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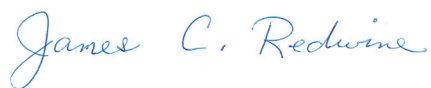


Semi-Annual Remedy Selection and Design Progress Report Plant Barry Ash Pond

Prepared for Alabama Power Company

June 2020

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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
MNA	monitored natural attenuation
Site	Ash Pond at Plant Barry
SEM	scanning electron microscopy
SM	Standard Method
SSE	selective sequential extraction
SSL	statistically significant level
USGS	U.S. Geological Survey
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) and the Alabama Department of Environmental Management's (ADEM's) Admin. Code r. 335-13-15-.06(8)(a), this *Semi-Annual Remedy Selection and Design Progress Report* has been prepared for the Ash Pond at Plant Barry (Site). Specifically, this *Semi-Annual Remedy Selection and Design Progress 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 2020. A previous semi-annual progress report was completed and submitted to ADEM in December 2019 (Anchor QEA 2019a).

In June 2019, Alabama Power Company (Alabama Power) completed an Assessment of Corrective Measures (ACM) (Anchor QEA 2019b) to address the occurrence of arsenic and cobalt in groundwater at statistically significant levels (SSLs). The ACM was submitted to ADEM pursuant to 40 CFR § 257.96, ADEM Admin. Code r. 335-13-15-.06(7), and Part C of Administrative Order No. 18-094-GW. This ACM was also placed in the Site's operating record and posted to the Site's CCR Rule Compliance website.

Pursuant to 40 CFR § 257.97 and ADEM Admin. Code r. 335-13-15-.06(8), Alabama Power is evaluating the selected and potential remedies presented in the ACM to identify a plan incorporating the remedy, or combination of remedies, as soon as feasible.

As discussed in the ACM, the following corrective measures are potentially feasible for use at the Site:

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

Any data obtained during on-site investigations, or to evaluate corrective action alternatives, in 2020 will be included in the subsequent *Semi-Annual Groundwater Monitoring and Corrective Action Reports*.

2 Summary of Work Completed

Site investigations have continued to support remedy selection and design. As discussed in the ACM (Anchor QEA 2019b), completing a final long-term corrective action plan is often a multi-year process. Additional assessment work has been completed since December 2019, and field work and preliminary data analysis have been conducted to support MNA and in situ geochemical manipulation as discussed in the ACM. 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 sulfide minerals). MNA and geochemical manipulation are both geochemically based, such that site-specific geochemical data and analyses can be applied to both technologies.

Activities performed since the submission of the December 2019 progress report include:

- Installing wells for additional vertical and horizontal delineation as proposed in the *Semi-Annual Progress Report* (SCS 2020). Well installation is complete, but data have not yet been received from groundwater sampling.
- Evaluating groundwater analytical data (primarily graphing) to look for evidence of natural attenuation occurring spatially and temporally.
- Collecting groundwater samples from unimpacted and impacted wells, and performing a complete chemical analysis on the samples to enable groundwater geochemistry modeling and the development of a geochemical conceptual site model (CSM).
- Performing geochemical modeling using the U.S. Geological Survey (USGS) computer program PHREEQC with the WATEQ4F thermodynamic database.
- Collecting solid precipitate samples from the bottom of monitoring wells.
- Analyzing precipitate samples to help identify attenuating mechanisms and their stability.

Solids analysis included:

- Chemical analysis by X-ray fluorescence (XRF)
- Mineralogical analysis by X-ray diffraction (XRD)
- Scanning electron microscopy (SEM) to directly observe attenuating mineral phases (in progress)
- Selective sequential extraction (SSE) to determine association of constituents of interest (COI) with attenuating phases, relative strength of attenuation, and provide a sense of permanence (in progress)
- Cation exchange capacity (CEC) to assess ion exchange as an attenuation mechanism (in progress)

2.1 Data Analysis

Existing groundwater data were used to generate concentration versus distance, and concentration versus time plots to determine if attenuation is occurring over space or time and to assess natural attenuation occurrence and rates. Arsenic, cobalt, and boron concentrations were plotted on the y-axis. Boron can be used as a conservative tracer because it is poorly chemically attenuated but is physically attenuated by dilution and dispersion. For the concentration versus distance plots, the distance between the pond boundary and the monitoring well was plotted on the x-axis. For the concentration versus time plots, the time between sampling events (in days) was plotted on the x-axis. Preliminary trends, if seen, were noted. Additional data should be collected and analyzed to confirm preliminary conclusions.

Concentration versus distance plots indicate that arsenic and boron concentrations in groundwater appear to decrease with distance away from the ash pond, showing spatial attenuation. Because of the limited time span of the dataset and associated small number of samples through time for a given well, no meaningful trends were noted for the concentration versus time plots. As additional data become available, plots will be updated and reevaluated for trends. Trends in time may not be observed until after pond closure activities (source control) are complete.

2.2 Remedy Selection Data Collection

Activities completed during the first semi-annual reporting period in 2020 have focused on:

1) conducting delineation activities to define the horizontal and vertical extent of arsenic and cobalt SSLs; and 2) collecting and analyzing groundwater and solids samples from wells to support MNA and geochemical manipulation. Additional hydrogeologic and geochemical data collected during delineation investigations are being used to refine the CSM and to further evaluate the feasibility of each proposed corrective measure. When feasible, data needed to refine the CSM will be collected concurrent with the routine assessment monitoring events.

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 permanence of the attenuating mechanisms
- Identifying potential geochemical manipulation approaches for COI based on site geochemical conditions and attenuation processes already occurring naturally

Analytical results generated during these studies will be included in subsequent semi-annual groundwater monitoring reports.

2.2.1 Groundwater Sampling and Analysis

Groundwater samples were collected by RDH Environmental, Inc., and analyzed by the Alabama Power General Test Laboratory to evaluate MNA and geochemical manipulation. Groundwater was collected from monitoring wells included in Table 1 and was analyzed for major cations, anions, and parameters influencing the chemical behavior of the COI. Analyzed constituents and their associated laboratory analysis methods are summarized in Table 2.

Table 1
Groundwater Sampling Locations

Well ID				
BY-AP-MW-1	BY-AP-MW-4	BY-AP-MW-8	BY-AP-MW-11	BY-AP-MW-14
BY-AP-MW-2	BY-AP-MW-5	BY-AP-MW-9	BY-AP-MW-12	BY-AP-MW-15
BY-AP-MW-3	BY-AP-MW-7	BY-AP-MW-10	BY-AP-MW-13	BY-AP-MW-16

Table 2
Analyzed Constituents and Laboratory Analytical Methods

Constituent	Analytical Method	Constituent	Analytical Method
Alkalinity (Total as CaCO ₃)	SM 2320 B	Lead (Dissolved)	EPA 200.8
Antimony (Dissolved)	EPA 200.8	Lead (Total)	EPA 200.8
Antimony (Total)	EPA 200.8	Lithium (Total)	EPA 200.7
Arsenic (Dissolved)	EPA 200.8	Magnesium (Total)	EPA 200.7
Arsenic (Total)	EPA 200.8	Manganese (Dissolved)	EPA 200.8
Barium (Total)	EPA 200.8	Manganese (Total)	EPA 200.8
Beryllium (Dissolved)	EPA 200.8	Molybdenum (Dissolved)	EPA 200.8
Beryllium (Total)	EPA 200.8	Molybdenum (Total)	EPA 200.8
Bicarbonate Alkalinity (Calculated)	SM 4500CO2 D	Nitrogen Nitrate (Calculated)	EPA 353.2
Boron (Total)	EPA 200.7	Nitrogen Nitrate/Nitrite	EPA 353.2
Cadmium (Dissolved)	EPA 200.8	Nitrogen Nitrite	EPA 353.2
Cadmium (Total)	EPA 200.8	Ortho Phosphate	SM 4500PF-OP
Calcium (Total)	EPA 200.7	Potassium (Total)	EPA 200.8
Carbonate Alkalinity (Calculated)	SM 4500CO2 D	Selenium (Dissolved)	EPA 200.8
Chloride	SM4500CI E	Selenium (Total)	EPA 200.8
Chromium (Dissolved)	EPA 200.8	Silica (Total; Calculated)	EPA 200.7
Chromium (Total)	EPA 200.8	Silicon (Total)	EPA 200.7
Cobalt (Dissolved)	EPA 200.8	Sodium (Total)	EPA 200.7
Cobalt (Total)	EPA 200.8	Sulfate	SM 4500SO4 E
Fluoride	SM 4500F G 2017	Thallium (Dissolved)	EPA 200.8
Iron (Dissolved)	EPA 200.7	Thallium (Total)	EPA 200.8
Iron (Total)	EPA 200.7	Total Organic Carbon	SM 5310 B

Prior to collecting groundwater samples, depth to water was measured from all wells included in Table 1. Within a 24-hour period, the depth-to-water level was measured in the monitoring wells using a water level probe (graduated to a hundredth of a foot). Each depth-to-water level was recorded to the nearest hundredth of a foot relative to the top of casing.

Groundwater samples were collected from monitoring wells included in Table 1 using the dedicated pump installed in each well. Wells were purged at a low flow rate to minimize drawdown and sampled using low-flow sampling techniques in accordance with 40 CFR § 257.93(a) and ADEM Admin. Code r. 335-13-15-.06(4)(a). Prior to sampling, each monitoring well was purged until field parameters (pH, temperature, specific conductance, dissolved oxygen, and oxidation-reduction potential) stabilized. Turbidity was measured during sampling but was not used as a stabilization criterion.

2.2.2 Well Solids Sampling and Analysis

Precipitation and coprecipitation may be major mechanisms for natural attenuation. Soil and aquifer media can also sorb COI, and their geochemistry can indicate if natural attenuation is occurring or has the potential to occur. If precipitates are forming and incorporating COI, then natural attenuation is occurring. Similarly, if precipitates are forming and incorporating COI, this suggests attenuation mechanisms that can be enhanced by geochemical manipulation under existing site conditions. Solids were collected from monitoring wells included in Table 3. The solids may be precipitates forming in the aquifer, or may be part of the mineralogy of the aquifer. Regardless, depending upon their chemistry and mineralogy, the solids may have the ability to attenuate COI.

Table 3
Well Solids Sampling Locations

Well ID	
BY-AP-MW-1	BY-AP-MW-10
BY-AP-MW-2	BY-AP-MW-11
BY-AP-MW-3	BY-AP-MW-12
BY-AP-MW-5	BY-AP-MW-13
BY-AP-MW-7	BY-AP-MW-14
BY-AP-MW-8	BY-AP-MW-15
BY-AP-MW-9	BY-AP-MW-16

Well solids samples were collected as follows:

- If present, groundwater-solid slurry samples were collected from the bottom of the monitoring well.
- The slurry was pumped through an inline filter (to reduce sample exposure to oxygen) with a 0.45-micrometer filter membrane until the filter clogged or the water ran clear.

- Each filter was placed in a petri dish. Each petri dish was placed in a Mylar bag with an oxygen-absorbent packet to retain the in situ geochemical conditions and prevent oxidation during transport.
- Samples were stored on ice and shipped under chain of custody to Anchor QEA's Environmental Geochemistry Laboratory (EGL) in Portland, Oregon, for analysis.

Upon arrival at EGL, samples were inspected and checked against the chain of custody. Samples were then stored under refrigeration until processing. To maintain in situ geochemical conditions, precipitates were removed from the filters under a nitrogen atmosphere in an aerobic glove box for analysis and geochemical characterization. Sediment retained on the sample filters was scraped and rinsed into centrifuge tubes. This mixture was then centrifuged, and the solids were transferred into a pre-weighed glass jar. The solids were then placed into the incubator portion of the glove box at 38°C for 24 to 72 hours until dry.

The well solids were analyzed as follows:

- Elemental analysis by XRF to determine the chemical composition of the matrix (e.g., iron compounds) and presence of COI
- XRD to determine mineral phases
- SEM to directly observe attenuating phases
- SSE to determine association of COI with attenuating phases, determine relative strength of attenuation, and provide a sense of permanence
- CEC to assess ion exchange as a mechanism for attenuation

All samples with sufficient volume were analyzed by XRF. After drying, processed samples were loaded and sealed in plastic sample containers for elemental analysis by XRF. XRF testing was performed by EGL staff using a Niton XL3t GOLDD+ XRF Analyzer rented from Thermo Fisher Scientific. Individual samples were analyzed by XRF by a custom program based on a mining profile that includes most elements heavier than sodium.

