluating additional information and selecting a remedy to potentially supplement the proposed corrective action.

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Tables

Table 1
Historical Groundwater Elevations Summary

Well ID	Average GW Elevation (feet MSL)	Highest GW Elevation (feet MSL)	Lowest GW Elevation (feet MSL)	GW Elevation Variation (feet)
BY-AP-MW-1	5.13	8.19	2.86	5.33
BY-AP-MW-2	4.26	7.59	2.49	5.10
BY-AP-MW-3	4.14	7.53	2.31	5.22
BY-AP-MW-4	3.99	7.41	2.10	5.31
BY-AP-MW-5	3.67	7.39	1.58	5.81
BY-AP-MW-6	3.63	7.48	1.36	6.12
BY-AP-MW-7	3.67	7.86	1.25	6.61
BY-AP-MW-8	3.46	7.90	0.92	6.98
BY-AP-MW-9	3.30	7.64	0.74	6.90
BY-AP-MW-10	3.35	7.77	0.88	6.89
BY-AP-MW-11	3.55	7.82	1.04	6.78
BY-AP-MW-12	3.23	7.43	0.73	6.70
BY-AP-MW-13	3.31	7.49	0.81	6.68
BY-AP-MW-14	2.86	6.89	0.36	6.53
BY-AP-MW-15	3.30	7.21	0.99	6.22
BY-AP-MW-16	3.75	7.34	1.76	5.58

Notes:
Source: Southern Company Services, 2019. *Plant Barry Ash Pond, 2018 Annual Groundwater Monitoring and Corrective Action Report.*

GW: groundwater
MSL: mean sea level

Table 2
Groundwater Monitoring Network Details

Well Name	Installation Date	Northing	Easting	Ground Elevation	Top of Casing Elevation	Top of Screen Elevation	Bottom of Screen Elevation	Purpose
BY-AP-MW-1	10/7/2015	362905.452	1811513.200	22.91	25.80	-10.304	-20.304	Downgradient
BY-AP-MW-2	10/7/2015	363375.014	1811104.860	21.10	23.89	-31.515	-41.515	Upgradient
BY-AP-MW-3	10/7/2015	364009.973	1810627.965	23.60	26.61	-46.581	-56.581	Upgradient
BY-AP-MW-4	10/7/2015	364620.885	1810128.368	24.05	26.97	-47.942	-57.942	Upgradient
BY-AP-MW-5	10/7/2015	365528.959	1809431.284	25.97	28.93	-30.023	-40.023	Downgradient
BY-AP-MW-6	10/7/2015	365906.041	1810555.372	23.78	26.69	-51.821	-61.821	Downgradient
BY-AP-MW-7	10/7/2015	366714.007	1811745.255	22.90	25.94	-53.98	-63.98	Downgradient
BY-AP-MW-8	10/7/2015	367064.508	1813172.112	25.57	28.45	-29.688	-39.688	Downgradient
BY-AP-MW-9	10/7/2015	366387.185	1814330.505	21.91	24.39	-37.082	-47.082	Downgradient
BY-AP-MW-10	10/7/2015	365296.811	1815400.957	23.61	26.89	-34.578	-44.578	Downgradient
BY-AP-MW-11	10/7/2015	364079.137	1815715.187	23.20	26.08	-37.999	-47.999	Downgradient
BY-AP-MW-12	10/7/2015	362704.953	1815677.689	21.24	23.88	-49.054	-59.054	Downgradient
BY-AP-MW-13	10/7/2015	361251.169	1815627.420	21.29	24.22	-39.29	-49.29	Downgradient
BY-AP-MW-14	10/1/2013	360520.621	1814694.666	8.89	11.74	-36.284	-46.284	Downgradient
BY-AP-MW-15	10/7/2015	360594.416	1813618.877	21.23	23.89	-48.791	-58.791	Downgradient
BY-AP-MW-16	10/7/2015	361610.794	1812571.016	22.05	25.01	-32.706	-42.706	Downgradient

Notes:

1. Northing and easting are in feet relative to the State Plane Alabama West North America Datum of 1983.
2. Elevations are in feet relative to the North American Vertical Datum of 1988 (ft MSL).

