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CORRECTIVE MEASURES ASSESSMENT
SANTEE COOPER BOTTOM ASH POND
CROSS, SOUTH CAROLINA

by
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for
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File No. 131539-003
September 11, 2019

Overview

This Corrective Measures Assessment (CMA) was prepared by Haley & Aldrich, Inc. (Haley & Aldrich) on behalf of South Carolina Public Service Authority (Santee Cooper) for the Bottom Ash Pond at the Cross Generating Station (CGS; Site) located in Berkeley County near the communities of Cross and Pineville, South Carolina. The CMA was completed in accordance with requirements stated in the U.S. Environmental Protection Agency's (EPA) rule entitled *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities*; 80 Fed. Reg. 21302 (Apr. 17, 2015) (promulgating 40 CFR §257.61); 83 Fed. Reg. 36435 (July 30, 2018) (amending 40 CFR §257.61) (CCR Rule).

Assessment Monitoring conducted in 2018 identified the presence of beryllium, cobalt, and lithium in one or more downgradient wells at statistically significant levels (SSL) exceeding the established groundwater protection standards (GWPS). In accordance with the CCR Rule update, published on July 30, 2018, the GWPS was set as the Maximum Contaminant Level (MCL) of 0.004 mg/L for beryllium and the EPA Regional Screening Levels (RSL) of 0.006 mg/L for cobalt and 0.04 mg/L for lithium. The MCL is a health-based standard for drinking water, whereas the RSL is a drinking water standard based on aesthetics (i.e., color, taste, or odor). As a result, and in accordance with the CCR Rule, Santee Cooper initiated an evaluation of the horizontal and vertical nature and extent of beryllium, cobalt, and lithium downgradient of the Bottom Ash Pond, including the installation of monitoring wells at the downgradient property line. Groundwater sampling from the newly installed monitoring wells showed that the extent of beryllium, cobalt, and lithium is confined to the uppermost aquifer on-site and does not extend into the underlying bedrock unit (Santee Limestone).

In performing this CMA, Haley & Aldrich considered the following: presence and distribution of beryllium, cobalt, and lithium, Cross Bottom Ash Pond configuration and operational history, hydrogeologic setting, and the results of the evaluation of the nature and extent available at this time.

The remedial alternatives evaluated in this CMA include the following:

- Alternative 1: Cap and close-in-place (CIP) plus monitored natural attenuation (MNA);
- Alternative 2: Cap and CIP plus hydraulic containment with direct discharge;
- Alternative 3: Cap and CIP plus hydraulic containment with ex-situ groundwater treatment;
- Alternative 4: Closure by removal (CBR) plus MNA;
- Alternative 5: CBR plus hydraulic containment with direct discharge; and
- Alternative 6: CBR plus hydraulic containment with ex-situ groundwater treatment.

These six alternatives were evaluated based on the threshold criteria provided in §257.97(b) of the CCR Rule and then compared to three of the four balancing criteria listed in §257.97(c)(1) of the CCR Rule. The threshold criteria must:

1. Be protective of human health and the environment;
2. Attain the GWPS as specified in § 257.95(h);
3. Control the source(s) of releases to reduce or eliminate, to the maximum extent feasible, further releases of constituents in appendix IV to this part into the environment;

4. Remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, considering factors such as avoiding inappropriate disturbance of sensitive ecosystems; and
5. Comply with standards for management of wastes as specified in § 257.98(d).

The four balancing criteria shall consider:

1. The long- and short-term effectiveness and protectiveness of the potential remedy(s), along with the degree of certainty that the remedy will prove successful;
2. The effectiveness of the remedy in controlling the source to reduce further releases;
3. The ease or difficulty of implementing a potential remedy; and,
4. The degree to which community concerns are addressed by a potential remedy.

Balancing criteria number four, above (consideration of community concerns), cannot be evaluated until after a public meeting is held and public input is obtained. Accordingly, a remedy cannot be selected until thirty days after the public meeting is held.

Observations and/or expectations associated with the groundwater remedial alternatives for the Cross Bottom Ash Pond are provided below and described more fully in this report:

- **Groundwater Compliance**: Under current conditions there is not a risk to human health and the environment associated with the Cross Bottom Ash Pond. Upon closure of the Cross Bottom Ash Pond beryllium, cobalt, and lithium concentrations are expected to decline below their GWPS through the chemical, physical, and biological processes of natural attenuation that occur without human intervention. Additional, or supplemental, remedial alternatives are included in this document for consideration in addition to MNA.
- **Groundwater Treatment:** In order to implement a groundwater alternative that includes treatment, laboratory testing would be required to demonstrate effective treatability of beryllium, cobalt, and lithium using either ex-situ treatment methods, such as ion exchange or reverse osmosis. Following laboratory-scale testing, pilot-scale treatment evaluations for the contaminants would also be required if such remedies were selected as part of the CMA process.

Groundwater Modeling: Groundwater and solute transport modeling was conducted using cobalt as a surrogate for lithium and beryllium to evaluate the timeframes to achieve GWPS for the various alternatives. Cobalt was chosen as the surrogate for the Cross Bottom Ash Pond because it was the constituent detected at the highest concentration in groundwater and because it was the Appendix IV constituent that had migrated furthest from the unit. As a result, remediation timeframes for cobalt represent a worse case condition. While Santee Cooper has been monitoring groundwater downgradient of the Cross Bottom Ash Pond under a South Carolina Department of Health and Environmental Control (SC DHEC) approved groundwater monitoring program, to the extent necessary and appropriate and in accordance with §257.98 of the CCR Rule, Santee Cooper may modify or expand the groundwater monitoring program to document the effectiveness of the selected remedial alternative. Corrective measures are considered complete when monitoring reflects groundwater downgradient of the Cross Bottom Ash Pond has fallen to below Appendix IV GWPS for three consecutive years. The corrective measures alternatives evaluated in this CMA are based on the data available at this time. Weather events and lack of availability to qualified drilling subcontractors has delayed completion of the nature and extent determination and as a result, a 60-day extension was required to complete the CMA.

In addition, EPA is in the process of modifying certain CCR Rule requirements and, depending upon the nature of such changes, assessments made herein could be modified or supplemented to reflect such future regulatory revisions. See *Federal Register (March 15, 2018; 83 FR 11584*).

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1. Introduction

Haley & Aldrich, Inc. (Haley & Aldrich) has prepared this Corrective Measures Assessment (CMA) on behalf of Santee Cooper for the Cross Bottom Ash Pond located at the Cross Generating Station (CGS) located at 533 Cross Station Road in Pineville, Berkeley County, South Carolina (see Figure 1).

1.1 FACILITY DESCRIPTION/BACKGROUND

The CGS is an electric power generating station with four steam units which utilize coal as the primary fuel source. Santee Cooper currently owns the land and operates the station for supplying electric power to electric cooperatives throughout the state and to the industrial, commercial, and residential customers in its service territory.

In 1993, Cross Bottom Ash Pond was constructed and lined with a geosynthetic clay liner (GCL). The Cross Bottom Ash Pond Liner Certification (WorleyParsons, 2016c), located within the CCR operating record, concluded the GCL does not meet the requirements of §257.71 of the CCR Rule. Therefore, the Cross Bottom Ash Pond is considered an existing unlined CCR surface impoundment and is subject to the requirements of §257.101.

The Cross Bottom Ash Pond is primarily used for treatment and storage of flue gas desulfurization FGD slurry (primarily gypsum) from the four generating units at CGS and wastewater from several sources; the Coal Pile Runoff Pond; the Landfill Leachate Collection Pond; the Unit 1 and 2 Stormwater Pond; the Unit 3 and 4 Stormwater Pond; and numerous station drainage sumps. The Cross Bottom Ash Pond previously received decant water from the Gypsum Pond, which was closed by removal in March 2017. It also previously received bottom ash, pyrites, and economizer ash. As of April 2019, all on-site pyrites and ash materials are no longer placed into the Cross Bottom Ash Pond. These waste streams are now either beneficially used or disposed of in the on-site Class 3 landfill.

Santee Cooper has long-term contracts with beneficial use customers to facilitate on-going beneficial use of fly ash, bottom ash and gypsum. The fly ash produced at Cross Generating Station is used in the cement industry. Bottom ash is used to produced concrete masonry blocks. Gypsum is used in the drywall, cement, and agriculture industries. Bottom ash and gypsum are currently being reclaimed from the Cross Bottom Ash Pond for beneficial use. Bottom ash has been reclaimed since the 1990's and used to make concrete block. Gypsum has been reclaimed since 2016 and used in the agricultural and cement industries. Since 2015, 190,000 tons of bottom ash and 333,000 tons of gypsum have been removed from the pond with the result being a net loss in CCR materials contained in the Cross Bottom Ash Pond during this timeframe.

1.2 GROUNDWATER MONITORING

Haley & Aldrich prepared a Groundwater Monitoring Plan (GMP) as required by the CCR Rule. The GMP presents the design of the groundwater monitoring system, groundwater sampling and analysis procedures, and groundwater statistical analysis methods. For the Cross Bottom Ash Pond, five downgradient groundwater monitoring wells were installed along with two upgradient/background wells identified for the Site (see Figure 2). Well placement was determined based on interpretations of site-specific hydrogeology including groundwater flow direction and rate of groundwater movement and exceeds the CCR Rule requirement for at least one background monitoring well. The water quality of the upgradient/background wells is not impacted or affected by the CCR management units at the CGS. The groundwater monitoring well network for the Cross Bottom Ash Pond was designed to comply with the CCR Rule by monitoring the uppermost aquifer at the CCR unit boundary.

Detection monitoring sampling events were completed by October 2017 as required. The results of the sampling events, summarized on Table 1, were compared to background values. A statistical evaluation was conducted to determine if Appendix III constituents downgradient of the Cross Bottom Ash Pond were present at concentrations above background, called statistically significant increases (SSI). The results of this analysis identified SSIs for boron, calcium, chloride, fluoride, sulfate, and total dissolved solids (TDS) in one or more downgradient wells triggering initiation of an Assessment Monitoring Program and respective notification of the same. The location of the Appendix III SSI's is shown on Figure 3.

During the Assessment Monitoring phase, CCR groundwater samples were collected and subsequently analyzed for Appendix IV constituents. The results of the two Assessment Monitoring rounds are summarized on Table 2. After establishing groundwater protection standards (GWPS) for the Appendix IV constituents, a statistical analysis of the Assessment Monitoring results was conducted to determine if the detected Appendix IV constituents were present in groundwater at statistically significant levels (SSLs) above the GWPS. This analysis produced SSLs for beryllium (CAP-9), cobalt (CAP-1, 3, 5, 7, 9), and lithium (CAP-1 and CAP-9). The GWPS was set as the Maximum Contaminant Level (MCL) of 0.004 mg/L for beryllium and the EPA Regional Screening Level (RSL) of 0.006 mg/L for cobalt and 0.04 mg/L for lithium as shown on Figure 4. Following the identification of SSLs for beryllium, cobalt, and lithium an evaluation of the nature and extent of the three contaminants was initiated as required by §257.95(g). A CMA was also initiated in accordance with §257.96.

1.3 CORRECTIVE MEASURES ASSESSMENT PROCESS

The CMA process involves identification of an array of groundwater remediation technologies that will satisfy the following threshold criteria: protection of human health and the environment, attainment of GWPS, source control, constituent removal, and compliance with standards for waste management. Once these technologies are demonstrated to meet these criteria, they are compared to one another with respect to long- and short-term effectiveness, source control, and implementability. Input from the community on such proposed measures will occur as part of a public meeting to be scheduled for the fall of 2019.

1.4 RISK REDUCTION AND REMEDY

The CCR Rule in §257.97 (Selection of Remedy) at (b)(1) requires that remedies must be protective of human health and the environment. Further, at §257.97 (c) the CCR Rule requires that in selecting a remedy, the owner or operator of the CCR unit shall consider specific evaluation factors, including the reduction in risk achieved by each of the proposed corrective measures. The following evaluation factors are those that consider risk to human health or the environment:

- (1)(i) Magnitude of reduction of existing risks;
- (1)(ii) Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy;

- (1)(iv) Short-term risks that might be posed to the community or the environment during implementation of such a remedy, including potential threats to human health and the environment associated with excavation, transportation, and re-disposal of contaminant;

- (1)(vi) Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment;

- (4) Potential risks to human health and the environment from exposure to contamination prior to completion of the remedy[1];

- (5)(i) Current and future uses of the aquifer;

- (5)(ii) Proximity and withdrawal rate of users; and

- (5)(iv) The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to CCR constituents.

[1] Factors 4 and 5 are not part of the CMA evaluation process as described in §257.97(d)(4), §257.97(d)(5)(i)(ii)(iv); rather they are factors the owner or operator must consider as part of the schedule for remedy implementation.

2. Groundwater Conceptual Site Model

The Site geology and hydrogeology was initially described in the *Site Hydrogeologic Characterization Report* prepared by Garrett & Moore in March 2012 and in the *Sampling and Analysis Plan* prepared by Santee Cooper in October 2013. This Conceptual Site Model (CSM) has been updated to reflect information gathered during installation of the groundwater monitoring network and groundwater sampling to comply with the CCR Rule.

2.1 SITE SETTING

The CGS is located north of the diversion canal that connects Lake Marion (northwest of the plant) to Lake Moultrie (southeast of the plant). The Site is located within the Lower Coastal Plain of the Atlantic Coastal Plain physiographic province in South Carolina between the Surry Scarp to the west and the Summerville Scarp to the east.

2.2 SITE TOPOGRAPHY

The Site is relatively flat with natural ground surface elevations varying from 79 to 83-feet above mean sea level (msl). Surface water runoff occurs via sheet flow to low-lying areas surrounding the Site and into storm water drainage canals located adjacent to the primary and secondary roads and parking areas.

2.3 GEOLOGY AND HYDROGEOLOGY

In addition to the ongoing, recent deposition of fluvial sediments and organic matter in low-lying areas or streams, previous investigations have described four geologic units beneath the Site. From youngest to oldest these units include the Wicomico Formation, the Raysor Formation, the Santee Limestone, and the Black Mingo Group. The four geologic units encountered beneath the Site are described below for reference, with emphasis on the Wicomico Formation and the Raysor Formation, which make up the uppermost aquifer and, as required by the CCR Rule, were the focus of the detection groundwater monitoring program. Beginning at ground surface and continuing downward from youngest to oldest, the geologic units beneath the site are described as follows:

Formation Name	Age	Hydrogeologic Unit	Description	Thickness in Feet
Wicomico Formation	Pleistocene	Uppermost Aquifer	Unconsolidated, upward-fining sequences of poorly sorted sand, silt, and clay deposited in a near-shore marine depositional setting that includes barrier island and back-barrier depositional environments. This depositional setting produces soil types that grade laterally and vertically from more sandy types to more clayey soil types.	12-23

Formation Name	Age	Hydrogeologic Unit	Description	Thickness in Feet
Raysor Formation	Pleistocene	Uppermost Aquifer	Unconsolidated or weakly cemented, discontinuous layer of sandy limestone that contains abundant weathered mollusk shells deposited in a shallow marine-shelf environment.	0-17
Santee Limestone	Eocene	Intermediate Aquifer	Thin highly weathered layer consisting of relatively dense partially indurated, shelly, fine to medium sand. This thin layer is underlain by a thick consolidated layer of variably weathered crystalline, soft to hard, medium to light gray, shelly to muddy limestone.	23-47
Black Mingo Group	Eocene	Lower Aquifer	These sediments are generally described as dark greenish gray sands with intervals of silty fine sand and silty clay.	100-125

The groundwater monitoring network for the Bottom Ash Pond was developed based on information contained in the existing reports prepared by others and reviewed by Haley & Aldrich to monitor the uppermost aquifer upgradient and downgradient of the Bottom Ash Pond (see Figure 2). Hydrogeologic units are defined based on their ability to transmit groundwater or serve as confining units between zones of groundwater. The uppermost aquifer at CGS includes saturated sediments of the Wicomico and Raysor Formation (uppermost deposits). In the western portion of the site recharge to the uppermost aquifer occurs through direct surface infiltration as well as recharge from Lake Marion. Near the CCR unit, recharge to the uppermost aquifer occurs by direct surface infiltration. Groundwater discharge to surface water is interpreted to occur at the diversion canal to the south and Lake Moultrie to the northeast.

Piezometric data recorded from the existing on-site monitoring wells, as presented in Table 3, shows that the unconfined uppermost aquifer is relatively flat and that variable recharge in the vicinity of storm water conveyances and retention areas can have a short-term effect on groundwater flow patterns. As shown in Figure 5, under equilibrium water table conditions, groundwater flow in the vicinity of the Bottom Ash Pond is radial. Groundwater flow velocity in the uppermost aquifer is calculated to be approximately 30-feet per year. Under equilibrium groundwater flow conditions, groundwater flows away from areas where the elevation of the Santee Limestone is high to surrounding areas where the elevation of the top of the Santee Limestone is low, with the primary direction of baseline flow toward the west-northwest, north, and northeast.

2.4 GROUNDWATER PROTECTION STANDARDS

Haley and Aldrich completed a statistical evaluation of groundwater samples using the methods and procedures outlined in the Groundwater Monitoring Plan's *Statistical Data Analysis Plan* to develop site-specific GWPS for each Appendix IV constituent. For the CGS, background concentrations of Appendix IV constituents did not exceed either the MCL or the RSL established by EPA as default GWPS. Accordingly, the MCL or the RSL (for those constituents that do not have a promulgated MCL) were used as GWPS.

2.5 NATURE AND EXTENT OF GROUNDWATER IMPACTS

Assessment Monitoring results were compared to the GWPS, and beryllium, cobalt, and lithium were identified as the Appendix IV constituents detected at SSLs above their respective GWPS downgradient of the Cross Bottom Ash Pond. As a result, and in accordance with the CCR Rule, Santee Cooper initiated an evaluation of the horizontal and vertical nature and extent (N&E) of beryllium, cobalt, and lithium downgradient of the Bottom Ash Pond. The N&E and CCR monitoring wells are screened within the uppermost aquifer. Included in this evaluation was the installation of two monitoring wells, CCMAP-1 and CCMAP-2, at the downgradient property line between the Bottom Ash Pond and potable water wells that supply drinking water to nearby residences. The location of the downgradient wells was selected based on the results of a direct-push groundwater screening evaluation. The direct-push screening evaluation included the collection of shallow and deep grab samples along two transects oriented parallel to the direction of groundwater flow. One transect generally oriented in a north-south direction and the second oriented in an east-west direction as shown on Figure 2. Cobalt was detected in the downgradient property line monitoring well CCMAP-1 at concentrations below the GWPS. Beryllium and lithium were not detected at CCMAP-1. Beryllium, cobalt, and lithium were not detected at downgradient property line monitoring well CCMAP-2. Analytical results from the nature and extent evaluation are summarized in Table 4. Boring logs are provided as Appendix A and laboratory analytical reports are provided as Appendix B.

Existing groundwater monitoring wells around the Cross Bottom Ash Pond (CAP-4, CAP-6, CAP-8, and CAP-10, as shown in Figure 2) were not included as part of the CCR monitoring network, as they are screened in the Santee Limestone bedrock aquifer, at depths ranging from 40 to 60 feet below ground surface. Groundwater samples from these wells were analyzed for cobalt, beryllium, and lithium in February and July 2019. Cobalt and lithium were detected in one well (CAP-8). Cobalt concentrations did not exceed the GWPS. However, lithium exceeded the GWPS at this location. As a result, additional evaluations to delineate the vertical extent of lithium are being considered. As additional data becomes available, modifications to this CMA, as necessary and appropriate, will be evaluated. Beryllium was not detected in the deeper bedrock wells.

To further support the conclusion that there is not a current risk to human health and the environment, the production well at CGS and an off-site private water supply well downgradient of CCMAP-2 were sampled for beryllium, cobalt, and lithium. The production well is screened beneath the Santee Limestone within the Black Mingo Formation, at a depth over 300 feet below ground surface. The owner of this private water supply well indicated the well was likely screened approximately 60-75 below ground surface within the Santee Limestone bedrock aquifer. Results obtained from these sampling locations did not detect beryllium, cobalt, and lithium confirming that these Appendix IV constituents do not extend vertically into the Santee Limestone or Black Mingo Formation bedrock aquifers at these locations and that there is not a current risk to human health and the environment.

As previously described, two transects were extended from the Cross Bottom Ash Pond to downgradient property lines, as shown in Figure 6. Transect 1 was extended from a point between CAP-7 and CAP-8 to CCMAP-1. CCMAP-1 was installed at the terminus of Transect 1, within the uppermost aquifer. Transect 2 was extended from a point between CAP-9 and CAP-10 to CCMAP-2. A direct push drill rig was used to collect soil and groundwater samples for analysis of beryllium, cobalt, and lithium. Soil samples were collected using a dual tube sampler with acetate liner to identify changes in subsurface conditions and the presence of groundwater. Soil samples were collected from the same interval as groundwater samples to assess the potential for naturally occurring sources of beryllium, cobalt, and lithium to be present. Groundwater samples were collected by advancing a drive-point sampler to the depth of groundwater as identified during soil sampling. Polyethylene tubing was then advanced within the drill string and a peristaltic pump was used to collect groundwater samples. Due to the high turbidity, which is inherent in this sampling method, both filtered and unfiltered samples were collected. A summary of the analytical results obtained from the N&E transect investigation is provided in Table 4.

N&E results indicate that Beryllium is present above GWPS at CCMAPT1-1, CCMAPT1-3, and CCMAPT1-4 along Transect 1 and at CCMAPT2-1, CCMAPT2-3, CCMAPT2-4, and CCMAPT2-5 along Transect 2. Beryllium was detected at concentrations below GWPS at CCMAPT1-2 and CCMAPT1-5 along Transect 1 and at CCMAPT2-2 and CCMAPT2-6 along Transect 2. Cobalt was detected above GWPS at CCMAPT1-1, CCMAPT1-2, CCMAPT1-3, CCMAPT1-4, CCMAPT1-5, CCMAPT1-6, and CCMAPT1-7 along Transect 1 and at CCMAPT2-1, CCMAPT2-3, CCMAPT2-4, and CCMAPT2-5 along transect 2. Cobalt was detected at concentrations below GWPS at CCMAPT2-2 and CCMAPT2-6 along Transect 2. Lithium was detected at concentrations above GWPS at CCMAPT2-1 along transect 1. Lithium was detected at concentrations below GWPS at CCMAPT1-1, CCMAPT1-3, CCMAPT1-4, and CCMAPT1-6 along Transect 1 and at CCMAPT2-3 along Transect 2.

To date data generated during the evaluation of the nature and extent of beryllium, cobalt, and lithium show that these Appendix IV constituents do not extend off-site at concentrations above the GWPS and are contained to the uppermost aquifer downgradient of the Cross Bottom Ash Pond, confirming that there is not a current risk to human health and the environment. As additional data becomes available modifications to this CMA, as necessary and appropriate, will be evaluated.

Groundwater monitoring wells in the uppermost aquifer at the downgradient property boundary installed as a part of the N&E evaluation CCMAP-1 and CCMAP-2 and the monitoring wells around the Cross Bottom Ash Pond that extend into the Santee Limestone (CAP-4, CAP-6, CAP-8, and CAP-10) will be added to the CCR groundwater monitoring network for groundwater sampling and analysis in accordance with § 257.94 and § 257.95.

3. Corrective Measures Alternatives

3.1 CORRECTIVE MEASURES ASSESSMENT GOALS

The overall goal of this CMA is to identify and evaluate the appropriateness of potential corrective measures to prevent further releases of beryllium, cobalt, and lithium above the GWPS, to remediate releases above the GWPS that have already occurred, and to restore groundwater in the affected area to a condition that is below the GWPS. The CMA provides an analysis of the effectiveness of six potential corrective measures in meeting the requirements and objectives of remedies as described under §257.97 (also shown graphically on Tables 5 and 6). This assessment also meets the requirements in §257.96 by evaluating the following:

- The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to residual contamination;
- The time required to complete the remedy; and,
- The institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy.

The criteria listed above are included in the balancing criteria considered during the corrective measures evaluation as described herein.

3.2 GROUNDWATER FATE AND TRANSPORT

Groundwater at the Site was modeled utilizing Groundwater Vista Version 7 for flow and solute transport. A description of the model construction, calibration, and subsequent simulations of remedy alternatives for Appendix IV constituents above the GWPS is provided as Appendix C. Site-specific parameters (i.e. groundwater elevations and hydraulic conductivity) were utilized for model preparation. MODFLOW 2005, a finite difference three-dimensional solver, was utilized for groundwater flow estimation. Modeled groundwater elevations were compared to observed values from the on-site well network (February 2019) to achieve a calibration of less than 10% scaled RMS. Once groundwater flow was calibrated in the model, solute transport was completed using MT3DMS, a three-dimensional solute transport modeling program. Parameters affecting transport such as advection, diffusion, dispersion, and adsorption are utilized within the MT3DMS package to estimate solute transport within the model domain. Outputs from the groundwater model from the various CMA options are presented in Figures 7 and 7A.

Timeframes to achieve GWPS were evaluated using cobalt as a surrogate for beryllium and lithium. Cobalt is considered a worse case condition because it is the Appendix IV constituent detected at the highest concentration and it is also the constituent that has migrated furthest from the Cross Bottom Ash Pond. To support the modeling effort, Haley & Aldrich evaluated the groundwater geochemistry to develop site-specific attenuation/degradation factors. The groundwater flow and solute transport model is being used to simulate the risks and remediation timeframes that can be predicted under each of the remedial alternatives so that each of the alternatives can be compared to one another. The solute transport model was set up using the groundwater screening results to simulate groundwater concentrations for cobalt detected along the two transects. As a result, the initial concentrations used in the modeling effort may be biased high due to the high turbidity inherent in direct-push sampling. Output from the model is considered reliable for comparing relative remediation timeframes associated with the individual alternatives but the specific number of years required to achieve GWPS may also be biased high due to the high starting concentrations.

As shown on Figures 7 and 7a, CBR with MNA achieves GWPS in the shortest timeframe followed closely by CIP with MNA. While both alternatives rely on MNA, the timeframe to address the source is shorter with CBR than it would be for CIP. The timeframes to achieve GWPS for the alternatives that rely on hydraulic containment are longer because groundwater withdrawal from the boundary of the unit will flatten the hydraulic gradients and reduce groundwater flushing downgradient.

3.3 CORRECTIVE MEASURES ALTERNATIVES

Corrective measures may be terminated when groundwater impacted by the Cross Bottom Ash Pond does not exceed the GWPS for three consecutive years of groundwater monitoring. In accordance with §257.97, the groundwater corrective measures alternatives evaluated herein meet the following threshold criteria:

1. Protect human health and the environment;
2. Attain the GWPS;
3. Control the source(s) of releases to reduce or eliminate, to the maximum extent feasible, further releases of COCs to the environment;
4. Remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, considering factors such as avoiding inappropriate disturbance of sensitive ecosystems; and,
5. Comply with standards (regulations) for waste management.

Each of the remedial alternatives assembled as part of this CMA meet the requirements of the threshold criteria listed above.

This CMA includes an evaluation of six groundwater remediation alternatives described below and presented on Table 5 and evaluated against the threshold and balancing criteria on Table 6, including:

- Alternative 1: Cap and close-in-place (CIP) plus monitored natural attenuation (MNA);
- Alternative 2: CIP plus hydraulic containment with direct discharge;
- Alternative 3: CIP plus hydraulic containment with ex-situ groundwater treatment;
- Alternative 4: Closure by removal (CBR) plus monitored natural attenuation (MNA);
- Alternative 5: CBR plus hydraulic containment with direct discharge; and
- Alternative 6: CBR plus hydraulic containment with ex-situ groundwater treatment.

This CMA, and the input received during the public comment period, will be used to identify a final corrective measure for implementation at the Bottom Ash Pond.

3.3.1 Alternative 1: Cap and Close-in-Place (CIP) plus Monitored Natural Attenuation (MNA)

The Bottom Ash Pond would be closed in-place with a low-permeability cap to reduce infiltration of surface water to groundwater. This cap selection would exceed regulatory requirements by more than two orders of magnitude (<$1x10^{-7}$ centimeters per second (cm/sec) planned versus $1x10^{-5}$ cm/sec required by the CCR Rule). Over time, depletion of Appendix IV constituents in CCR would allow the concentration of these constituents in downgradient groundwater to decline and overall groundwater concentrations to attenuate.

Closure-in-place (CIP) with MNA can be completed safely, in compliance with applicable federal and state regulations, and be protective of public health and the environment. In general, CIP consists of installing a cap/cover designed to significantly reduce infiltration from surface water or rainwater, resist erosion, contain CCR materials, and prevent exposures to CCR. CIP will require the mounding of the remaining CCRs within the pond in order to create a surface with adequate slope to construct a cap and prevent the mounding and ponding of stormwater. This will require extensive excavation and transferring of the material within the pond. Excavation and construction safety during closure is another concern due to heavy equipment (e.g., bulldozers, excavators, front end loaders, and off-road trucks) and dump truck operation within the active CGS site. Additionally, the stormwater runoff will need to be managed, requiring additional time to design and construct a stormwater runoff pond.

MNA is a viable remedial technology recognized by both state and federal regulators that is applicable to inorganic compounds in groundwater. The USEPA defines MNA as "the reliance on natural attenuation processes to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods". The 'natural attenuation 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. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants" (USEPA, 2015). When combined with a low-permeability cap to address the source by limiting the infiltration of precipitation into and through the CCR, MNA can reduce concentrations of beryllium, cobalt, and lithium in groundwater at the Cross Bottom Ash Pond boundary. Following the installation of the cap system, Santee Cooper would implement post-closure care activities. Post-closure care includes cap system maintenance and long-term groundwater monitoring until such time that groundwater conditions return to below GWPS. Future development of the capped surface could be used for solar photovoltaic arrays or other site staging/ancillary operational needs.

3.3.2 Alternative 2: CIP with Capping and Hydraulic Containment Through Groundwater Pumping and Direct Discharge

The Cross Bottom Ash Pond would be closed in-place as described in Section 3.3.1 to reduce infiltration of surface water to groundwater. Beryllium, cobalt, and lithium in groundwater would be addressed with hydraulic containment through groundwater pumping to hydraulically control the migration of those constituents downgradient. Pumping would be limited to the uppermost aquifer since beryllium, cobalt, and lithium have not been detected in the bedrock aquifer. If possible, the pumping well effluent would be discharged directly to surface water under existing or future discharge permits. No treatment would be used prior to discharge. Verification that the effluent could be discharged under current permits or application for and approval of a new permit would be required.

Implementation of a large-scale hydraulic containment system will require a detailed and lengthy design effort. Pilot testing, such as pumping tests and additional groundwater modeling will be needed to verify the hydraulic capture zone.

The pumping well effluent would be discharged directly to a receiving water body in accordance with a National Pollutant Discharge Elimination System (NPDES) Permit (i.e. the Discharge Canal). No treatment would be used prior to discharge. The construction of a transport system from the Cross Bottom Ash Pond to the receiving water body will require engineering design, permitting, and site construction. In order for the effluent to be discharged to a receiving water body, the existing CGS NPDES Operating Permit may need to be modified or a new permit issued. Either option will require wastewater testing or modeling to support a permit application. The anticipated timeline for permitting and construction of this option is one year.

Following the installation of the groundwater pumping well network, Santee Cooper would implement post-closure care activities that includes operation and maintenance of the hydraulic containment system, long-term groundwater sampling to monitor hydraulic control system performance, and cap and cover system maintenance. Over time, processes of MNA would decrease source concentrations of cobalt to values less than the GWPS and operation of the hydraulic containment system would cease. Future development of the capped surface could be used for solar photovoltaic arrays or other site staging/ancillary operational needs.

3.3.3 Alternative 3: CIP with Capping and Hydraulic Containment Through Groundwater Pumping and Ex-Situ Treatment

The Cross Bottom Ash Pond would be closed in-place as described in Section 3.3.1 to reduce infiltration of surface water to groundwater. Beryllium, cobalt, and lithium detected at the boundary of the unit at concentrations above the GWPS would be addressed with hydraulic containment through groundwater pumping to hydraulically control the migration of those constituents downgradient. Pumping would be limited to the uppermost aquifer since beryllium, cobalt, and lithium have not been detected in the bedrock aquifer. Pumping well effluent would be treated ex-situ, likely with an ion exchange or a reverse osmosis (RO) treatment system. Both systems would have ongoing operation and maintenance and would generate a secondary waste stream – including regeneration/replacement of the ion exchange media or accumulation of reject water from the RO system.

The design and construction of an ion exchange or RO system would require development of additional land at CGS, which could trigger the need for a wetlands permit. Most of the undeveloped property near the Cross Bottom Ash Pond is wetlands. The time to obtain a 401 certification, a 404 Army Corps of Engineers permit, and Ocean Coastal Resource Management (OCRM) approval is typically one year, which will extend the closure schedule by the time required for applicable permit approvals. Additionally, a 404 permit will not be granted if there are more favorable options available that have less environmental impacts, such as Alternative 1.

As noted in the previous option, implementation of a large-scale hydraulic containment system will require a detailed and lengthy design effort. Pilot testing, such as pumping tests and additional groundwater modeling, will be needed to verify the hydraulic capture zone. The timeline for permitting and construction of this option is estimated to be 2 years.

Following the installation of the low-permeability cap, groundwater pumping well network, and ex-situ treatment system, Santee Cooper would implement post-closure care activities that includes operation and maintenance of the hydraulic containment system, long-term groundwater sampling to monitor hydraulic containment system performance, and cover system maintenance. Over time, processes of MNA would decrease source concentrations of cobalt to values less than the GWPS and operation of the hydraulic containment system would cease. Future development of the capped surface could be used for solar photovoltaic arrays or other site staging/ancillary operational needs.

3.3.4 Alternative 4: Closure by Removal (CBR) with MNA

This alternative consists of removal of the Cross Bottom Ash Pond CCR material followed by natural attenuation of beryllium, cobalt, and lithium in groundwater. This alternative would eliminate the source (through removal), and over time, allow the concentrations of these constituents in downgradient groundwater to attenuate. Through on-going beneficial use of reclaimed bottom ash and gypsum, the amount of material that will need to be removed from the Pond has been greatly reduced. The existence of long term contracts with the agricultural and cement industries for the beneficial use along with the proven success of Santee Cooper's beneficial use program makes the option of CBR extremely viable.

Since the Class 3 Landfill exists at CGS, on-site and off-site disposal options were considered for non-marketable CCR material from the pond. The Class 3 Landfill was designed and constructed to store existing and future CCRs from CGS and any residual CCR material from the Cross Bottom Ash Pond. Additionally, the on-going beneficial use program minimizes the use of the on-site landfill in this CBR scenario.

CGS presents materials management challenges that may impact the implementation and closure times for the CBR alternative. CCRs in the Cross Bottom Ash Pond will be dewatered to remove free water before being hauled to, and placed in, the existing on-site lined Class 3 Landfill. Following the removal of the CCRs and residual materials from the Pond, the existing liner and revetment material will be evaluated. If there is residual CCR contamination of the liner and revetment materials, they will be disposed of in either the on-site Cross Class 3 landfill, assuming permit approval by SC DHEC, or in an off-site permitted landfill.

Technical and logistical challenges of implementing a large-scale ash removal project have already been addressed by Santee Cooper through their ongoing beneficial use program. Removal activities require dewatering and temporary staging/stockpiling of material for drying prior to transportation, which may affect productivity and extend the timeframe to complete removal. During periods of rain and inclement weather, the removal schedule will be negatively impacted. Excavation and construction safety during the removal duration is another concern due to heavy equipment (e.g., bulldozers, excavators, front end loaders, and off-road trucks) and dump truck operation within the active CGS site.

Groundwater would be addressed through MNA. MNA is a viable remedial technology recognized by both state and federal regulators that is applicable to inorganic compounds in groundwater. The USEPA defines MNA as "the reliance on natural attenuation processes to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods". The 'natural attenuation 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. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants" (USEPA, 2015). When combined with a low-permeability cap to address the source by limiting the infiltration of precipitation into and through the CCR, MNA can reduce concentrations of beryllium, cobalt, and lithium in groundwater at the Cross Bottom Ash Pond boundary.

Long-term, Santee Cooper would implement post-closure care activities that includes long-term groundwater sampling.

3.3.5 Alternative 5: CBR with Hydraulic Containment Through Groundwater Pumping and Direct Discharge

Similar to Alternative 5, the Bottom Ash Pond would be closed by removal. However, under this alternative, beryllium, cobalt, and lithium detected in groundwater at concentrations above GWPS would be addressed through groundwater pumping to hydraulically control the migration of those constituents downgradient. Pumping would be limited to the uppermost aquifer since beryllium, cobalt, and lithium have not been detected in the bedrock aquifer.

Implementation of a large-scale hydraulic containment system will require a detailed and lengthy design effort. Pilot testing, such as pumping tests and additional groundwater modeling, will be needed to verify the hydraulic capture zone.

The pumping well effluent would be discharged directly to a receiving water body in accordance with a National Pollutant Discharge Elimination System (NPDES) Permit (i.e.,) no treatment would be used prior to discharge. The construction of a transport system from the Cross Bottom Ash Pond to the receiving water body will require engineering design, permitting, and site construction. In order for the effluent to be discharged to a receiving water body, the existing CGS NPDES Operating Permit may be modified or a new permit issued. Either option will require wastewater testing or modeling to support a permit application. The anticipated timeline for permitting and construction of this option is one year. Following CCR removal, beryllium, cobalt, and lithium concentrations would decrease through active pumping and natural attenuation and pumping would eventually cease. Further reduction of beryllium, cobalt, and lithium concentrations, if required, would occur through natural attenuation until concentrations attenuate to levels less than the GWPS. Because active groundwater pumping along the boundary of the Cross Bottom Ash Pond would reduce groundwater flux, the time period for active pumping will be greater than MNA alone.

Long-term, Santee Cooper would implement post-closure care activities that includes long-term groundwater sampling.

3.3.6 Alternative 6: CBR with Hydraulic Containment Through Groundwater Pumping and Ex-Situ Treatment

Similar to Alternative 4, the Bottom Ash Pond would be closed by removal; however, under this alternative, beryllium, cobalt, and lithium detected in groundwater at concentrations above GWPS would be addressed with hydraulic containment through groundwater pumping to hydraulically control the migration of those constituents downgradient. Pumping well effluent would be treated ex-situ, likely with an ion exchange or a reverse osmosis (RO) treatment system. Both systems would have on-going operation and maintenance and would generate a secondary waste stream – including regeneration/replacement of the ion exchange media or concentration of reject water from the RO system.

The design and construction of an ion exchange or RO system would require development of additional land at CGS, which would likely trigger the need for a wetlands permit. Most of the undeveloped property near the Cross Bottom Ash Pond is wetlands. The time to obtain a 401 certification, a 404

Army Corps of Engineers permit, and OCRM approval is typically one year, which will extend the closure schedule by the time required for applicable permit approvals. Additionally, a 404 permit will not be granted if there are more favorable options available that have less environmental impacts, such as Alternative 4.

As noted in the previous option, implementation of a large-scale hydraulic containment system will require a detailed and lengthy design effort. Pilot testing, such as pumping tests and additional groundwater modeling, will be needed to verify the hydraulic capture zone. The timeline for permitting and construction of this option is an estimated 2 years.

Following CCR removal, beryllium, cobalt, and lithium concentrations in groundwater would decrease through active pumping and natural attenuation. The timeline for active treatment is expected to be 8-years. Further reduction of beryllium, cobalt, and lithium concentrations, if required, would occur through natural attenuation until concentrations attenuate to levels less than the GWPS. Because active groundwater pumping along the boundary of the Cross Bottom Ash Pond would decrease groundwater flux, the time period for active pumping and treatment will be greater than MNA alone.

Long-term, Santee Cooper would implement post-closure care activities that includes long-term groundwater sampling.

4. Comparison of Corrective Measures Alternatives

The purpose of this section is to evaluate, compare, and rank the six corrective measures alternatives using the balancing criteria described in §257.97.

4.1 EVALUATION CRITERIA

In accordance with §257.97, remedial alternatives that satisfy the threshold criteria are then compared to four balancing (evaluation) criteria. The balancing criteria allow a comparative analysis for each corrective measure, thereby providing the basis for final corrective measure selection. The four balancing criteria include the following:

1. The long- and short-term effectiveness and protectiveness of the potential remedy(s), along with the degree of certainty that the remedy will prove successful;
2. The effectiveness of the remedy in controlling the source to reduce further releases;
3. The ease or difficulty of implementing a potential remedy; and,
4. The degree to which community concerns are addressed by a potential remedy.

Public input and feedback will be considered following a public information session to be held in the fall of 2019.

4.2 COMPARISON OF ALTERNATIVES

This section compares the alternatives to each other based on evaluation of the balancing criteria listed above. The goal of this analysis is to identify the alternative that is technologically feasible, relevant and readily implementable, provides adequate protection to human health and the environment, and minimizes impacts to the community.

A graphic is provided within each subsection below to provide a visual snapshot of the favorability of each alternative, where green represents favorable, yellow represents less favorable, and red represents least favorable.

4.2.1 The Long- and Short-Term Effectiveness and Protectiveness of the Potential Remedy, along with the Degree of Certainty that the Remedy Will Prove Successful

As summarized in the following sections, this balancing criterion takes into consideration the following sub-criteria relative to the long-term and short-term effectiveness of the remedy, along with the anticipated success of the remedy:

1. Magnitude of reduction of risks;
2. Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy;
3. The type and degree of long-term management required, including monitoring, operation, and maintenance;
4. Short-term risks that might be posed to the community or the environment during implementation of such a remedy;
5. Time until full protection is achieved;

6. Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment;
7. Long-term reliability of the engineering and institutional controls; and
8. Potential need for replacement of the remedy.

4.2.1.1 Magnitude of reduction of existing risks

As indicated by the N&E evaluation and the most recent groundwater sampling results, no unacceptable risk to human health and the environment exists with respect to the Cross Bottom Ash Pond. Therefore, none of the remedial alternatives are necessary to reduce risks because no such exposure to beryllium, cobalt, or lithium currently exists. However, other types of impacts may be posed by the various remedial alternatives considered here. Alternative 4 (Closure by Removal and MNA) is the most favorable option because the source is completely removed from the environment, the ongoing beneficial use program has already reduced the volume of material in the Pond, long term contracts are in place for the remaining CCRs, and the concept has been proven to be a viable option for this location. Alternative 1 is considered less favorable because the source is left in place. Alternatives 3 and 6, which incorporate hydraulic containment and ex--situ treatment) have the highest potential impact due to the installation of pumping wells, construction of treatment systems, long-term operation, and generation of secondary waste streams with associated off-site disposal.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 1 - Subcriteria i) Magnitude of reduction of risks						

4.2.1.2 Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy

Alternatives 4 through 6, which include closure by removal, have the lowest long-term residual risk because the CCR materials are being removed from the environment and are either being beneficially used or being placed in an on-site lined Class 3 landfill with secondary leachate collection. Alternative 4 (CBR with MNA) has the lowest residual risk because groundwater is being addressed in-situ through natural processes as opposed to Alternatives 5 and 6 which include a pumping component with direct discharge or ex-situ treatment of effluent. For Alternatives 1 through 3, which include closure in-place with a cap and cover system, the source is controlled through the installation of a low permeability cap which will significantly reduce the amount of infiltration through the CCR material. Alternative 3 (CIP plus hydraulic containment with ex-situ treatment) has the highest long-term residual risk because the CCR material will be closed in-place and the groundwater treatment system will require long-term O&M and generate secondary waste streams. Additionally, the CGS is located within a seismic hazard area with potential for liquification, Alternatives 4 through 6 are lower risk than leaving the material in place in Alternatives 1 through 3.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 1 - Subcriteria ii) Magnitude of residual risk in terms of likelihood of further release						

4.2.1.3 The type and degree of long-term management required, including monitoring, operation, and maintenance

Alternative 4 (CBR with MNA) is the most favorable alternative with respect to this criterion because it requires the least amount of long-term management and involves no mechanical systems as part of the remedy. Alternative 1 (CIP with capping and MNA) is slightly less favorable because it requires maintenance of a cap and cover system. The remaining alternatives, which include hydraulic containment require long-term O&M, and those alternatives that contain ex-situ treatment (Alternatives 3 and 6) are the least favorable due to the O&M of groundwater treatment systems and the generation of secondary waste streams.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 1 - Subcriteria iii) Type and degree of long-term management required						

4.2.1.4 Short-term risks that might be posed to the community or the environment during implementation of such a remedy

Community impacts include general impacts to the community due to increased truck traffic on public roads during construction and operation of the remedies, along with generation of secondary waste streams with transportation and off-site disposal of waste streams. Because of the current beneficial use and use of the existing Class 3 landfill, there will be temporary and relatively minimal increase in truck traffic for all options.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 1 - Subcriteria iv) Short term risk to community or environment during implementation						

4.2.1.5 Time until full protection is achieved

As previously stated, there is currently no exposure to groundwater impacted by beryllium, cobalt, and lithium associated with the Cross Bottom Ash Pond; therefore, protection is already achieved. The timeframes to achieve GWPS were evaluated using a predictive model as described in Section 3.2. Based upon predictive modeling, Alternatives 1 and 4 (CIP with MNA and CBR with MNA) which assume no continuing source, beryllium, cobalt, and lithium concentrations will attain GWPS in the shortest amount of time (see Figure 7). Closure by removal with MNA is predicted to take slightly more time to achieve GWPS due to the longer period of time required to implement the remedy. Due to the size of the impacted area, the alternatives that rely on hydraulic containment at the waste boundary for groundwater treatment, are predicted to take the greatest amount of time to reduce COC concentrations and are therefore less favorable.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 1 - Subcriteria v) Time until full protection is achieved						

4.2.1.6 Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment

Because the extent of groundwater impacted by the Cross Bottom Ash Pond is limited to the uppermost aquifer on-site, Alternative 1 (CIP with MNA) has the lowest potential for exposure to human and environmental receptors and is considered most favorable with respect to this criteria. Alternatives 4 through 6, which all include excavation, transportation, and disposal of CCR material on- and off-site have potential risk for exposure to humans and environmental receptors due to long-term construction and transportation. Alternatives that include hydraulic containment with ex-situ treatment also have a potential risk associated with the generation and management of secondary waste streams and are considered least favorable.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 1 - Subcriteria vi) Potential for exposure of humans and environmental receptors to remaining wastes						

4.2.1.7 Long-term reliability of the engineering and institutional controls

Alternative 4 (CBR with MNA) is expected to have high long-term reliability and is considered most favorable with respect to this criteria. Alternative 1 (CIP with MNA) is considered slightly less reliable due to the long-term maintenance of the cap and cover system. Hydraulic containment (Alternatives 2, 3, 5 and 6) are considered reliable, proven technologies and would have high long-term reliability, but require field pilot studies and bench scale testing and rely on mechanical systems (groundwater pumping and/or treatment systems) to operate and maintain. Alternatives 3 and 6 are considered least favorable with respect to this criteria.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 1 - Subcriteria vii) Long-term reliability of engineering and institutional controls						

4.2.1.8 Potential need for replacement of the remedy

Alternatives 4, 5, and 6, which incorporate closure by removal are considered the most reliable due to the removal of the source of contaminants. Alternative 1, which includes closure in-place with MNA is considered less favorable since it relies on the cap and cover system to reduce infiltration and control the source and natural processes to reduce the concentrations of beryllium, cobalt, and lithium in groundwater. Should monitoring results indicate that the selected remedial alternative is not effective at reducing the concentration of COCs over time, alternate and/or additional active remedial methods for groundwater may be considered in the future. From the perspective of needing to replace the remedy, the alternatives that rely on operating systems (Alternatives 2, 3, 5, and 6) are considered less reliable, with alternatives 3 and 6 being the least reliable due to the O&M of an ex-situ treatment system.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 1 - Subcriteria viii Potential need for replacement of the remedy						

4.2.1.9 Long- and short-term effectiveness and protectiveness criterion summary

The graphic below provides a summary of the long- and short-term effectiveness and protectiveness of the potential remedy, along with the degree of certainty that the remedy will prove successful.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
CATEGORY 1 Long- and Short Term Effectiveness, Protectiveness, and Certainty of Success						

4.2.2 The Effectiveness of the Remedy in Controlling the Source to Reduce Further Releases

This balancing criterion takes into consideration the ability of the remedy to control a future release, and the degree of complexity of treatment technologies that will be required.

4.2.2.1 The extent to which containment practices will reduce further releases

For Alternatives 1-3, the source will be controlled by the construction of a low-permeability cap which will significantly reduce the infiltration of surface water into the pond and therefore decrease the potential for beryllium, cobalt, and lithium to enter groundwater over time. Alternative 1 (CIP with MNA) relies on natural attenuation to decrease the downgradient concentration of the contaminants over time. For alternatives 1 through 3, predictive modeling indicates that Alternative 1 (CIP with MNA) will achieve GWPS in the shortest timeframe. However, if the concentration of beryllium, cobalt, and/or lithium are not decreasing over time additional active remedial options will be considered.

For Alternatives 4-6, the source will be controlled by removing the CCR material from the environment by beneficial use of the CCR material or by placing it in a lined landfill thereby minimizing or eliminating the potential for beryllium, cobalt, and/or lithium to enter groundwater over time. Alternative 4 (CBR with MNA) relies on natural attenuation to decrease the downgradient concentration of the contaminants over time and was shown by predictive modeling to achieve GWPS in the shortest timeframe of the closure by removal alternatives.

Alternatives 2, 3, 5, and 6 rely on hydraulic containment to achieve the performance criteria at the waste boundary addressing beryllium, cobalt, and lithium in groundwater migrating downgradient and are considered less favorable with respect to this criteria. Under Alternatives 2 and 5 pumping system effluent is discharged elsewhere on the property without treatment. Alternatives 3 and 6, which include ex-situ treatment, additional waste streams requiring management on and off site will be generated.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 2 - Subcriteria ii Extent to which containment practices will reduce further releases						

4.2.2.2 *The extent to which treatment technologies may be used*

In-situ groundwater treatment technologies have not been identified that will successfully treat the combination of beryllium, cobalt, and lithium, and as a result in-situ treatment alternatives were not considered in this comparative analysis. With respect to Alternatives 1 and 4, no groundwater treatment technologies, other than natural attenuation will be used. Alternatives 2 and 5 will rely on one technology (hydraulic containment) to address groundwater with the effluent being directly discharge elsewhere on the property. For Alternatives 3 and 6, which include hydraulic containment with ex-situ treatment, two technologies, hydraulic containment and ex-situ treatment, will be utilized. The operation of an ex-situ treatment system will create a secondary waste stream, such as concentrated reject water (from RO) requiring off-site disposal, or depleted resin (from ion exchange), requiring regeneration or off-site disposal.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 2 - Subcriteria iii Extent to which treatment technologies may be used						

4.2.2.3 *Effectiveness of the remedy in controlling the source to reduce further releases summary*

The graphic below provides a summary of the effectiveness of the remedial alternatives to control the source to reduce further releases. Alternatives 1 and 4 (CBR with MNA and CIP with MNA) are the most favorable, while Alternatives 2, 3, 5, and 6 are less favorable.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
CATEGORY 2 Effectiveness in controlling the source to reduce further releases						

4.2.3 The Ease or Difficulty of Implementing a Potential Remedy

This balancing criterion takes into consideration the following technical and logistical challenges required to implement a remedy:

1. Degree of difficulty associated with constructing the technology;
2. Expected operational reliability of the technologies;
3. Need to coordinate with and obtain necessary approvals and permits from other agencies;
4. Availability of necessary equipment and specialists; and
5. Available capacity and location of needed treatment, storage, and disposal services.

4.2.3.1 Degree of difficulty associated with constructing the technology

For Alternative 4 (CBR with MNA), the concept is already proven and in progress at CGS with the on-going beneficial use of reclaimed gypsum and bottom ash from the Cross Bottom Ash Pond, with over 100,000 tons of CCR material being removed each year. To facilitate closure within 5 years, this volume will likely be doubled. For Alternative 1 (CIP with MNA), CCR contained in the Cross Bottom Ash Pond will be addressed by constructing a low-permeability cap which will reduce the infiltration of surface water into the pond and the potential for beryllium, cobalt, and lithium to reach groundwater over time.

Alternatives 2, 3, 5, and 6, which incorporate hydraulic containment, will be more difficult to implement and will require additional treatability testing, field scale pilot studies, and permitting, and Alternatives 3 and 6 will be the most difficult due to the O&M of ex-situ treatment systems.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 3 - Subcriteria i) Degree of difficulty associated with constructing the technology						

4.2.3.2 Expected operational reliability of the technologies

Alternative 4 (CBR with MNA) is considered the most favorable from an operational perspective because removal of the source followed by MNA has a proven track record and only requires long-term monitoring following implementation. Alternative 1 (CIP with MNA) is considered slightly less favorable because it relies on construction and long-term maintenance of the cap and cover system to control the source. While Alternatives 2, 3, 5, and 6, which include hydraulic containment, are also expected to be reliable, these alternatives will utilize additional groundwater treatment technologies which will require treatability studies and operations and maintenance and therefore are considered the least favorable when compared to the other alternatives.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 3 - Subcriteria ii) Expected operational reliability of the technologies						

4.2.3.3 Need to coordinate with and obtain necessary approvals and permits from other agencies

Alternative 4 (CBR with MNA) is the most favorable since the implementation of the remedy is straightforward and only includes MNA. The remaining alternatives will require additional extensive permitting and approvals for treatability testing, field scale pilot testing, groundwater discharge, groundwater treatment, and disposal of secondary waste streams. Alternatives 1 through 3, which include CIP, are considered the least favorable due to the lack of separation between CCR materials and groundwater and the uncertainty associated with obtaining permit approval from SC DHEC.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 3 - Subcriteria iii) Need to coordinate with and obtain necessary approvals and permits from other agencies						

4.2.3.4 Availability of necessary equipment and specialists

Alternative 1 (CIP with capping and MNA) and Alternative 4 (CBR with MNA) are the most favorable since specialty equipment and specialists will not be required to implement the MNA remedy. Alternatives 2 and 5 will require equipment for pumping and are less favorable than Alternatives 1 and 4 but equipment required should not present great challenge. Alternatives 3 and 6 which include an ex-situ treatment component are the least favorable since they will require construction, operation, and maintenance of ex-situ treatment systems.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 3 - Subcriteria iv) Availability of necessary equipment and specialists						

4.2.3.5 Available capacity and location of needed treatment, storage, and disposal services

Alternatives 4, 5, and 6 which include closure by removal require adequate capacity, storage, and disposal service for on-site and off-site receiving facilities. This will be addressed through the beneficial use of CCR combined with both on- and off-site disposal of CCR and liner and revetment materials. The 1.5 million cubic yards of CCR will be excavated and hauled to the onsite Class III Landfill. Additionally, the ex-situ treatment system may generate a concentrated waste stream which would require onsite treatment or off-site transportation and disposal that the other alternatives would not require and is therefore considered the least favorable.

Except for Alternatives 3 and 6, which include hydraulic containment with ex-situ treatment the remaining alternatives would not generate a waste stream and therefore would not require treatment, storage, or disposal services. For Alternatives 3 and 6, the ex-situ treatment system may generate a concentrated waste stream which would require off-site transportation and disposal that the other alternatives would not require and are therefore considered the least favorable.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treament
Category 3 - Subcriteria v) Available capacity and location of needed treatment, storage, and disposal services						

4.2.3.6 Ease or difficulty of implementation summary

The graphic below provides a summary of the ease or difficulty that will be needed to implement each alternative. Alternative 1 (CIP with capping and MNA) and Alternative 4 (CBR with MNA) are considered the most favorable, while the remaining alternatives that include a hydraulic containment component are considered less favorable with alternative 3 being the least favorable.

	Alternative 1 Cap with CIP & MNA	**Alternative 2** Cap with CIP & Hydraulic Containment & Direct Discharge	**Alternative 3** Cap with CIP & Hydraulic Containment & Ex-Situ Treatment	**Alternative 4** CBR with MNA	**Alternative 5** CBR with Hydraulic Containment & Direct Discharge	**Alternative 6** CBR with Hydraulic Containment & Ex-Situ Treatment
CATEGORY 3 Ease of implementation						

HALEY ALDRICH

5. Summary

This CMA has evaluated the following alternatives:

- Alternative 1: CIP with capping and MNA
- Alternative 2: CIP with capping and hydraulic containment through groundwater pumping and direct discharge;
- Alternative 3: CIP with capping and hydraulic containment through groundwater pumping and ex-situ treatment;
- Alternative 4: CBR with MNA;
- Alternative 5: CBR with hydraulic containment through groundwater pumping and direct discharge; and
- Alternative 6: CBR with hydraulic containment through groundwater pumping and ex-situ treatment

In accordance with §257.97, each of these alternatives has been evaluated in the context of the following threshold criteria:

- Protect human health and the environment;
- Attain the GWPS;
- Control the source(s) of releases to reduce or eliminate, to the maximum extent feasible, further releases of COCs to the environment;
- Remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, considering factors such as avoiding inappropriate disturbance of sensitive ecosystems; and,
- Comply with standards (regulations) for waste management.

In addition, in accordance with §257.96, each of the alternatives has been evaluated in the context of the following balancing criteria:

- The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to residual contamination;
- The time required to complete the remedy; and,
- The institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy.

This CMA, and the input received during the public comment period, will be used to select a final corrective measure for implementation at the Bottom Ash Pond.

References

1. USEPA. 2015a. Final Rule: Disposal of Coal Combustion Residuals (CCRs) for Electric Utilities. 80 FR 21301-21501. U.S. Environmental Protection Agency, Washington, D.C. Available at: https://www.govinfo.gov/content/pkg/FR-2015-04-17/pdf/2015-00257.pdf

2. USEPA. 2015b. Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites.

3. USEPA. 2018a. USEPA Regional Screening Levels. November 2018, values for tap water. U.S. Environmental Protection Agency. Available at: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

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TABLES

TABLE 1
DETECTION MONITORING ANALYTICAL RESULTS
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

			Chemical Group	Detection Monitoring - EPA Appendix III Constituents						Field Parameters				
			Chemical Name	Boron, Total	Calcium, Total	Chloride	Fluoride	Sulfate	Total Dissolved Solids (TDS)	Dissolved Oxygen	ORP	pH	Temperature	Turbidity
			MCL/RSL	-	-	-	4	-	-	-	-	-	-	-
			Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mv	pH units	Deg C	NTU
Impound-ment	**Location**	**Sample Date**	**Sample Type**											
Background	CBW-1	10/19/2015	N	**0.032**	**27**	**3.21**	**0.25**	**81.5**	**150**	**0.91**	**340**	**4.45**	**21.29**	**291**
Background	CBW-1	01/26/2016	N	**0.0218**	**27**	**2.95**	**0.3**	**88.2**	**120**	**0.8**	**346**	**4.12**	**17.01**	**7.9**
Background	CBW-1	04/19/2016	N	**0.0183**	**29.4**	**2.33**	**0.29**	**86**	**120**	**0.5**	**146**	**4.33**	**18.72**	**0**
Background	CBW-1	07/18/2016	N	**0.0217**	**28.7**	**2.95**	**0.27**	**90.1**	**132**	**0.84**	**64**	**4.38**	**22.89**	**0**
Background	CBW-1	10/11/2016	N	**0.0302**	**22.7**	**3**	**0.28**	**73.7**	**151.7**	**1.08**	**98**	**4.14**	**19.9**	**1.9**
Background	CBW-1	01/23/2017	N	**0.0249**	**26.2**	**2.45**	**0.25**	**77.7**	**148**	**0.81**	**150**	**4.32**	**16.58**	**1.3**
Background	CBW-1	04/17/2017	N	**0.018**	**25.6**	**2.96**	**0.22**	**71.2**	**62**	**0.72**	**248**	**4.26**	**22.55**	**2.8**
Background	CBW-1	07/25/2017	N	**0.022**	-	**2.61**	-	**73.3**	**92**	**3.52**	**75**	**4.21**	**24.41**	**0**
Background	CBW-1	09/25/2017	N	**0.024**	**21.9**	**2.51**	**0.23**	**74.5**	< 40	**0.76**	**142**	**4.32**	**25.07**	**41.3**
Background	CBW-1	10/09/2017	N	**0.023**	**23**	**2.73**	**0.22**	**76.8**	**115**	**0.83**	**111**	**4.25**	**25.04**	**0**
Background	PM-1	01/26/2015	N	-	-	-	-	-	**142.5**	**0.47**	**117**	**4.53**	**17.13**	**0**
Background	PM-1	02/16/2015	N	-	-	-	-	-	**106.2**	-	**74**	**4.68**	**14.88**	**26.5**
Background	PM-1	06/16/2015	N	-	-	-	-	-	**158**	-	**63**	**4.74**	**21.8**	**3.7**
Background	PM-1	07/06/2015	N	-	-	-	-	-	**151**	-	-	**5.25**	**23.05**	**0.4**
Background	PM-1	10/19/2015	N	**0.0178**	**26**	**12.7**	< 0.1	**26.5**	**206**	**1.33**	**20**	**5.47**	**20.94**	**19**
Background	PM-1	01/26/2016	N	< 0.015	**27**	**11.3**	< 0.1	**25.5**	**165**	**1.2**	**65**	**5.2**	**15.83**	**22.3**
Background	PM-1	04/19/2016	N	< 0.015	**23.3**	**12.1**	< 0.1	**20.2**	**130**	**0.52**	**81**	**5.32**	**18.9**	**0**
Background	PM-1	07/18/2016	N	**0.0163**	**18.8**	**13.2**	< 0.1	**16**	**124**	**0.97**	**61**	**5.2**	**24.19**	**0**
Background	PM-1	10/11/2016	N	**0.0165**	**16.4**	**12.8**	< 0.1	**19.3**	**200**	**1.37**	**54**	**5.01**	**19.75**	**2.2**
Background	PM-1	01/23/2017	N	< 0.015	**10.4**	**13.5**	< 0.1	**8.82**	**138**	**0.9**	**87**	**5.01**	**15.45**	**1.9**
Background	PM-1	04/17/2017	N	**0.019**	**12.5**	**12.7**	< 0.1	**9.71**	**56**	**0.85**	**84**	**5.19**	**21.17**	**1.4**
Background	PM-1	07/12/2017	N	-	**18.5**	**12.1**	-	**11.1**	**108**	**0.87**	**89**	**5.11**	**27.03**	**0**
Background	PM-1	08/31/2017	RS	< 0.015	-	-	-	-	-	**0.8**	**96**	**5.17**	**25.04**	**1.1**
Background	PM-1	09/25/2017	N	**0.018**	**15.4**	**13.3**	< 0.1	**8.03**	< 40	**0.92**	**92**	**5.27**	**24.37**	**0**
Background	PM-1	10/09/2017	N	**0.021**	**17**	**12.6**	< 0.1	**8.77**	**80**	**1.13**	**66**	**5.21**	**24.3**	**1.6**
AshPond	CAP-1	10/21/2015	N	**0.261**	**380**	**261**	**0.46**	**650**	**1858**	**0.47**	**-2**	**5.26**	**22.06**	**0**
AshPond	CAP-1	10/21/2015	FD	**0.274**	**360**	**262**	**0.44**	**654**	**1870**	-	-	-	-	-
AshPond	CAP-1	01/25/2016	N	**0.0713**	**140**	**86.5**	**0.16**	**262**	**792.5**	**1.16**	**-32**	**6.1**	**15.39**	**8.6**
AshPond	CAP-1	01/25/2016	FD	**0.0869**	**160**	**113**	**0.19**	**300**	**925**	-	-	-	-	-
AshPond	CAP-1	04/19/2016	N	**0.159**	**368**	**236**	**0.36**	**633**	**1687**	**0.38**	**108**	**5.46**	**20.04**	**0**
AshPond	CAP-1	07/18/2016	N	**0.33**	**284**	**220**	< 0.1	**516**	**1400**	**0.61**	**83**	**5.13**	**28.12**	**0**
AshPond	CAP-1	10/12/2016	N	**0.298**	**287**	**91**	**0.79**	**232**	**1560**	**0.56**	**-58**	**5.24**	**26.92**	**0**
AshPond	CAP-1	01/26/2017	N	**0.24**	**145**	**104**	**0.69**	**301**	**804**	**0.58**	**47**	**5.71**	**18.09**	**0**
AshPond	CAP-1	04/17/2017	N	**0.28**	**334**	**229**	**0.66**	**607**	**1444**	**0.86**	**56**	**5.37**	**19.74**	**0.7**
AshPond	CAP-1	07/12/2017	N	-	**177**	**157**	-	**333**	**880**	**1.03**	**104**	**5.14**	**27.07**	**8.8**
AshPond	CAP-1	09/27/2017	N	**0.42**	**161**	**160**	**1.4**	**373**	**782**	**0.89**	**61**	**5.2**	**24.33**	**6.1**
AshPond	CAP-1	10/09/2017	N	**0.4**	**300**	**247**	**0.95**	**693**	**1415**	**2.46**	**118**	**4.65**	**26.62**	**0**
AshPond	CAP-3	10/19/2015	N	**8.4**	**650**	**722**	**0.13**	**890**	**3654**	**0.46**	**75**	**6.24**	**24.17**	**0**
AshPond	CAP-3	10/19/2015	FD	**7.98**	**670**	**706**	**0.13**	**861**	**3516**	-	-	-	-	-
AshPond	CAP-3	01/25/2016	N	**6.98**	**670**	**1190**	**0.13**	**1630**	**3122**	**0.84**	**78**	**6.39**	**20.04**	**9.8**
AshPond	CAP-3	04/19/2016	N	**6.97**	**764**	**727**	< 0.1	**922**	**3555**	**0.46**	**104**	**6.35**	**22.74**	**0**
AshPond	CAP-3	07/18/2016	N	**7.21**	**715**	**702**	< 0.1	**863**	**2898**	**0.57**	**106**	**6.21**	**24.73**	**0**
AshPond	CAP-3	10/12/2016	N	**3.51**	**430**	**512**	< 0.1	**630**	**2518**	**0.73**	**219**	**6.08**	**21.55**	**0**
AshPond	CAP-3	01/26/2017	N	**8.44**	**697**	**726**	**0.1**	**929**	**3020**	**0.68**	**112**	**6.28**	**18**	**10**
AshPond	CAP-3	03/01/2017	N	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-3	04/18/2017	N	**7.5**	**736**	**688**	< 0.1	**890**	**3152**	**0.79**	**177**	**6.25**	**24.2**	**0.5**
AshPond	CAP-3	07/24/2017	N	-	**655**	**746**	-	**966**	**3110**	**0.61**	**51**	**6.31**	**27.02**	**0**
AshPond	CAP-3	09/27/2017	N	**6.7**	**631**	**617**	< 0.1	**869**	**2788**	**0.64**	**131**	**6.2**	**27.88**	**0**
AshPond	CAP-3	10/10/2017	N	**8.1**	**710**	**707**	**0.11**	**1030**	**3550**	**0.84**	**72**	**6.49**	**23.02**	**2.3**
AshPond	CAP-5	10/21/2015	N	< 0.015	**130**	**359**	**0.25**	**4.99**	**1088**	**1.05**	**131**	**4.86**	**21.3**	**0**
AshPond	CAP-5	01/25/2016	N	**0.0154**	**110**	**447**	**0.36**	< 2	**915**	**0.98**	**353**	**3.85**	**19.52**	**0**
AshPond	CAP-5	04/19/2016	N	< 0.015	**125**	**490**	**0.6**	< 2	**1048**	**0.49**	**299**	**3.93**	**21.24**	**0**
AshPond	CAP-5	07/19/2016	N	< 0.015	**124**	**489**	**0.54**	< 2	**1094**	**0.97**	**245**	**3.83**	**26.07**	**0**
AshPond	CAP-5	10/11/2016	N	< 0.015	**121**	**468**	**0.44**	**10.8**	**1095**	**1.08**	**216**	**4**	**20.77**	**2**
AshPond	CAP-5	01/26/2017	N	**0.044**	**129**	**517**	**0.55**	< 2	**856**	**0.49**	**322**	**3.85**	**18.53**	**0**
AshPond	CAP-5	03/01/2017	N	-	-	-	-	-	-	-	-	-	-	-

TABLE 1
DETECTION MONITORING ANALYTICAL RESULTS
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

			Chemical Group	Detection Monitoring - EPA Appendix III Constituents						Field Parameters				
			Chemical Name	Boron, Total	Calcium, Total	Chloride	Fluoride	Sulfate	Total Dissolved Solids (TDS)	Dissolved Oxygen	ORP	pH	Temperature	Turbidity
			MCL/RSL	-	-	-	4	-	-	-	-	-	-	-
			Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mv	pH units	Deg C	NTU
Impound-ment	**Location**	**Sample Date**	**Sample Type**											
AshPond	CAP-5	04/18/2017	N	< 0.015	136	523	0.52	< 2	1054	0.7	295	3.9	21.45	0
AshPond	CAP-5	07/24/2017	N	-	130	527	-	< 2	1170	0.81	128	3.81	21.8	3.9
AshPond	CAP-5	09/27/2017	N	< 0.015	134	546	0.57	< 2	1046	0.73	286	3.85	25.12	0
AshPond	CAP-5	10/10/2017	N	< 0.015	150	552	0.57	< 2	1293	0.64	159	4.06	25.14	0
AshPond	CAP-7	10/21/2015	N	20.7	780	1440	0.12	1910	5026	1.12	102	5.29	23.36	0
AshPond	CAP-7	01/25/2016	N	19.4	770	1390	0.15	2020	4795	0.92	78	5.42	19.3	8.7
AshPond	CAP-7	04/19/2016	N	17.2	888	1340	< 0.1	1890	5033	0.4	109	5.32	20.72	0
AshPond	CAP-7	07/19/2016	N	22.1	856	1520	< 0.1	2050	4882	0.67	72	5.49	31.55	2.8
AshPond	CAP-7	10/11/2016	N	20.3	901	1510	0.16	1960	5282	0.81	83	5.39	22.34	0
AshPond	CAP-7	01/26/2017	N	20.8	830	1390	< 0.1	1850	4782	0.66	110	5.37	19.04	0
AshPond	CAP-7	03/01/2017	N	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-7	04/19/2017	N	20	900	1450	< 0.1	1820	4920	0.91	114	5.4	20.26	0
AshPond	CAP-7	07/12/2017	N	-	855	1560	-	2000	4660	1.05	126	5.41	28.87	0
AshPond	CAP-7	09/27/2017	N	24	836	1510	< 0.1	1960	4818	1.19	121	5.28	27.59	0
AshPond	CAP-7	10/10/2017	N	24	880	1610	0.15	2200	5083	0.68	100	5.41	25.42	0
AshPond	CAP-9	10/21/2015	N	4.46	430	1080	1.6	281	3192	0.92	313	3.71	24.11	0
AshPond	CAP-9	01/25/2016	N	4.83	410	1030	1.41	284	2498	0.98	430	3.31	19.33	7.8
AshPond	CAP-9	04/19/2016	N	4.21	459	1020	2.21	279	2905	0.48	345	3.55	22.57	0
AshPond	CAP-9	04/19/2016	FD	3.98	464	1010	2.27	280	2875	-	-	-	-	-
AshPond	CAP-9	07/19/2016	N	5.2	500	1080	1.93	345	2990	0.67	316	3.76	28.22	0
AshPond	CAP-9	07/19/2016	FD	5.08	495	1090	2	351	2815	-	-	-	-	-
AshPond	CAP-9	10/11/2016	N	5.24	432	1010	1.8	327	2900	0.96	271	3.71	21.93	3.8
AshPond	CAP-9	10/11/2016	FD	4.59	424	1020	1.75	313	2728	-	-	-	-	-
AshPond	CAP-9	01/26/2017	N	4.94	454	1010	2.25	333	2358	0.55	421	3.25	19.95	0
AshPond	CAP-9	01/26/2017	FD	5.13	457	1010	2.22	327	2406	-	-	-	-	-
AshPond	CAP-9	03/01/2017	N	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-9	03/01/2017	FD	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-9	04/19/2017	N	5.6	497	1020	2.16	358	3074	0.61	324	3.67	21.77	0
AshPond	CAP-9	04/19/2017	FD	5.6	484	1030	2.33	349	3032	-	-	-	-	-
AshPond	CAP-9	07/12/2017	N	-	489	1000	-	417	2526	0.84	303	3.88	30.4	0
AshPond	CAP-9	09/27/2017	N	6.3	469	1160	4.4	498	2806	0.63	276	3.76	27.37	0.5
AshPond	CAP-9	09/27/2017	FD	6	470	1160	3.1	452	2830	-	-	-	-	-
AshPond	CAP-9	10/10/2017	N	6.2	490	1090	3.92	485	3013	0.63	253	3.92	25.64	0
AshPond	CAP-9	10/10/2017	FD	6.5	520	1070	3.9	452	3155	-	-	-	-	-

ABBREVIATIONS AND NOTES:
mg/L: milligram per liter
uS/cm: microSiemen per centimeter
mv: millivolt
NTU: Nephelometric Turbidity Units
< 0.005: Analyte not detected above detection limit
-: Not Analyzed
MCL/RSL: The applicable Maximum Contaminant Level (MCL) or Regional Screening Level (RSL) is shown. Dashed where a standard is not provided.
FD: Field duplicate
RS: Resample
-Highlighted where a result exceeds the applicable MCL/RSL.

- Criteria used for cobalt, lithium, and molybdenum are RSL for Tapwater where THQ=1.0 (May 2018)
- USEPA. 2016. Final Rule: Disposal of Coal Combustion Residuals from
  Electric Utilities. July 26. 40 CFR Part 257.
  https://www.epa.gov/coalash/coal-ash-rule

TABLE 2
ASSESSMENT MONITORING ANALYTICAL RESULTS
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

			Chemical Group	Assessment Monitoring - EPA Appendix IV Constituents														Radiological		
			Chemical Name	Antimony, Total	Arsenic, Total	Barium, Total	Beryllium, Total	Cadmium, Total	Chromium, Total	Cobalt, Total	Fluoride	Lead, Total	Lithium, Total	Mercury, Total	Molybdenum, Total	Selenium, Total	Thallium, Total	Radium-226	Radium-228	Radium-226 & 228
			MCL/RSL	0.006	0.01	2	0.004	0.005	0.1	0.006	4	0.015	0.04	0.002	0.1	0.05	0.002	-	-	5
			Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pCi/L	pCi/L	pCi/L
Impound-ment	**Location**	**Sample Date**	**Sample Type**																	
Background	CBW-1	02/07/2018	N	< 0.005	< 0.005	0.0436	< 0.0005	< 0.0005	< 0.005	0.00088	0.19	0.0027	< 0.01	< 0.0002	< 0.01	< 0.01	< 0.001	1 U	3 U	4 U
Background	CBW-1	06/20/2018	N	< 0.025	< 0.005	0.043	< 0.0005	< 0.0005	< 0.005	0.001	0.2	0.003	< 0.01	< 0.0002	< 0.01	< 0.01	< 0.001	1 U	3 U	4 U
Background	CBW-1	10/01/2018	N	-	< 0.005	0.0428	< 0.0005	-	-	0.00076	0.19	0.0031	< 0.01	< 0.0002	-	< 0.01	-	2.11	3 U	5.11 J
Background	CBW-1	11/29/2018	RS	-	-	-	-	-	-	-	-	-	-	< 0.0002	-	-	-	-	-	-
Background	CBW-1	02/12/2019	N	< 0.005	< 0.005	0.0427	-	< 0.0005	< 0.005	0.00084	0.18	0.0025	< 0.01	< 0.0002	< 0.01	< 0.01	< 0.001	1 U	3 U	0.346
Background	PM-1	02/07/2018	N	< 0.005	< 0.005	0.0756	< 0.0005	< 0.0005	< 0.005	0.00089	< 0.1	< 0.001	< 0.01	< 0.0002	< 0.01	< 0.01	< 0.001	1 U	3 U	4 U
Background	PM-1	06/20/2018	N	< 0.025	< 0.005	0.103	< 0.0005	< 0.0005	< 0.005	0.001	< 0.1	< 0.001	< 0.01	< 0.0002	< 0.01	< 0.01	< 0.001	4.09	3 U	7.09 J
Background	PM-1	10/01/2018	N	-	< 0.005	0.0769	< 0.0005	-	-	0.00084	< 0.1	< 0.001	< 0.01	< 0.0002	-	< 0.01	-	13.3	3 U	16.3 J
Background	PM-1	11/29/2018	RS	-	-	-	-	-	-	-	-	-	-	< 0.0002	-	-	-	-	-	-
Background	PM-1	02/12/2019	N	< 0.005	< 0.005	0.0817	< 0.0005	< 0.0005	< 0.005	0.00091	< 0.1	< 0.001	< 0.01	< 0.0002	< 0.01	< 0.01	< 0.001	1 U	3 U	0.585
AshPond	CAP-1	02/21/2018	N	-	< 0.005	0.042	-	< 0.0005	< 0.005	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-1	06/26/2018	N	< 0.025	< 0.005	0.033	0.01	< 0.0005	< 0.005	0.024	0.63	< 0.001	0.13	< 0.0002	< 0.01	< 0.01	< 0.001	2.14	3 U	5.14 J
AshPond	CAP-1	10/02/2018	N	-	< 0.005	0.0442	0.0062	-	-	0.0187	1.97	0.0018	0.11	-	-	< 0.01	-	2.24	3 U	5.24 J
AshPond	CAP-1	10/02/2018	FD	-	< 0.005	0.0406	0.0059	-	-	0.02	1.82	0.0011	0.12	-	-	< 0.01	-	3.97	3 U	6.97 J
AshPond	CAP-1	02/14/2019	N	< 0.005	< 0.005	0.0543	0.0067	< 0.0005	< 0.005	0.0172	1.74	< 0.001	0.078	< 0.0002	< 0.01	< 0.01	< 0.001	1 U	3 U	2.1
AshPond	CAP-3	02/27/2018	N	-	< 0.005	0.237	-	< 0.0005	< 0.005	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-3	06/20/2018	N	< 0.025	< 0.005	0.069	< 0.0005	< 0.0005	< 0.005	0.026	0.12	< 0.001	0.011	< 0.0002	< 0.01	< 0.01	< 0.001	0.868	3 U	3.868 J
AshPond	CAP-3	10/01/2018	N	-	< 0.005	0.0761	< 0.0005	-	-	0.0251	< 0.1	< 0.001	< 0.01	-	-	< 0.01	-	1 U	3 U	4 U
AshPond	CAP-3	02/14/2019	N	< 0.005	< 0.005	0.0852	< 0.0005	< 0.0005	< 0.005	0.0267	< 0.1	< 0.001	0.011	< 0.0002	< 0.01	< 0.01	< 0.001	1 U	3 U	2.14
AshPond	CAP-5	02/26/2018	N	-	< 0.005	1.43	-	< 0.0005	< 0.005	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-5	06/25/2018	N	< 0.025	< 0.005	1.43	0.005	< 0.0005	< 0.005	0.013	0.1	0.007	0.012	< 0.0002	< 0.01	< 0.01	< 0.001	6.71	10.8	17.51
AshPond	CAP-5	10/01/2018	N	-	< 0.005	1.29	0.0035	-	-	0.0124	0.54	0.008	0.012	-	-	< 0.01	-	8.46	4.05	12.51
AshPond	CAP-5	02/18/2019	N	< 0.005	< 0.005	1.49	0.0046	< 0.0005	< 0.005	0.0155	0.63	0.0053	0.012	< 0.0002	< 0.01	< 0.01	< 0.001	4.09	10.5	14.6
AshPond	CAP-7	02/26/2018	N	-	< 0.005	0.0287	-	< 0.0005	< 0.005	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-7	06/25/2018	N	< 0.025	< 0.005	0.031	< 0.0005	< 0.0005	< 0.005	0.009	< 0.1	< 0.001	< 0.01	< 0.0002	< 0.01	< 0.01	< 0.001	3.56	3 U	6.56 J
AshPond	CAP-7	10/01/2018	N	-	0.0052	0.0363	< 0.0005	-	-	0.0102	0.11	< 0.01	< 0.01	-	-	< 0.01	-	2.99	3 U	5.99 J
AshPond	CAP-7	02/18/2019	N	< 0.005	< 0.005	0.0312	< 0.0005	< 0.0005	< 0.005	0.0095	< 0.1	< 0.001	< 0.01	< 0.0002	< 0.01	< 0.01	< 0.001	1 U	3.05	3.72
AshPond	CAP-9	02/22/2018	N	-	0.0067	0.048	-	< 0.0005	< 0.005	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-9	06/25/2018	N	< 0.025	0.006	0.041	0.018	< 0.0005	< 0.005	0.038	0.5	0.009	0.061	< 0.0002	< 0.01	0.031	< 0.001	1 U	3.81	4.81 J
AshPond	CAP-9	06/25/2018	FD	< 0.025	0.006	0.042	0.018	< 0.0005	< 0.005	0.037	1.43	0.009	0.06	< 0.0002	< 0.01	0.028	< 0.001	1 U	3 U	4 U
AshPond	CAP-9	10/01/2018	N	-	0.0103	0.061	0.0123	-	-	0.036	2.62	0.0137	0.062	-	-	< 0.01	-	4.31	3 U	7.31 J
AshPond	CAP-9	02/18/2019	N	< 0.005	0.0056	0.0161	0.0152	< 0.0005	< 0.005	0.0169	3.56	0.0032	0.056	< 0.0002	< 0.04	< 0.01	< 0.001	1 U	3 U	1.19
AshPond	CAP-9	02/18/2019	FD	< 0.005	0.0055	0.0508	0.015	< 0.0005	< 0.005	0.0365	3.53	0.0123	0.056	< 0.0002	< 0.04	< 0.01	< 0.001	1 U	2.77	3.25

ABBREVIATIONS AND NOTES:
mg/L: milligram per liter
uS/cm: microSiemen per centimeter
mv: millivolt
NTU: Nephelometric Turbidity Units
pCi/L: picoCurie per liter
< 0.005: Analyte not detected above detection limit
-: Not Analyzed
MCL/RSL: The applicable Maximum Contaminant Level (MCL) or Regional Screening Level (RSL) is shown. Dashed where a standard is not provided.
FD: Field duplicate
RS: Resample
Highlighted where a result exceeds the applicable MCL/RSL

QUALIFIERS:
U: Not detected, value is the laboratory reporting limit
J: Estimated result

- Criteria used for cobalt, lithium, and molybdenum are RSL for Tapwater where THQ=1.0 (May 2018)
- USEPA. 2016. Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities. July 26. 40 CFR Part 257. https://www.epa.gov/coalash/coal-ash-rule

TABLE 2
ASSESSMENT MONITORING ANALYTICAL RESULTS
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

			Chemical Group	Field Parameters					
			Chemical Name	Conductivity	Dissolved Oxygen	ORP	pH	Temperature	Turbidity
			MCL/RSL	-	-	-	-	-	-
			Units	uS/cm	mg/L	mv	pH units	Deg C	NTU
Impound-ment	**Location**	**Sample Date**	**Sample Type**						
Background	CBW-1	02/07/2018	N	199	0.93	138	4.42	19.15	0.9
Background	CBW-1	06/20/2018	N	196	0.85	105	4.32	22.69	1.9
Background	CBW-1	10/01/2018	N	196	0.92	127	4.09	23.78	0
Background	CBW-1	11/29/2018	RS	-	-	-	-	-	-
Background	CBW-1	02/12/2019	N	202	0.99	111	4.5	18.04	0.5
Background	PM-1	02/07/2018	N	188	1.09	85	5.29	17.02	1
Background	PM-1	06/20/2018	N	279	0.81	123	5.58	23.54	1.6
Background	PM-1	10/01/2018	N	201	0.99	104	5.08	25.31	0
Background	PM-1	11/29/2018	RS	-	-	-	-	-	-
Background	PM-1	02/12/2019	N	191	0.92	78	5.47	17.02	9.4
AshPond	CAP-1	02/21/2018	N	1500	0.82	88	5.1	22.74	9.3
AshPond	CAP-1	06/26/2018	N	1920	0.52	111	4.62	27.58	8.9
AshPond	CAP-1	10/02/2018	N	1480	0.97	133	4.86	23.71	7.3
AshPond	CAP-1	10/02/2018	FD	-	-	-	-	-	-
AshPond	CAP-1	02/14/2019	N	1910	0.76	64	5.25	17.52	0
AshPond	CAP-3	02/27/2018	N	1300	1.03	1	6.15	18.01	7.3
AshPond	CAP-3	06/20/2018	N	3140	0.62	87	6.28	29.71	0
AshPond	CAP-3	10/01/2018	N	3400	0.76	100	5.97	26.67	0
AshPond	CAP-3	02/14/2019	N	1470	1.61	43	6.23	19.55	4.7
AshPond	CAP-5	02/26/2018	N	1900	0.69	270	3.9	18.84	0
AshPond	CAP-5	06/25/2018	N	1750	0.63	74	3.95	23.95	0
AshPond	CAP-5	10/01/2018	N	1720	0.69	228	3.72	29.4	0
AshPond	CAP-5	02/18/2019	N	2020	0.9	258	3.93	18.99	0
AshPond	CAP-7	02/26/2018	N	670	0.97	110	5.39	18.97	1.6
AshPond	CAP-7	06/25/2018	N	6480	0.67	90	5.48	26.18	0
AshPond	CAP-7	10/01/2018	N	6560	0.78	127	5.08	25.52	0
AshPond	CAP-7	02/18/2019	N	6890	0.81	90	5.5	19.03	0
AshPond	CAP-9	02/22/2018	N	3990	0.71	335	3.58	23.15	0
AshPond	CAP-9	06/25/2018	N	3770	0.57	175	3.92	28.16	7.1
AshPond	CAP-9	06/25/2018	FD	-	-	-	6.89	-	-
AshPond	CAP-9	10/01/2018	N	4080	0.87	281	3.46	25.84	0
AshPond	CAP-9	02/18/2019	N	4080	0.86	297	3.65	19.43	0
AshPond	CAP-9	02/18/2019	FD	-	-	-	-	-	-

ABBREVIATIONS AND NOTES:
mg/L: milligram per liter
uS/cm: microSiemen per centimeter
mv: millivolt
NTU: Nephelometric Turbidity Units
pCi/L: picoCurie per liter
< 0.005: Analyte not detected above detection limit
-: Not Analyzed
MCL/RSL: The applicable Maximum Contaminant Level (MCL) or Regional Screening Level (RSL) is shown. Dashed where a standard is not provided.
FD: Field duplicate
RS: Resample
-Highlighted where a result exceeds the applicable MCL/RSL

QUALIFIERS:
U: Not detected, value is the laboratory reporting limit
J: Estimated result

- Criteria used for cobalt, lithium, and molybdenum are RSL for Tapwater where THQ=1.0 (May 2018)
- USEPA. 2016. Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities. July 26. 40 CFR Part 257. https://www.epa.gov/coalash/coal-ash-rule

TABLE 3
SUMMARY OF GROUNDWATER MEASUREMENTS
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

Location	Measurement Date	Depth to Water	Groundwater Elevation
CBW-1	10/19/2015	7.78	78.02
CBW-1	1/26/2016	8.11	77.69
CBW-1	4/19/2016	9.13	76.67
CBW-1	7/18/2016	10.67	75.13
CBW-1	10/11/2016	7.32	78.48
CBW-1	1/23/2017	8.33	77.47
CBW-1	4/17/2017	8.90	76.90
CBW-1	7/25/2017	8.99	76.81
CBW-1	9/25/2017	8.80	77.00
CBW-1	10/9/2017	9.73	76.07
CBW-1	2/7/2018	9.80	76.00
CBW-1	6/20/2018	10.35	75.45
CBW-1	10/1/2018	10.51	75.29
CBW-1	2/12/2019	8.66	77.14
CBW-1	5/20/2019	8.66	77.14
PM-1	1/26/2015	7.25	75.99
PM-1	2/16/2015	7.60	75.64
PM-1	6/16/2015	7.92	75.32
PM-1	7/6/2015	8.45	74.79
PM-1	10/19/2015	7.42	75.82
PM-1	1/26/2016	7.03	76.21
PM-1	4/19/2016	7.62	75.62
PM-1	7/18/2016	8.36	74.88
PM-1	10/11/2016	7.10	76.14
PM-1	1/23/2017	7.16	76.08
PM-1	4/17/2017	7.48	75.76
PM-1	7/12/2017	7.58	75.66
PM-1	8/31/2017	7.11	76.13
PM-1	9/25/2017	7.81	75.43
PM-1	10/9/2017	8.42	74.82
PM-1	2/7/2018	7.91	75.33
PM-1	6/20/2018	8.88	74.36
PM-1	10/1/2018	8.01	75.23
PM-1	2/12/2019	7.32	75.92
PM-1	5/20/2019	8.52	74.72
CAP-1	1/26/2015	5.07	77.63
CAP-1	7/6/2015	6.81	75.89
CAP-1	10/21/2015	5.28	77.42
CAP-1	1/25/2016	5.15	77.55
CAP-1	4/19/2016	5.50	77.20
CAP-1	7/18/2016	7.92	74.78
CAP-1	10/12/2016	4.77	77.93
CAP-1	1/26/2017	5.24	77.46
CAP-1	4/17/2017	5.49	77.21
CAP-1	7/12/2017	7.14	75.56
CAP-1	9/27/2017	5.77	76.93
CAP-1	10/9/2017	6.30	76.40
CAP-1	2/21/2018	5.97	76.73
CAP-1	6/26/2018	6.65	70.05
CAP-1	10/2/2018	6.56	76.14
CAP-1	2/14/2019	5.40	77.30
CAP-1	5/21/2019	6.78	75.92
CAP-3	1/28/2015	14.71	76.78
CAP-3	7/8/2015	16.23	75.26
CAP-3	10/19/2015	14.48	77.01
CAP-3	1/25/2016	14.35	77.14
CAP-3	4/19/2016	14.70	76.79

TABLE 3
SUMMARY OF GROUNDWATER MEASUREMENTS
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

Location	Measurement Date	Depth to Water	Groundwater Elevation
CAP-3	7/18/2016	16.17	75.32
CAP-3	10/12/2016	14.09	77.40
CAP-3	1/26/2017	14.45	77.04
CAP-3	3/1/2017	14.79	76.70
CAP-3	4/18/2017	14.61	76.88
CAP-3	7/24/2017	15.11	76.38
CAP-3	9/27/2017	14.82	76.67
CAP-3	10/10/2017	15.61	75.88
CAP-3	2/27/2018	15.41	76.08
CAP-3	6/20/2018	15.75	75.74
CAP-3	10/1/2018	16.04	75.45
CAP-3	2/14/2019	14.39	77.10
CAP-3	5/21/2019	16.05	75.44
CAP-5	1/27/2015	14.42	77.36
CAP-5	7/7/2015	17.86	73.92
CAP-5	10/21/2015	14.83	76.95
CAP-5	1/25/2016	14.46	77.32
CAP-5	4/19/2016	15.21	76.57
CAP-5	7/19/2016	18.04	73.74
CAP-5	10/11/2016	14.26	77.52
CAP-5	1/26/2017	14.57	77.21
CAP-5	3/1/2017	15.23	76.55
CAP-5	4/18/2017	15.11	76.67
CAP-5	7/24/2017	16.51	75.27
CAP-5	9/27/2017	15.71	76.07
CAP-5	10/10/2017	16.18	75.60
CAP-5	2/26/2018	15.69	76.09
CAP-5	6/25/2018	17.85	73.93
CAP-5	10/1/2018	17.56	74.22
CAP-5	2/18/2019	14.89	76.89
CAP-5	5/22/2019	18.01	73.77
CAP-7	1/27/2015	14.32	77.32
CAP-7	7/7/2015	16.98	74.66
CAP-7	10/21/2015	14.39	77.25
CAP-7	1/25/2016	14.26	77.38
CAP-7	4/19/2016	14.90	76.74
CAP-7	7/19/2016	16.65	74.99
CAP-7	10/11/2016	13.96	77.68
CAP-7	1/26/2017	14.30	77.34
CAP-7	3/1/2017	14.81	76.83
CAP-7	4/19/2017	14.81	76.83
CAP-7	7/12/2017	15.34	76.30
CAP-7	9/27/2017	14.88	76.76
CAP-7	10/10/2017	15.39	76.25
CAP-7	2/26/2018	15.01	76.63
CAP-7	6/25/2018	16.79	74.85
CAP-7	10/1/2018	16.30	75.34
CAP-7	2/18/2019	14.57	77.07
CAP-7	5/22/2019	16.82	74.82
CAP-9	1/27/2015	14.23	77.36
CAP-9	7/7/2015	16.72	74.87
CAP-9	10/21/2015	14.17	77.42
CAP-9	1/25/2016	14.14	77.45
CAP-9	4/19/2016	14.51	77.08
CAP-9	7/19/2016	15.10	76.49
CAP-9	10/11/2016	13.75	77.84
CAP-9	1/26/2017	14.13	77.46

TABLE 3
SUMMARY OF GROUNDWATER MEASUREMENTS
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

Location	Measurement Date	Depth to Water	Groundwater Elevation
CAP-9	3/1/2017	14.42	77.17
CAP-9	4/19/2017	14.50	77.09
CAP-9	7/12/2017	14.52	77.07
CAP-9	9/27/2017	14.31	77.28
CAP-9	10/10/2017	14.67	76.92
CAP-9	2/22/2018	14.41	77.18
CAP-9	6/25/2018	16.11	75.48
CAP-9	10/1/2018	14.86	76.73
CAP-9	2/18/2019	14.37	77.22
CAP-9	5/22/2019	16.56	75.03
CCMAP-1	6/4/2019	8.39	71.82
CCMAP-2	6/4/2019	8.28	72.96

Notes and Abbreviations:
-: Not Collected

TABLE 4
SUMMARY OF GROUNDWATER ANALYTICAL RESULTS FOR NATURE AND EXTENT
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

			Chemical Group	Detection Monitoring - EPA Appendix III Constituents				Assessment Monitoring - EPA Appendix IV Constituents			Field Parameters						Dissolved Metals					Dissolved I	
			Chemical Name	Calcium, Total	Chloride	Sulfate	Total Dissolved Solids (TDS)	Beryllium, Total	Cobalt, Total	Lithium, Total	Conductivity	Dissolved Oxygen	ORP	pH	Temperature	Turbidity	Beryllium, Dissolved	Calcium, Dissolved	Cobalt, Dissolved	Iron, Dissolved	Lithium, Dissolved	Magnesium, Dissolved	Manganese, Dissolved
			MCL/RSL	-	-	-	-	0.004	0.006	0.04	-	-	-	-	-	-	0.004	-	0.006	-	0.04	-	-
			Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	uS/cm	mg/L	mv	pH units	Deg C	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Impound-ment	**Location**	**Sample Date**	**Sample Type**																				
Background	CBW-1	05/20/2019	N	**42.2**	**2.9**	**115**	**181.2**	< 0.0005	**0.00079**	< 0.01	**202**	**0.99**	**111**	**4.5**	**18.04**	**0.5**	< 0.0005	**41.1**	**0.00075**	< 0.05	< 0.01	**2.3**	**0.015**
Background	PM-1	05/20/2019	N	**16.4**	**12.7**	**10.5**	**162.5**	< 0.0005	**0.00091**	< 0.01	**187**	**0.77**	**39**	**5.26**	**25.6**	**0**	< 0.0005	**15.8**	**0.00088**	**15.6**	< 0.01	**0.8**	**0.0135**
AshPond	CAP-1	05/21/2019	N	**291**	**256**	**704**	**1392**	**0.0111**	**0.024**	**0.12**	**1770**	**0.67**	**98**	**4.73**	**25.59**	**64**	**0.0094**	**297**	**0.0227**	**42.3**	**0.11**	**8.1**	**0.148**
AshPond	CAP-3	05/21/2019	N	**514**	**634**	**907**	**3080**	< 0.0005	**0.0273**	**0.011**	**3250**	**0.54**	**84**	**6.35**	**28.9**	**1.4**	< 0.0005	**550**	**0.0238**	**0.692**	< 0.01	**56.5**	**2.44**
AshPond	CAP-4	02/21/2019	N	**695**	**996**	**888**	**4060**	< 0.0005	< 0.0005	**0.028**	**4670**	**0.78**	**0**	**6.3**	**19.64**	**0.4**	-	-	-	-	-	-	-
AshPond	CAP-4	02/21/2019	FD	-	-	-	-	< 0.0005	< 0.0005	**0.028**	-	-	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-4	07/09/2019	N	**577**	**940**	**793**	**4459**	< 0.0005	< 0.0005	**0.028**	**4170**	**1.88**	**444**	**7.02**	**25.25**	**0**	-	-	-	-	-	-	-
AshPond	CAP-5	05/22/2019	N	**149**	**578**	< 2	**1624**	**0.0046**	**0.014**	**0.012**	**1970**	**3.8**	**104**	**3.96**	**21.99**	**3.8**	**0.0044**	**139**	**0.0135**	**94.6**	**0.013**	**3.5**	**0.0573**
AshPond	CAP-6	02/21/2019	N	**291**	**425**	**180**	**1998**	< 0.0005	< 0.0005	< 0.01	**1890**	**3.85**	**125**	**7.19**	**18.55**	**1.3**	-	-	-	-	-	-	-
AshPond	CAP-6	02/21/2019	FD	-	-	-	-	< 0.0005	< 0.0005	< 0.01	-	-	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-6	07/10/2019	N	**305**	**428**	**165**	**1955**	< 0.0005	< 0.0005	< 0.01	**1910**	**0.47**	**-201**	**7.06**	**22.02**	**0**	-	-	-	-	-	-	-
AshPond	CAP-7	05/22/2019	N	**887**	**1680**	**1700**	**5512**	< 0.0005	**0.0091**	< 0.01	**6880**	**0.79**	**81**	**5.47**	**23.34**	**0**	< 0.0001	**786**	**0.0091**	**214**	< 0.01	**225**	**7.11**
AshPond	CAP-9	05/22/2019	N	**509**	**1060**	**518**	**3422**	**0.0179**	**0.0372**	**0.06**	-	-	-	-	-	-	**0.0148**	**477**	**0.0372**	**82.2**	**0.059**	**47.9**	**0.89**
AshPond	CAP-9	05/22/2019	N	**518**	**1070**	**541**	**3359**	**0.0157**	**0.0383**	**0.065**	**4020**	**0.66**	**252**	**3.86**	**24.63**	**0**	**0.015**	**472**	**0.0365**	**84.3**	**0.062**	**49.9**	**0.903**
AshPond	CAP-8	02/21/2019	N	**773**	**1200**	**1250**	**5144**	< 0.0005	**0.0028**	**0.048**	**5560**	**6.22**	**138**	**7.24**	**18.32**	**2.2**	-	-	-	-	-	-	-
AshPond	CAP-8	02/21/2019	FD	-	-	-	-	< 0.0005	**0.003**	**0.048**	-	-	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-8	07/10/2019	N	**818**	**1210**	**1290**	**5074**	< 0.0005	**0.00309**	**0.052**	**5410**	**2.5**	**103**	**6.81**	**21.79**	**0**	-	-	-	-	-	-	-
AshPond	CAP-10	02/20/2019	N	**72.9**	**18.5**	**10.9**	**288.8**	< 0.0005	< 0.0005	< 0.01	**471**	**4.33**	**228**	**7.57**	**17.34**	**0**	-	-	-	-	-	-	-
AshPond	CAP-10	02/20/2019	FD	-	-	-	-	< 0.0005	< 0.0005	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-10	07/10/2019	N	**76.9**	**18.2**	**9.45**	**450**	< 0.0005	< 0.0005	< 0.01	**448**	**3.31**	**53**	**7.35**	**22.34**	**0**	-	-	-	-	-	-	-
AshPond	CCMAP-1	06/04/2019	N	**79.9**	**6.5**	< 2	**231.2**	< 0.0005	**0.00119**	**0.011**	-	-	-	-	-	-	< 0.0005	**58.6**	< 0.001	**0.229**	< 0.01	**2**	**0.177**
AshPond	CCMAP-1	06/04/2019	FD	**72.8**	**6.31**	< 2	**263.8**	< 0.0005	**0.00103**	< 0.01	-	-	-	-	-	-	< 0.0005	**54.6**	< 0.001	**0.153**	< 0.01	**2.01**	**0.176**
AshPond	CCMAP-2	06/04/2019	N	**11.2**	**4.95**	< 2	**71.25**	< 0.0005	< 0.001	< 0.01	-	-	-	-	-	-	< 0.0005	**11.7**	< 0.001	< 0.1	< 0.01	**0.37**	**0.0232**
AshPond_Tran1	CCMAPT 1-1S	05/17/2019	N	**494**	**887**	**385**	**3201**	**0.0042**	**0.0277**	**0.017**	**3420**	**2.17**	**146**	**4.38**	**22.7**	**>1000**	**0.0031**	**490**	**0.024**	**2.42**	**0.018**	**31.8**	**0.746**
AshPond_Tran1	CCMAPT 1-2S	05/17/2019	N	**34.5**	**97.2**	**13.3**	**377.5**	**0.0023**	**0.0323**	< 0.01	**362**	**3.37**	**197**	**4.99**	**25.54**	**455**	**0.0022**	**32.9**	**0.0282**	**0.663**	< 0.01	**5.8**	**0.219**
AshPond_Tran1	CCMAPT 1-3S	05/17/2019	N	**75**	**165**	**18.7**	**595**	**0.0158**	**0.0726**	**0.015**	**527**	**0.96**	**187**	**4.97**	**27.69**	**155**	**0.002**	**67.7**	**0.0204**	**2.8**	**0.013**	**7.6**	**0.172**
AshPond_Tran1	CCMAPT 1-4S	05/24/2019	N	**11.6**	**12.1**	< 2	**136.2**	**0.0133**	**0.102**	**0.013**	**77**	-	**120**	**6.88**	**17.95**	**>1000**	< 0.0005	**5.9**	**0.0036**	**0.077**	< 0.01	**0.44**	**0.0934**
AshPond_Tran1	CCMAPT 1-5S	05/24/2019	N	**1.5**	**6.47**	< 2	**76.25**	**0.00079**	**0.0061**	< 0.01	**96**	-	**32**	**2.46**	**19.78**	**300**	< 0.0005	**1.6**	**0.0044**	**11.5**	< 0.01	**0.58**	**0.124**
AshPond_Tran1	CCMAPT 1-6	05/30/2019	N	**7000**	**9.9**	< 2	**423.8**	< 0.004	**0.0055**	**0.011**	**138**	**6.27**	**100**	**5.73**	**25.33**	**>1000**	< 0.004	**5900**	**0.0012**	**3.8**	**0.011**	**750**	**0.026**
AshPond_Tran1	CCMAPT 1-7	05/30/2019	N	**120000**	< 2	< 2	**273.8**	< 0.004	**0.0066**	< 0.01	**11**	**6.33**	**181**	**5.81**	**33.95**	**>1000**	< 0.004	**84000**	**0.0029**	**0.46**	< 0.01	**3100**	**0.47**
AshPond_Tran2	CCMAPT 2-2S	05/23/2019	N	**18.9**	**6.1**	**2.65**	**348.8**	**0.0013**	**0.0045**	< 0.01	**159**	**6.31**	**135**	**6.86**	**28.72**	**>1000**	< 0.0005	**14.7**	**0.00084**	**0.666**	< 0.01	**0.66**	**0.0166**
AshPond_Tran2	CCMAPT 2-3S	05/22/2019	N	**81**	**15.9**	< 2	**438.8**	**0.011**	**0.0156**	**0.018**	**355**	**4.57**	**23**	**7.46**	**34.09**	**682**	**0.0021**	**72.3**	**0.0021**	**3**	**0.01**	**1.1**	**0.168**
AshPond_Tran2	CCMAPT 2-4S	05/22/2019	N	**499**	**568**	**489**	**2534**	**0.00092**	**0.149**	< 0.01	**2500**	**2.81**	**28**	**6.74**	**31.48**	**>1000**	< 0.0005	**46**	**0.13**	**1.93**	< 0.01	**18.6**	**1.8**
AshPond_Tran2	CCMAPT 2-5S	05/22/2019	N	**10.4**	**43.8**	< 2	**142.5**	**0.00065**	**0.0628**	< 0.01	**184**	**3.9**	**107**	**5.3**	**21.46**	**752**	**0.00061**	**10.9**	**0.0598**	**2.58**	< 0.01	**3.8**	**0.511**
AshPond_Tran2	CCMAPT 2-6S	05/22/2019	N	**3.3**	**7.13**	< 2	**58.75**	**0.00087**	**0.004**	< 0.01	**76**	**6.42**	**94**	**5.08**	**19.93**	**508**	< 0.0005	**3.1**	**0.00084**	**1.29**	< 0.01	**0.59**	**0.0599**
AshPond_Tran2	CLMAPT 2-1S	05/16/2019	N	**373**	**991**	**683**	**2746**	**0.012**	**0.0365**	**0.047**	**336**	**1.3**	**206**	**4.11**	**26.33**	**>1000**	**0.011**	**338**	**0.0292**	**135**	**0.043**	**46.4**	**0.698**

ABBREVIATIONS AND NOTES:
mg/L: milligram per liter
µS/cm: microSiemen per centimeter
mv: millivolt
NTU: Nephelometric Turbidity Units
< 0.005: Analyte not detected above detection limit
-: Not Analyzed
MCL/RSL: The applicable Mximum Contaminant Level (MCL) or Regional Screening Level (RSL) is shown. Dashed where a standard is not provided.
FD: Field Duplicate
Highlighted where result exceeds the applicable MCL/RSL
Bold where detected above method detction limit
>1000: Turbidity greater than instrument limit

- Criteria used for cobalt, lithium, and molybdenum are RSL for Tapwater where THQ=1.0 (May 2018)
- USEPA. 2016. Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities. July 26. 40 CFR Part 257.

https://www.epa.gov/coalash/coal-ash-rule

QUALIFIERS:
U: Not detected, value is the laboratory reporting limit

TABLE 4
SUMMARY OF GROUNDWATER ANALYTICAL RESULTS F
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

			Chemical Group	Metals		Total Metals					Other				
			Chemical Name	Potassium, Dissolved	Sodium, Dissolved	Iron, Total	Magnesium, Total	Manganese, Total	Potassium, Total	Sodium, Total	Alkalinity, Bicarbonate	Alkalinity, Total (as CaCO3)	Dissolved Organic Carbon (DOC)	Sulfide	Total Organic Carbon (TOC)
			MCL/RSL	-	-	-	-	-	-	-	-	-	-	-	-
			Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Impound-ment	**Location**	**Sample Date**	**Sample Type**												
Background	CBW-1	05/20/2019	N	**0.58**	**1.9**	**0.141**	**2.1**	**0.0147**	**0.57**	**1.8**	**19.7**	**19.7**	**3.21**	< 0.1	**2.71**
Background	PM-1	05/20/2019	N	**0.57**	**5.5**	**16.9**	**0.75**	**0.0122**	**0.57**	**5.3**	**58.6**	**58.6**	**7.21**	< 0.1	**6.72**
AshPond	CAP-1	05/21/2019	N	**0.56**	**67**	**42.4**	**8.2**	**0.131**	**0.57**	**66.7**	**25.8**	**25.8**	**6.57**	< 0.1	**7.5**
AshPond	CAP-3	05/21/2019	N	**3.5**	**87.4**	**1.36**	**59.1**	**2.77**	**3.9**	**91.7**	**333**	**333**	**3.58**	< 0.1	**3.54**
AshPond	CAP-4	02/21/2019	N	-	-	**12**	**77.9**	-	**8.4**	**126**	-	-	-	-	-
AshPond	CAP-4	02/21/2019	FD	-	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-4	07/09/2019	N	-	-	< 0.05	**68.6**	-	**7.9**	**121**	-	-	-	-	-
AshPond	CAP-5	05/22/2019	N	**0.66**	**78.6**	**0.0576**	**3.7**	**0.0576**	**0.72**	**87**	< 4	< 4	**3.23**	< 0.1	**2.34**
AshPond	CAP-6	02/21/2019	N	-	-	**0.589**	**6**	-	**1.6**	**41.9**	-	-	-	-	-
AshPond	CAP-6	02/21/2019	FD	-	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-6	07/10/2019	N	-	-	**0.434**	**7.1**	-	**1.7**	-	-	-	-	-	-
AshPond	CAP-7	05/22/2019	N	**14.1**	**163**	**218**	**183**	**7.54**	**15.3**	**188**	**52.1**	**52.1**	**3.67**	< 0.1	**4.56**
AshPond	CAP-9	05/22/2019	N	**6.7**	**131**	**89.3**	**52300**	**0.904**	**6.8**	**155**	< 4	< 4	**1.93**	< 0.1	**3.11**
AshPond	CAP-9	05/22/2019	N	**6.9**	**136**	**94.6**	**55200**	**0.937**	**7.2**	**156**	< 4	< 4	**2.04**	< 0.1	**1.9**
AshPond	CAP-8	02/21/2019	N	-	-	**0.122**	**96.6**	-	**7.3**	**148**	-	-	-	-	-
AshPond	CAP-8	02/21/2019	FD	-	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-8	07/10/2019	N	-	-	< 0.05	**110**	-	**8.3**	-	-	-	-	-	-
AshPond	CAP-10	02/20/2019	N	-	-	< 0.05	**1.6**	-	**1.5**	**10.4**	-	-	-	-	-
AshPond	CAP-10	02/20/2019	FD	-	-	-	-	-	-	-	-	-	-	-	-
AshPond	CAP-10	07/10/2019	N	-	-	**0.05**	**1.7**	-	**1.5**	-	-	-	-	-	-
AshPond	CCMAP-1	06/04/2019	N	**0.912**	**8.51**	**0.267**	**2.33**	**0.309**	**0.965**	**9.39**	**176**	-	**1.75**	< 0.1	**1.83**
AshPond	CCMAP-1	06/04/2019	FD	**0.916**	**9.09**	**0.362**	**2.17**	**0.248**	**0.943**	**8.8**	**194**	-	**3.7**	< 0.1	-
AshPond	CCMAP-2	06/04/2019	N	**1.01**	**9.45**	< 0.1	**0.357**	**0.0235**	**1.02**	**9.55**	**45.9**	-	**1.67**	< 0.1	-
AshPond_Tran1	CCMAPT 1-1S	05/17/2019	N	**7.5**	**95.9**	**36.1**	**32.8**	**0.805**	**9.4**	**98.2**	< 4	< 4	**1.18**	< 0.1	< 1
AshPond_Tran1	CCMAPT 1-2S	05/17/2019	N	**3.5**	**17.6**	**3.48**	**6**	**0.23**	**3.9**	**17.9**	**4.02**	**4.02**	**1.05**	< 0.1	< 1
AshPond_Tran1	CCMAPT 1-3S	05/17/2019	N	**3.7**	**22.5**	**147**	**14.2**	**0.405**	**7.6**	**20.2**	**11.1**	**11.1**	**1.18**	< 0.1	**1.01**
AshPond_Tran1	CCMAPT 1-4S	05/24/2019	N	**0.81**	**4.9**	**107**	**5.3**	**1.13**	**5.1**	**4.7**	**29.6**	**29.6**	< 1	< 0.1	< 1
AshPond_Tran1	CCMAPT 1-5S	05/24/2019	N	**0.6**	**5.2**	**19.9**	**1.2**	**0.149**	**1.5**	**5.8**	**29.8**	**29.8**	**1.22**	< 0.1	< 1
AshPond_Tran1	CCMAPT 1-6	05/30/2019	N	**830**	**8800**	**7.8**	**1300**	**0.046**	**1500**	**9000**	**21.1**	**21.1**	**1.98**	< 0.1	< 2
AshPond_Tran1	CCMAPT 1-7	05/30/2019	N	**1800**	**12000**	**6.2**	**3900**	**0.53**	**2200**	**11000**	**978**	**978**	**2.84**	< 0.1	**3.71**
AshPond_Tran2	CCMAPT 2-2S	05/23/2019	N	**1.1**	**3.8**	**18.9**	**2.5**	**0.0404**	**2.9**	**4**	**67.6**	**67.6**	**1.47**	< 0.1	< 1
AshPond_Tran2	CCMAPT 2-3S	05/22/2019	N	**0.8**	**6.4**	**38.4**	**1.9**	**0.493**	**1.9**	**6.4**	**183**	**183**	**1.39**	< 0.1	< 1
AshPond_Tran2	CCMAPT 2-4S	05/22/2019	N	**3.1**	**69.9**	**8.74**	**20**	**1.78**	**4.3**	**75.3**	**193**	**193**	**1.9**	< 0.1	**1.69**
AshPond_Tran2	CCMAPT 2-5S	05/22/2019	N	**2.6**	**9.6**	**2.89**	**3.8**	**0.515**	**2.9**	**10.1**	**38.2**	**38.2**	**1**	< 0.1	< 1
AshPond_Tran2	CCMAPT 2-6S	05/22/2019	N	**0.77**	**4.2**	**32.9**	**0.95**	**0.124**	**2**	**3.8**	**35.6**	**35.6**	**1.25**	< 0.1	**1.03**
AshPond_Tran2	CLMAPT 2-1S	05/16/2019	N	**5.3**	**136**	**178**	**47.8**	**0.774**	**6.3**	**143**	< 4	< 4	**1.87**	< 0.1	**1.84**

ABBREVIATIONS AND NOTES:
mg/L: milligram per liter
µS/cm: microSiemen per centimeter
mv: millivolt
NTU: Nephelometric Turbidity Units
< 0.005: Analyte not detected above detection limit
-: Not Analyzed
MCL/RSL: The applicable Mximum Contaminant Level (MCL) or Regional Screening Level (RSL) is shown. Dashed where a standard is not provided.
FD: Field Duplicate
Highlighted where result exceeds the applicable MCL/RSL
Bold where detected above method detction limit
>1000: Turbidity greater than instrument limit

- Criteria used for cobalt, lithium, and molybdenum are RSL for Tapwater where THQ=1.0 (May 2018)
- USEPA. 2016. Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities. July 26. 40 CFR Part 257. https://www.epa.gov/coalash/coal-ash-rule

QUALIFIERS:
U: Not detected, value is the laboratory reporting limit

TABLE 5
REMEDIAL ALTERNATIVE ROADMAP
CROSS GENERATING STATION - BOTTOM ASH POND
SANTEE COOPER
CROSS, SOUTH CAROLINA

Alternative Number	Remedial Alternative Description	Cross Bottom Ash Pond	Groundwater Remedy Components		
			1. Groundwater Remedy Approach	2. Groundwater Treatment Method	3. Long-Term Monitoring Actions
1	Closure In Place (CIP) with Capping and Monitored Natural Attenuation (MNA)	CIP with Synthetic Cap	**Natural Attenuation with Monitoring** Mitigate off-site migration of groundwater with CCR constituents above GWPS through process of natural attenuation	**No Active Treatment** No active treatment technologies for groundwater to address CCR constituents	**MNA** Long-term groundwater monitoring to confirm reduction of CCR constituents
2	CIP with Capping and Hydraulic Containment through Groundwater Pumping and Direct Discharge	CIP with Synthetic Cap	**Hydraulic Containment** Mitigate off-site migration of groundwater with CCR constituents above GWPS using extraction wells pumped directly to surface water	**No Active Treatment** No active treatment technologies for groundwater to address CCR constituents	**Pump Long-Term** Continue to operate hydraulic containment system to maintain reduction of CCR constituents in groundwater
3	CIP with Capping and Hydraulic Containment through Groundwater Pumping and Ex-Situ Treatment	CIP with Synthetic Cap	**Hydraulic Containment** Mitigate off-site migration of groundwater with CCR constituents above GWPS using extraction wells	**Ex-Situ Treatment** Treatment system (ion exchange or reverse osmosis) to remove CCR constituents from groundwater and discharge under applicable permits	**Pump & Treat Long-Term** Continue to operate hydraulic containment system to maintain reduction of CCR constituents in groundwater
4	Closure by Removal (CBR) with MNA	CBR	**Natural Attenuation with Monitoring** Mitigate off-site migration of groundwater with CCR constituents above GWPS through process of natural attenuation	**No Active Treatment** No active treatment technologies for groundwater to address CCR constituents	**MNA** Long-term groundwater monitoring to confirm reduction of CCR constituents
5	CBR with Capping and Hydraulic Containment through Groundwater Pumping and Direct Discharge	CBR	**Hydraulic Containment** Mitigate off-site migration of groundwater with CCR constituents above GWPS using extraction wells pumped directly to surface water	**No Active Treatment** No active treatment technologies for groundwater to address CCR constituents	**Pump Long-Term** Continue to operate hydraulic containment system to maintain reduction of CCR constituents in groundwater
6	CBR with Capping and Hydraulic Containment through Groundwater Pumping and Ex-Situ Treatment	CBR	**Hydraulic Containment** Mitigate off-site migration of groundwater with CCR constituents above GWPS using extraction wells	**Ex-Situ Treatment** Treatment system (ion exchange or reverse osmosis) to remove CCR constituents from groundwater and discharge under applicable permits	**Pump & Treat Long-Term** Continue to operate hydraulic containment system to maintain reduction of CCR constituents in groundwater

Alternative	Remedial Alternative Synopsis	THRESHOLD CRITERIA					BALANCING CRITERIA		
		§ 257.97(b)(1) Be Protective of Human Health and the Environment	§ 257.97(b)(2) Attain the groundwater protective standard	§ 257.97(b)(3) Control the Source of Releases	§ 257.97(b)(4) Remove as much material from the environment released from the CCR unit as is feasible	§ 257.97(b)(5) Management of waste all applicable RCRA requirements	§ 257.97(c)(1) Long- and Short Term Effectiveness, Protectiveness, and Certainty of Success[1]	§ 257.97(c)(2) Effectiveness to Control Further Releases[2]	§ 257.97(c)(3) Difficulty of Implementation[3]
1	**Capping with CIP with and MNA.** