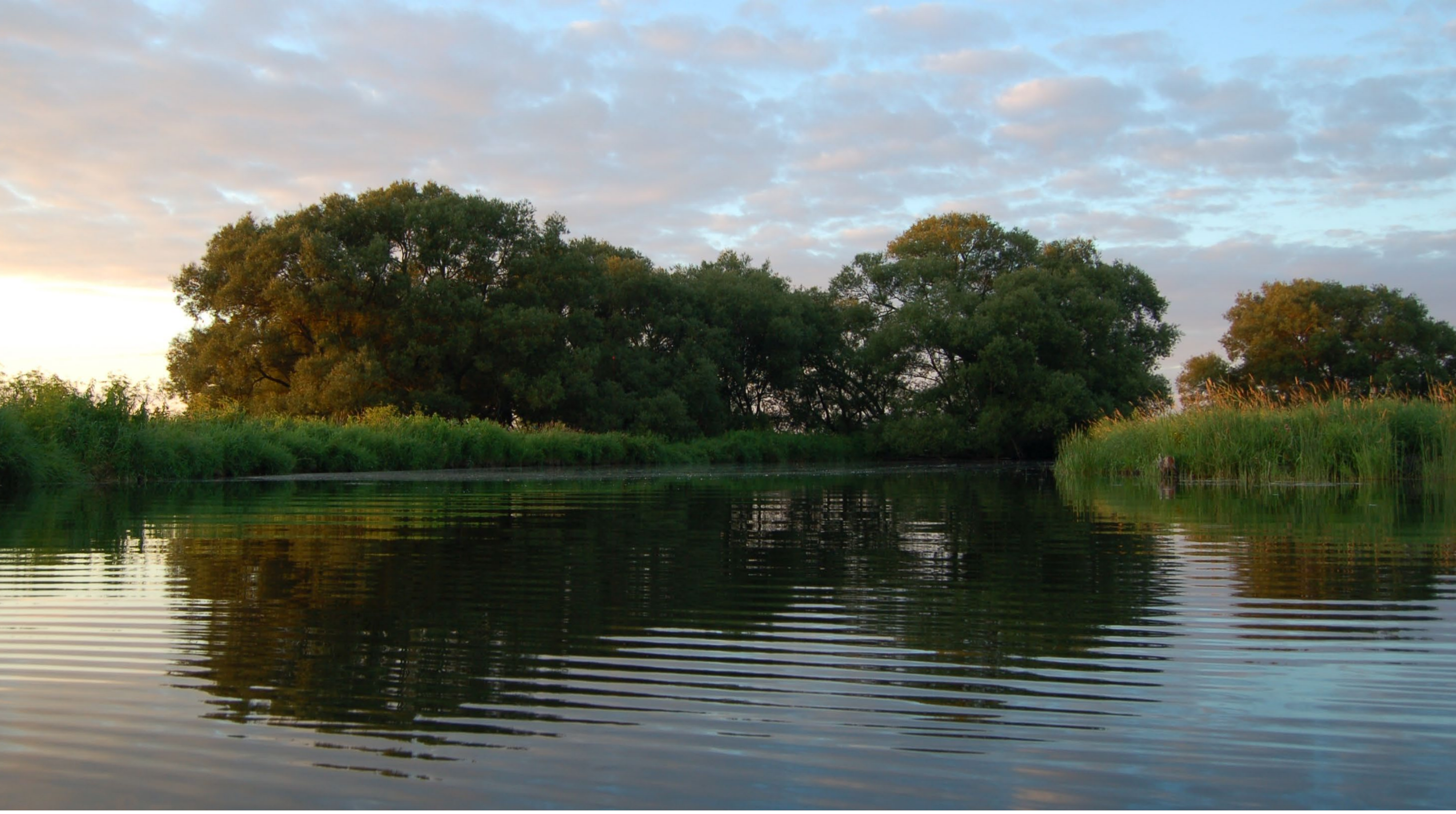

June 2021

Semi-Annual Remedy Selection and Design Progress Report
Plant Miller

Prepared for Alabama Power Company

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ABBREVIATIONS

ACM	Assessment of Corrective Measures
ADEM	Alabama Department of Environmental Management
Alabama Power	Alabama Power Company
CCR	coal combustion residuals
CEC	cation exchange capacity
CFR	Code of Federal Regulations
COI	constituents of interest
CSM	conceptual site model
EGL	Environmental Geochemistry Laboratory
EPA	U.S. Environmental Protection Agency
GWPS	groundwater protection standards
MNA	monitored natural attenuation
SEM	scanning electron microscopy
Site	Ash Pond at Plant Miller
SSE	selective sequential extraction
XRD	X-ray diffraction
XRF	X-ray fluorescence

1 Introduction

In accordance with the U.S. Environmental Protection Agency's (EPA's) coal combustion residuals (CCR) Rule 40 Code of Federal Regulations (CFR) § 257.97(a), the Alabama Department of Environmental Management's (ADEM's) Admin. Code r. 335-13-15-.06(8)(a), and Part C of Administrative Order No. 18-098-GW, this *Semi-Annual Remedy Selection and Design Progress Report* has been prepared for the Ash Pond at Plant Miller (Site). Specifically, this report has been prepared to describe the progress made in evaluating the selected remedy and alternative remedies and designing a remedy plan in the first semi-annual period of 2021.

In June 2019, Alabama Power Company (Alabama Power) completed an Assessment of Corrective Measures (ACM; Anchor QEA 2019) to address the occurrence of arsenic, cobalt, and lithium in groundwater at statistically significant levels. In the ACM, the following remedies were considered feasible for corrective measures for groundwater:

- Monitored natural attenuation (MNA)
- Hydraulic containment (pump and treat)
- Geochemical manipulation via injections (i.e., enhanced natural attenuation)
- Permeation grouting

As required by the Administrative Order, MNA was proposed as the main groundwater corrective action remedy for the Site. Source control measures consisting of consolidation, dewatering, and capping of the ash (source) were already planned as part of pond closure.

The EPA defines MNA as 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 time frame that is reasonable compared to that offered by other more active methods" (EPA 1999, 2015). An MNA demonstration consists of the following steps or tiers (EPA 2015):

1. Demonstrate that the area of impacts (plume) is stable or shrinking.
2. Determine the mechanisms and rates of attenuation.
3. Determine that 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 as expected.

In the previous reporting periods, assessment work was completed to evaluate and demonstrate MNA and geochemical manipulation as corrective measures at the Site. As shown in Table 1, the MNA investigations during the previous reporting period primarily supported Tiers 1 (area of impacts stable or shrinking); 2a (mechanisms of attenuation); and, to some extent, 3b (stability of attenuation) for an MNA demonstration. Groundwater samples and solids (precipitates) were collected from select wells, and groundwater sampling results were used to perform geochemical modeling, which predicted attenuating species under Site geochemical conditions. Well solids were analyzed to determine attenuating phases for the constituents of interest (COI; arsenic, cobalt, and lithium) at the Site. Solids analysis also provides insight into the stability of the attenuating mechanisms.

Table 1
Monitored Natural Attenuation Demonstration

Tier	Approach	Status MNA Demonstration
Tier 1: Area of Impacts Stable or Shrinking	Concentration vs. time and/or distance graphs, statistics, isoconcentrations in plan and/or section view, Ricker Method (part of ongoing monitoring)	In progress; areas of impacts expected to decrease post-closure
Tier 2a: Determine Mechanisms of Attenuation	Analysis of well solids: XRF, XRD, SEM, CEC, SSE; complete analysis of groundwater (major cations and anions); geochemical modeling	Satisfied
Tier 2b: Determine Rates of Attenuation	Derived from concentration vs. time graphs, batch and/or column tests, geochemical modeling	In progress
Tier 3a: Determine System (Aquifer) Capacity for Attenuation	Batch and/or column tests, geochemical modeling	In progress
Tier 3b: Determine Stability of the Attenuating Mechanisms (Solids) and COI	SSE on tested materials from batch and column tests, geochemical modeling, inference from mechanisms	Satisfied (inferred from identified attenuation mechanisms) Column tests in progress
Tier 4a: Design a Performance Monitoring Program	Additional wells, repeat well solids and/or complete groundwater analysis, triggers	In progress
Tier 4b: Identify Alternative Remedies Should MNA Not Perform as Expected	Completed as part of the ACM; some technologies may need further testing and/or development (bench and pilot)	Satisfied

Investigations during the current reporting period were designed to support Tiers 2b (rates of attenuation), 3a (aquifer capacity for attenuation), and 3b (stability of attenuation) for an MNA demonstration. Soil (aquifer) and groundwater samples from multiple locations were collected and analyzed to conduct column laboratory experiments to determine capacity, rates, and stability of MNA. Soil and groundwater characterization and column study experiments are currently in progress.

Any data obtained during on-site investigations or to evaluate corrective action alternatives will be included in the subsequent *Semi-Annual Groundwater Monitoring and Corrective Action Reports*.

2 Summary of Work Completed

Assessment work has been completed and laboratory work has been performed to support MNA and in situ geochemical manipulation as discussed in the ACM. MNA and geochemical manipulation are both geochemically based, such that site-specific geochemical data and analyses can be applied to both technologies.

2.1 Synopsis of Work Completed During Previous Reporting Periods

During previous reporting periods, laboratory analysis of groundwater and precipitates (attenuating solids) was conducted to support MNA and geochemical manipulation. The major rationale for these investigations includes the following:

- Identifying attenuating mechanisms
- Gaining an understanding of the stability of the attenuating mechanisms
- Identifying potential geochemical manipulation approaches for COI based on Site geochemical conditions and attenuation processes already occurring naturally

To support these investigations, the following field and laboratory investigations were performed in previous reporting periods:

- Evaluated groundwater analytical data (primarily graphing) to look for evidence of natural attenuation occurring in space and time
- Collected groundwater samples from background and impacted wells and performed a complete chemical analysis on the samples to enable groundwater geochemical modeling and the development of a geochemical conceptual site model (CSM)
- Performed geochemical modeling using the U.S. Geological Survey computer program PHREEQC with the WATEQ4F thermodynamic database
- Collected precipitate (solid) samples from the bottom of monitoring wells
- Analyzed precipitate samples by X-ray fluorescence (XRF) and X-ray diffraction (XRD)
- Directly observed attenuating mineral phases by scanning electron microscopy (SEM)
- Determined association of COI with attenuating phases, determined relative strength of attenuation, and provided a sense of permanence by selective sequential extraction (SSE)
- Assessed ion exchange as an attenuation mechanism by cation exchange capacity (CEC)
- Analyzed the laboratory data described above to develop a geochemical CSM and to evaluate MNA and geochemical manipulation

Results from existing groundwater data analysis, geochemical modeling, and well solids analyses provide multiple lines of evidence for attenuation mechanisms for arsenic, cobalt, and lithium, as summarized in Table 2. The attenuating mechanisms identified include sorption-coprecipitation on iron oxides, cation exchange on clays, and precipitation of barium arsenate. Supporting data for Table 2 and the geochemical CSM are provided in previous progress reports (Anchor QEA 2020a, 2020b).

Table 2
Geochemical Evidence for Attenuation Mechanisms for Arsenic, Cobalt, and Lithium

Mechanism	Geochemical Modeling	XRF	XRD	SSE	CEC
Sorption on iron oxides (arsenic and cobalt)	X	X			
Cation exchange on clays (cobalt, lithium)			X	X	X
Coprecipitation in iron oxides and/or carbonates (cobalt)	X			X	
Precipitation in barium arsenate (arsenic)	X				

2.2 Synopsis of Work Completed During Current Reporting Period

Site investigations and preliminary design work have continued at the Site to support remedy selection and design. As discussed in the ACM (Anchor QEA 2019), completing a final long-term corrective action plan is often a multi-year process.

Impacted groundwater is likely traveling through both relatively thin and discontinuous unconsolidated residual material (referred to as soil for simplicity) and fractures in the rock aquifer at the site. Soil, rock, and groundwater samples were collected for laboratory studies to help determine capacity, rates, and stability of MNA. Soil and/or rock samples were collected from MR-AP-MW-2V, MR-AP-MW-3V, and MR-AP-MW-20H the week of April 5, 2021. Groundwater samples were collected from MR-AP-MW-2, MR-AP-MW-6V, and MR-AP-MW-15 on April 26 and 28, 2021. Soil and groundwater sampling locations are shown in Figure 1. When possible, both soil/rock and groundwater samples were collected from areas with greater impacts for both soil/rock and groundwater. Note that delineation wells are not compared to groundwater protection standards (GWPS) and are therefore not included as statistically significant levels in Figure 1.

Figure 1
Soil and Groundwater Sampling Locations

During the current reporting period, soil/rock samples were collected from core boxes in a core storage area, sealed in zip-lock bags, labeled, packed in coolers, and shipped to Anchor QEA's Environmental Geochemistry Laboratory (EGL) in Portland, Oregon, for column study experiments. Preservation of these samples was not required.

Groundwater was collected in a manner to preserve oxidation-reduction conditions of samples. Prior to groundwater sample collection, the well was purged until the following field parameters were stabilized: turbidity, oxidation-reduction potential, dissolved oxygen, specific conductance, temperature, and pH. Groundwater samples were collected by pumping from the well directly into a collapsible Cubitainer, which was filled completely and capped with zero headspace. Groundwater was field-filtered with a standard in-line 0.45-micron capsule filter. The filled container was packed and sealed inside a large Mylar bag containing oxygen-absorbent packets and shipped on ice to Anchor QEA's EGL for column study experiments.

Characterization of the soil samples is ongoing and will consist of the following analyses: grain size, XRF, XRD, SEM, CEC, and SSE. Results from these analyses will be used to select discrete samples for column study experiments. Concentrations of COI in groundwater will be measured prior to beginning the column study experiments.

Column studies will be performed using Site soil and groundwater samples to inform rates and stability of attenuation, and the capacity of the aquifer (part of Tier 3) to attenuate arsenic, lithium, and cobalt. Concentrations of COI in groundwater will be measured prior to beginning the column study experiments.

Site groundwater containing arsenic, lithium, and/or cobalt will be run through the columns until the COI are found in the elutriate (i.e., until breakthrough occurs). SSE will be performed on the tested soil from the columns to provide information on the mechanisms of attenuation and to assess their stability.

Based on the results of column studies, groundwater modeling will be performed to assess the rates and capacity of the aquifer for attenuation using a 1D or 2D version of geochemical models such as PHREEQC, PHAST, or PHT3D. The column test results will be used to constrain key model parameters, including concentrations(s) of sorbing phases.

The fractures in the rock, as well as the rock matrix, are anticipated to have some capacity for attenuation of COI. Capacity and stability of attenuation processes in rock can be determined by evaluating rock properties (both chemical and physical), followed by groundwater flow and transport modeling. Typical laboratory analyses on the rock matrix and fractures/fracture fillings would include the following:

- Physical parameters
  - Porosity, bulk density, and laboratory permeability
- Geochemical parameters and analyses

- Total organic carbon
- Thin section petrography (cut perpendicular to and including fracture surfaces, where appropriate)
- Bulk chemistry by XRF (fracture surface and matrix separately)
- Extractable iron, manganese, and aluminum oxides (fracture surface and matrix separately)
- SSE of COIs
- CEC (fracture surface and matrix separately)
- Mineralogy of fracture fillings by XRD and/or SEM

A suitable model for this evaluation would be a 2D, steady-state MODFLOW model coupled with PHT3D for reactive transport simulation. Existing physical information such as hydraulic conductivity, hydraulic gradient, calculated fracture apertures, and fracture spacings would be used to build the flow portion of the model. Groundwater geochemical data from previous studies would be used as input to the reactive transport component of the model. The model could be used to simulate current conditions and to predict future conditions (including attenuation in the rock) after pond closure.

In addition to the laboratory studies, corrective actions in the context of site-specific conditions were compared to the evaluation criteria in the CCR Rule, with emphasis on deficiencies that could eliminate a corrective action from further consideration. The corrective action evaluation table from the ACM (Anchor QEA 2019) was updated based on a more detailed analysis of site-specific conditions (Appendix A).

After more detailed evaluation in the context of site-specific conditions, the following technologies are recommended for additional evaluation: MNA, geochemical manipulation via injection (enhanced MNA), and permeation grouting. Hydraulic containment (pump-and-treat) is not recommended for additional evaluation.

For groundwater corrective action at the Site, the intent of permeation grouting would be to cut off the flow groundwater in water-bearing fractures and bedding planes. The rock matrix between the water-bearing fractures and bedding planes is expected to have very low permeability (hydraulic conductivity) already. Permeation grouting could be applied as an initial remedial action in conjunction with pond closure, or later (if needed) as part of an adaptive site management program.

Prior to initiation of a grouting program, grouting would be performed along a test section to help design the program. Information from previous grouting at similar sites such as Plant Gorgas would be used to design the test section. The test section would provide information on hole spacings, depths, staging, grout mixtures and quantities (takes), and pressures. Hydraulic conductivity testing (likely packer testing) would be performed before and after grouting along the test section to demonstrate the effectiveness of the permeation grouting.

Hydraulic containment is not recommended for the following reasons:

- Need to drill many relatively deep (up to approximately 200 feet) extraction wells in rock
- Uncertainty of intersecting enough permeable fractures in rock, particularly near-vertical fractures, for hydraulic containment to be effective
  - Lack of recharge and observed low-flow/low-yield in some wells
- High operation and maintenance requirements
- Long time required to achieve GWPS, likely beyond the post-closure period of 30 years
- Low sustainability (excessive use of resources)

Hydraulic containment (pump-and-treat) will likely not offer any time advantage to achieving GWPS over MNA or enhanced MNA, due to the slow release of COI from the aquifer media. In fact, MNA and enhanced MNA may achieve GWPS sooner than pump-and-treat. Natural attenuation is occurring at the Site, and pump-and-treat would operate against (essentially try to reverse) the natural processes already occurring. Geochemical manipulation, on the other hand, would be designed to enhance natural attenuation.

Due to the many required pumping wells drilled into rock, ongoing water treatment, and long duration required (decades), hydraulic containment (pump-and-treat) would require many resources (electricity, water treatment chemicals, etc.) without offering any advantages over MNA or geochemical manipulation (enhanced MNA).

3 Planned Activities and Anticipated Schedule

The following conceptual-level feasibility study activities are planned for the next reporting period (July to October 2021) to evaluate MNA, geochemical manipulation (enhanced MNA), and possibly other corrective action technologies:

- Complete laboratory work to determine MNA capacity, rates, and stability
- Continue to compare site-specific corrective actions to the evaluation criteria in the CCR Rule, with emphasis on deficiencies that could eliminate a corrective action from further consideration
- Continue to determine how corrective actions could be integrated with pond closure, such as dewatering and associated water treatment systems

Though substantial evidence for natural attenuation exists for the Site (Section 2), natural attenuation is expected to increase as source control measures are implemented (i.e., dewatering, consolidation, and capping). MNA will almost certainly be one component, if not the only component, of corrective action. MNA could be implemented immediately upon pond closure.

The longer-term schedule for developing a groundwater corrective action system at the Site is as follows:

- Prepare a Remedy Selection Report by October 31, 2021
- Develop a Corrective Action Groundwater Monitoring Program by January 29, 2022

During the next reporting period, other potential remedies identified in the ACM will continue to be evaluated with respect to technical feasibility, ability to attain target standards, and ease of implementation.

During the next reporting period, groundwater monitoring will continue, a final remedy plan will be developed, and the Remedy Selection Report will be prepared describing the remedy plan and how it demonstrably meets the requirements of 40 CFR § 257.97(a) and ADEM Administrative Code r. 335-13-15-.06(8)(a). The adaptive site management approach and adaptive triggers will be discussed in the Corrective Action Groundwater Monitoring Program description.

4 References

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EPRI (Electric Power Research Institute), 2015. *Corrective Action for Closed and Closing Ash Ponds*. Final Report. 3002006292. December 2015.

Appendix A
Plant Miller Groundwater Corrective Action Evaluation Summary

Table A-1
Plant Miller Groundwater Corrective Action Evaluation Summary

Technology	Evaluation Criteria							Correction Action Feasibility
	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	Medium because processes may be primarily physical (i.e., less chemical attenuating potential for rock fractures)	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 > 30 years[1]	None identified	**Feasible**
Hydraulic Containment (pump-and-treat)	High; reduces constituents to compliance levels when online	Medium to high; system offline at times for maintenance	Moderate to moderately difficult due to design and installation of pump-and-treat system at a site with fractured bedrock	Pumping could impact water supply wells, if present	12-24 months	Estimated > 30 years[1] As constituents move through a fractured rock aquifer, they tend to diffuse from the flowing fracture water into pore spaces (if present) in the rock matrix (as in sandstones). This process tends to slow constituent transport but substantially increases the difficulty of purging constituents from the aquifer (Mutch et al. 1993).	Needs to be compatible with Site NPDES permit; would potentially need to permit withdrawals from the impacted aquifer	**Not recommended** due to the need to drill relatively large numbers of extraction wells relatively deep (up to 200 feet) in bedrock, uncertainty in intersecting enough permeable (water-bearing) fractures, high O&M requirements, long time to achieve groundwater protection standards, and low sustainability (excessive use of resources). Pump-and-treat systems require relatively high O&M due to well, pump, and piping maintenance and the water treatment system. Poor sustainability; continual use of energy and chemicals over a long period of time (EPRI 2015) with no time advantage to reach GWPS over MNA. In fact, the time to achieve GWPS may be longer than MNA due to the difficulty in removing constituents from a fractured sedimentary rock aquifer (see Time to Achieve Groundwater Protection Standard at the Waste Boundary column).
Geochemical Manipulation (in situ injection, spot treatment, enhanced MNA)	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	**Feasible**
Permeation Grouting	High because grouting is a conventional and proven technology	Medium; some fractures may be missed	Moderate due to near-vertical fractures that may require angled borings to effectively grout	Will alter groundwater flow hydraulics beneath and adjacent to the Site	12-24 months	Estimated 10 to greater than 30 years[2]	None identified	**Feasible**

Notes:

1. Time frames shown are estimated based on case histories of hydraulic containment of arsenic-impacted sites. Detailed estimate of time requires further investigation.
2. MNA or other technologies may be required to remediate groundwater beyond the grout curtain. Detailed estimate of time requires further investigation.

GWPS: groundwater protection standards
MNA: monitored natural attenuation
NPDES: National Pollutant Discharge Elimination System
O&M: operation and maintenance

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