Source: Southern Company Services, 2019. *Plant Barry Ash Pond, 2018 Annual Groundwater Monitoring and Corrective Action Report.*

Table 3
Barry Ash Pond GWPS

Constituent Name	Units	GWPS	Reference
Antimony	mg/L	0.006	MCL
Arsenic	mg/L	0.01	MCL
Barium	mg/L	2	MCL
Beryllium	mg/L	0.004	MCL
Cadmium	mg/L	0.005	MCL
Chromium	mg/L	0.1	MCL
Cobalt	mg/L	0.01845	Background
Combined Radium 226+228	pCi/L	5	MCL
Fluoride	mg/L	4	MCL
Lead	mg/L	0.015	Rule
Lithium	mg/L	0.04	Rule
Mercury	mg/L	0.002	MCL
Molybdenum	mg/L	0.1	Rule
Selenium	mg/L	0.05	MCL
Thallium	mg/L	0.002	MCL

Note:

Source: Southern Company Services, 2018. *Plant Barry Ash Pond, 2017 Annual Groundwater Monitoring and Corrective Action Report.*

Table 4
May 2018 Assessment Sampling Results

Well ID	Purpose	Sample Date	Arsenic[1] (mg/L)	Cobalt[2] (mg/L)
BY-AP-MW-1	Downgradient	5/1/2018	0.0777	ND
BY-AP-MW-2	Upgradient	5/1/2018	0.00166 J	0.00693 J
BY-AP-MW-3	Upgradient	5/1/2018	ND	ND
BY-AP-MW-4	Upgradient	5/1/2018	ND	0.0126
BY-AP-MW-5	Downgradient	5/2/2018	0.0315	ND
BY-AP-MW-6	Downgradient	5/2/2018	ND	ND
BY-AP-MW-7	Downgradient	5/2/2018	0.0218	0.0169
BY-AP-MW-8	Downgradient	5/2/2018	0.0572	ND
BY-AP-MW-9	Downgradient	5/2/2018	0.0437	ND
BY-AP-MW-10	Downgradient	5/2/2018	0.0433	ND
BY-AP-MW-11	Downgradient	5/2/2018	0.0158	ND
BY-AP-MW-12	Downgradient	5/2/2018	0.0239	0.00271 J
BY-AP-MW-13	Downgradient	5/2/2018	0.0175	ND
BY-AP-MW-14	Downgradient	5/2/2018	0.0156	ND
BY-AP-MW-15	Downgradient	5/1/2018	0.0181	0.0298
BY-AP-MW-16	Downgradient	5/1/2018	0.0114	0.0189

Notes:

1. Groundwater protection standard for arsenic is 0.01 mg/L.
2. Groundwater protection standard for cobalt is 0.0127 mg/L.

J: Estimated value; value may not be accurate. Spike recovery or relative percent difference outside of criteria.

mg/L: milligrams per liter

ND: non-detect

Table 5
November 2018 Assessment Sampling Results

Well ID	Purpose	Sample Date	Arsenic[1] (mg/L)	Cobalt[2] (mg/L)
BY-AP-MW-1	Downgradient	11/28/2018	0.0677	ND
BY-AP-MW-2	Upgradient	11/27/2018	0.00144 J	0.0066
BY-AP-MW-3	Upgradient	11/27/2018	ND	ND
BY-AP-MW-4	Upgradient	11/27/2018	ND	0.00363 J
BY-AP-MW-5	Downgradient	11/27/2018	0.0283	ND
BY-AP-MW-6	Downgradient	11/28/2018	ND	ND
BY-AP-MW-7	Downgradient	11/28/2018	0.0209	0.0178
BY-AP-MW-8	Downgradient	11/27/2018	0.0536	ND
BY-AP-MW-9	Downgradient	11/28/2018	0.0422	ND
BY-AP-MW-10	Downgradient	11/28/2018	0.0536	ND
BY-AP-MW-11	Downgradient	11/28/2018	0.0140	ND
BY-AP-MW-12	Downgradient	11/28/2018	0.0216	0.00274 J
BY-AP-MW-13	Downgradient	11/28/2018	0.0141	ND
BY-AP-MW-14	Downgradient	11/27/2018	0.0145	ND
BY-AP-MW-15	Downgradient	11/27/2018	0.0158	0.0311
BY-AP-MW-16	Downgradient	11/27/2018	0.0108	0.0182

Notes:

1. Groundwater protection standard for arsenic is 0.01 mg/L.
2. Groundwater protection standard for cobalt is 0.01845 mg/L.

J: Estimated value; value may not be accurate. Spike recovery or relative percent difference outside of criteria.

mg/L: milligrams per liter

ND: non-detect

Table 6
Groundwater Corrective Action Evaluation Summary

Technology	Evaluation Criteria						
	Performance	Reliability	Ease or Difficulty of Implementation	Potential Impacts of Remedy	Time to Implement Remedy (Influenced by Regulatory Approval Process)	Time to Achieve Groundwater Protection Standard at the Waste Boundary	Institutional Requirements
Monitored Natural Attenuation [2]	Medium due to sandy aquifer	High due to little O&M and other potential repair needs	Easy due to minimal infrastructure (e.g., monitoring wells) needed to implement remedy	None	18-24 months	Estimated > 25 years[1]	None identified
Hydraulic Containment (pump-and-treat)	High; reduces constituents to compliance levels when online	Medium to high; system offline at times for maintenance	Moderate due to design and installation of pump-and-treat system	Pumping could impact water supply wells, if present	12-24 months	Estimated > 25 years[1]	Needs to be compatible with Site NPDES permit; would potentially need to permit withdrawals from Unit 3 aquifer
Permeable Reactive Barriers (funnel and gate)	Medium to high; reduces constituents to compliance levels downgradient of reactive barrier	Medium; reactive media will need to be replaced periodically	Moderate to moderately difficult due to depth of wall and potential need for mixed media	Will alter groundwater flow hydraulics beneath and adjacent to the Site, could be evaluated with groundwater model	24-48 months	Estimated > 25 years	None identified
Barrier Walls (in conjunction with hydraulic containment or PRB gates)	High	High due to minimal need for O&M or replacement	Moderate to moderately difficult due to depth of wall	Will alter groundwater flow hydraulics beneath and adjacent to the Site, could be evaluated with groundwater model	12-24 months	Contingent on companion technology, i.e. > 25 years for PRB walls and hydraulic containment	None identified
Geochemical Manipulation (in situ injection, spot treatment)	Medium	Medium; site geochemical conditions need to be maintained to prevent rebound	Easy to moderate due to minimal infrastructure (e.g., injection wells)	Constituents may be mobilized initially upon injection before ultimate immobilization	12-24 months	Estimated 10 years (for small, localized areas)	State Underground Injection Control permit may be required

Notes:
1. Timeframes shown are estimated based on case histories of MNA and hydraulic containment of arsenic-impacted sites. Detailed estimate of time requires further investigation.
2. MNA is often used in combination with other remedial technologies.

Table 7
Technology Advantages and Disadvantages

Technology	Advantages (After EPRI 2015)	Disadvantages (After EPRI 2015)
MNA	• Minimal site disruption • Sustainable • Applicable in congested, sensitive or less accessible areas where other technologies may not be feasible	• Other treatment technologies may be required
Hydraulic Containment (pump-and-treat)	• Existing onsite water treatment plant • Pump-and-treat systems are very effective at hydraulically containing impacted groundwater • Systems can be installed as deep as typical well drilling technology allows • Systems can be modified over time to increase or decrease extraction rates or modify the system to adapt changing site conditions	• More labor, O&M required than other technologies • Constituent levels can rebound if treatment is halted • System may reach a point of diminishing returns where concentrations stabilize above regulatory standards for inorganic constituents
Permeable Reactive Barriers (funnel and gate)	• Low labor, O&M requirements until media needs to be replaced • No need to manage extracted groundwater • Reduced need to dispose treatment by-products until media needs to be replaced	• Requires construction of impermeable barrier wall sections prior to PRB gates • Depth required may be at or beyond the limit of construction • Reactive media will need to be replaced at some point; used media will need to be assessed for hazardous characteristics
Barrier Walls (in conjunction with hydraulic containment or PRB gates)	• Reliable and widely accepted technology	• Construction would likely need to be from the top of the dike • Mounding, end-around, or under-flow could occur if hydraulics not evaluated properly • Depth required may be at or beyond the limit of construction
Geochemical Manipulation (in situ injection, spot treatment)	• Ability to treat small, localized areas • Minimal site disruption • Applicable in congested, sensitive or less accessible areas where other technologies may not be feasible	• Emerging technology; permanence for inorganic constituents being demonstrated • Not proven for large-scale corrective action

Notes:
EPRI: Electric Power Research Institute
MNA: monitored natural attenuation
O&M: operation and maintenance
PRB: permeable reactive barrier

Table 8
Schedule

Number	Task	Estimated Completion Date
1	Field Studies and Data Collection	June 2019 – May 2020
2	Groundwater Flow and Geochemical Modeling	June 2019 – May 2020
3	Bench Testing and Pilot Studies	October 2019 – September 2020
4	Preliminary Conceptual Design	October 2020 – March 2021

Figures

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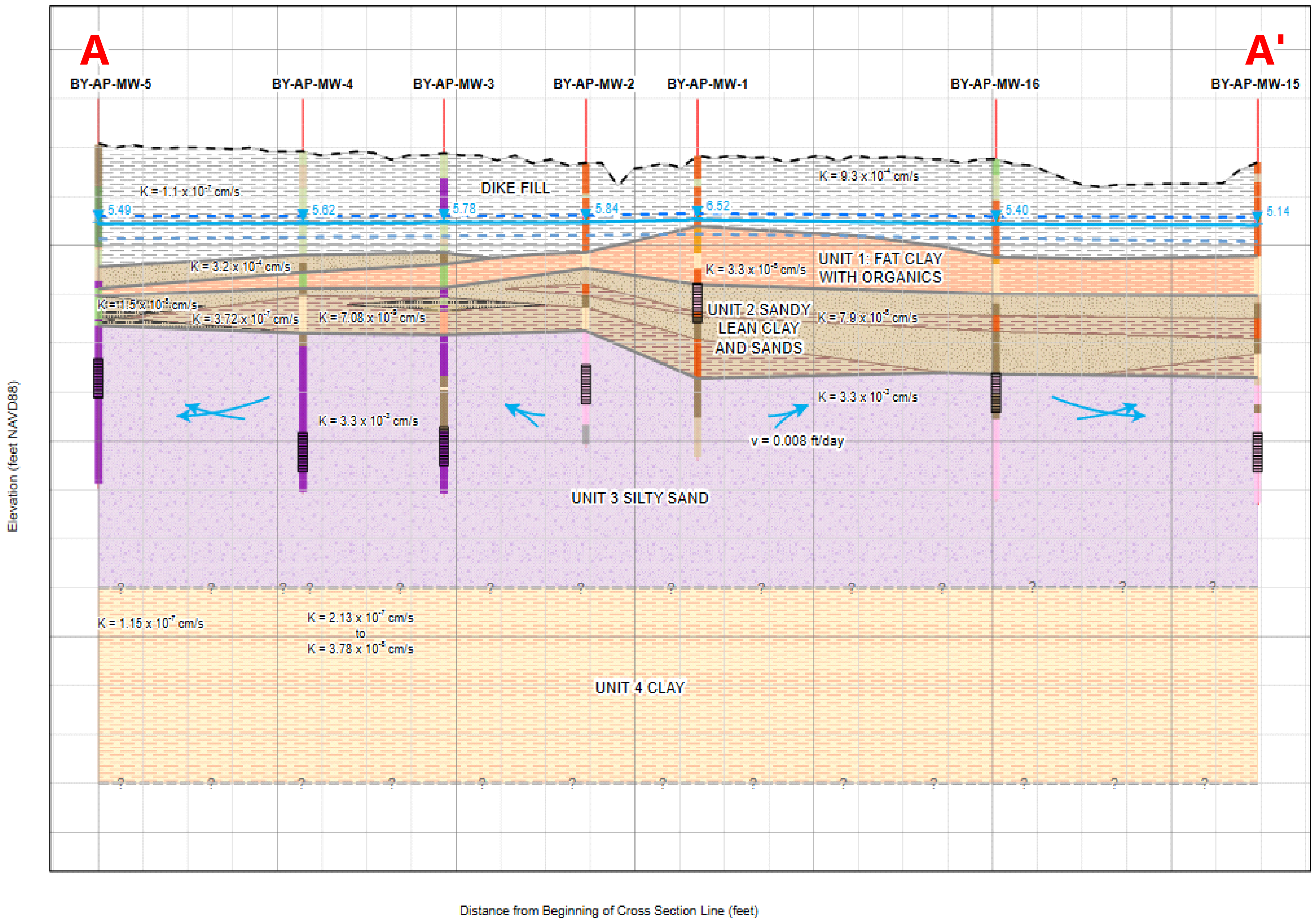
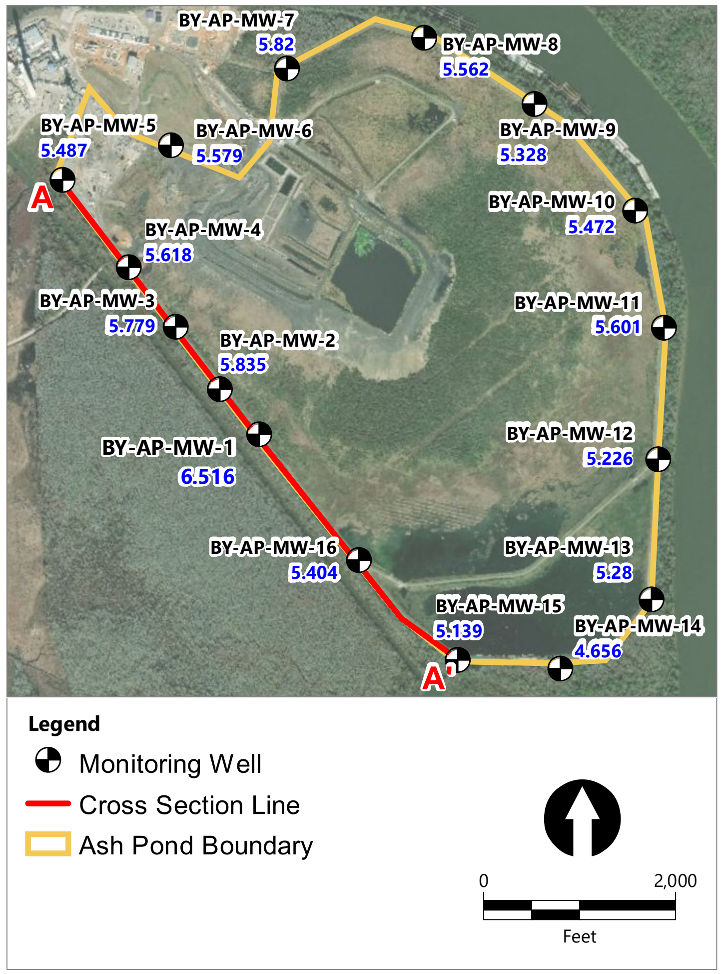
Figure 1
Site Location Map
Assessment of Corrective Measures
Alabama Power Company - Plant Barry





Cross-Section Legend

- ▼ Approximate Groundwater Elevation
- ▽ Artesian Well
- — Approximate Groundwater Elevation
- - - Maximum Groundwater Elevation
- - - Minimum Groundwater Elevation
- ⊙ Represents GW flow directly toward reader
- ▤ Screen Interval
- ⁄ Ground Surface Elevation
- — Monitoring Well Location
- — Unit Boundary
- ▨ No Recovery
- ▨ Fat Clay
- ▨ Lean Clay
- ▨ Sandy Fat Clay
- ▨ Sandy Lean Clay
- ▨ Silt
- ▨ Elastic Silt
- ▨ Sandy Elastic Silt
- ▨ Clayey Sand
- ▨ Silty Sand
- ▨ Poorly-graded Sand with Silt
- ▨ Poorly-graded Sand
- ▨ Fill
- ▨ Unit 1: Fat Clay with Organics
- ▨ Unit 2: Sandy Lean Clay and Sands
- ▨ Unit 2: Silts
- ▨ Unit 2: Sandy Lean Clay
- ▨ Unit 3: Silty Sand
- ▨ Unit 4: Clay

NOTES:
1. Source of ground surface elevation data: Lidar
2. NAVD88 indicates North American Vertical Datum of 1988.
3. Approximate groundwater elevation data was collected on April 30, 2018.
4. Maximum and minimum groundwater elevation data were derived from the highest and lowest groundwater elevation values recorded during events spanning December 14, 2015 to April 30, 2018.
5. "v" indicates groundwater flow velocity
6. Cross-section data from *Plant Barry Ash Pond Facility Plan for Groundwater Investigation*, Southern Company Services, October 2018.

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Figure 2
Geologic Cross-Section
Assessment of Corrective Measures
Alabama Power Company - Plant Barry

NOTES:

1. Groundwater elevations calculated from depth to water measurements collected in November 2018.
2. Groundwater elevation data from MW-1 was excluded from potentiometric surface calculations due to the screened interval not being in the Unit 3 aquifer.

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Figure 3

Potentiometric Surface Map

Assessment of Corrective Measures
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