A select number of samples were chosen to be analyzed by XRD to determine predominant mineralogy. Samples were selected by looking at a variety of data, including, but not limited to, XRF data, field parameters, sample location, chemical analysis, and recovered sample mass. Selected samples were delivered to RC Imaging and Analysis in Portland, Oregon, under chain of custody for XRD analysis. RC Imaging analyzed the samples and reported the results to the EGL.

After XRD analysis, samples for SSE analysis were selected using the criteria above and the results of the XRD analysis. SSE targets a series of operationally defined mineral fractions. In SSE, samples are leached with increasingly aggressive solutions to determine the chemical associations. Generally, each

successive step represents stronger attenuation and greater permanence than the previous step. From most available to least available under environmental conditions, these fractions are as follows:

- Soluble
 - Readily exchangeable COI weakly adsorbed to mineral surfaces
 - Leached with elevated ionic strength, pH neutral solution
- Exchangeable
 - Weak acid soluble minerals, such as carbonates and potentially poorly crystalline minerals
 - Leached with mildly acidic phosphate
- Reducible
 - Reducible iron and manganese oxides
 - Leached with acidified reductant
- Oxidizable
 - Oxidizable COI in sulfides and organic matter
 - Leached with strong acid
- Residual
 - Residual COI strongly bound in highly crystalline mineral phases
 - Leached with strong acid plus strong oxidant

2.3 Groundwater Geochemical Equilibrium Modeling

The investigations described above and geochemical equilibrium modeling will be used to develop a geochemical CSM. The geochemical CSM will include probable attenuating mechanisms for arsenic and cobalt, and the relative permanence of those mechanisms. Geochemical equilibrium modeling was performed to help determine what is controlling the mobility and attenuation of arsenic and cobalt, as well as the behavior of other species (such as iron) that influence the behavior of arsenic and cobalt. Geochemical modeling was performed using the USGS computer program PHREEQC with the WATEQ4F thermodynamic database to evaluate charge balance, calculate aqueous speciation, and determine the saturation indices for minerals for groundwater samples collected. Saturation index calculations can be useful in determining potential solid phase controls on water chemistry and reactivity of an aqueous solution toward specific mineral phases. In addition, the Geochemist's Workbench software may be used to plot Eh-pH data on Pourbaix stability diagrams to assess geochemical stability of controlling phases as needed.

2.4 Preliminary Results from the Geochemical Analysis

In solid samples collected from nine monitoring wells, XRF detected at least one COI and elements associated with natural attenuation (iron and calcium). XRD identified at least two potentially attenuating minerals in each solid sample from six wells. The potentially attenuating minerals include montmorillonite, zeolite, vermiculite, kaolinite, and ferrihydrite. Solids from well BY-AP-MW-9 contained all five potentially attenuating minerals. SSE, SEM, and CEC analysis are currently being

performed on select samples to verify the results of the XRD work. Minerals may be identified by their shape (morphology) as observed on an SEM image. In addition, analogous to XRD, an electron beam may be used to determine the internal crystalline structure and hence the identity of minerals observed in an SEM image.

Preliminary geochemical modeling results include the following:

- Arsenic concentrations are likely controlled by sorption on iron oxides (such as ferrihydrite), as well as by a barium arsenate mineral phase ($\text{Ba}_3(\text{AsO}_4)_2$).
- Cobalt concentrations may be controlled by a CoFe_2O_4 oxide phase.
- Iron concentrations are likely controlled by iron oxides (ferrihydrite and/or goethite).
- Due to the somewhat reducing conditions, manganese (IV) minerals (e.g., pyrolusite) are expected to be undersaturated. Rhodochrosite (MnCO_3) is near equilibrium, and the mineral phase MnHPO_4 is slightly supersaturated.
- Calcite, dolomite ($\text{CaMg}(\text{CO}_3)_2$), and barite (BaSO_4) mineral phases are also near equilibrium; siderite (FeCO_3) is slightly supersaturated.

Geochemical modeling predicted that arsenic concentrations in groundwater are likely controlled by ferrihydrite, a hydrous iron oxide with a very large surface area. Ferrihydrite was identified in solids from one well at the Site. Ferrihydrite is often poorly crystalline (making identification by XRD difficult), so it is likely present in more than just one well at the Site. Ferrihydrite is extensively documented in the scientific literature as an attenuating mineral for arsenic and is also reported to attenuate cobalt.

As one of several geochemical manipulation techniques, ferrihydrite could be created in situ at the Site by the injection of iron compounds (e.g., ferrous sulfate) to attenuate arsenic (Pugh et al. 2012) and likely cobalt.

Montmorillonite, vermiculite, kaolinite, and zeolite (all clay or clay-like minerals) could possibly attenuate arsenic and cobalt by ion exchange and/or sorption mechanisms. SSE, SEM, and CEC are expected to provide additional information on the attenuation mechanisms for arsenic and cobalt at the Site.

3 Planned Activities and Anticipated Schedule

The following activities are planned in the near term (June to August 2020) to complete the initial evaluation of MNA and geochemical manipulation:

- Complete SSE, SEM, and CEC work
- Integrate the XRD, SEM, SSE, CEC, and geochemical modeling results into a geochemical CSM; perform additional geochemical modeling if needed

The SSE will determine the associations of COI with various mineral phases to help determine attenuating minerals and their stability. XRD, SEM, SSE, CEC, and geochemical modeling will be integrated to develop a geochemical CSM, i.e., to determine probable attenuation phases and their stability (permanence). As new groundwater monitoring data become available, concentration versus distance and concentration versus time graphs will be updated to identify decreasing concentration trends that indicate natural attenuation. Geochemical data and other site-specific information will be used to determine effective compositions of injected treatment solutions and where injection treatment might be applied.

Though indications of natural attenuation are present at the Site, natural attenuation is expected to increase as source control measures continue to be implemented (i.e., continued dewatering, consolidation, and capping). A groundwater pressure relief system consisting of more than 200 pumping wells and operating greater than 50% of the year is currently planned to enable consolidation and closure activities. Pressure relief wells will not all be operating concurrently and will be phased during the closure period. MNA will almost certainly be one component, if not the only component, of corrective action.

The longer-term schedule for advancing corrective action at the Site is as follows:

- Perform a conceptual-level feasibility study of potentially viable corrective actions (June to December 2020)
 - Show where the viable corrective actions could be applied on Site maps and on geologic sections
 - 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
 - Determine how corrective actions could be integrated with pond closure, such as dewatering and associated water treatment systems
 - Determine data gaps and develop plans to collect additional data as needed
- Develop a conceptual corrective action strategy plan
- Develop plans for laboratory treatability and field pilot tests as needed (June to December 2020)
- Collect additional data to fill identified data gaps (2021)
- Perform laboratory treatability studies and implement field pilot tests (2021)
- Develop a detailed groundwater remedy plan (2022)

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. Based on the site-specific evaluation, additional studies may be implemented.

Using available information, we anticipate developing a conceptual corrective action strategy plan for the Site. The conceptual corrective action strategy will serve as the basis for developing a final remedy plan and include: a description of the conceptual corrective action strategy, identified points of compliance, performance standards, potential data gaps, monitoring approaches, and adaptive triggers. The conceptual corrective action strategy will serve as the basis for developing a final remedy and remedy selection report for the Site.

The schedule of activities above is considered typical and will be affected by the pond closure activities and schedule. For example, some of the activities could be performed sooner, to enable integration of corrective action with pond closure. Similarly, pond closure activities might delay implementation of some of the items above.

Pursuant to 40 CFR § 257.97(a) and ADEM Admin. Code r. 335-13-15-.06(8)(a), semi-annual status progress reports will continue to be finalized in June and December until a final remedy plan is developed. Upon developing a final remedy plan, a report will be prepared describing the remedy plan and how it demonstrably meets the requirements of § 257.97 and r. 335-13-15-.06(8). Details regarding adaptive management triggers and criteria will be included in the final Remedy Selection Report.

Alabama Power will continue groundwater monitoring at the Site. In addition to performing the work described previously, the following will also be completed:

- Submit a completed Groundwater Investigation Report following completed delineation activities
- Submit the next *Semi-Annual Groundwater Monitoring and Corrective Action Report* to ADEM by July 31, 2020
- Submit the next *Semi-Annual Progress Report* to ADEM by September 30, 2020
- Submit the next *Semi-Annual Remedy Selection and Design Progress Report* by December 15, 2020

4 References

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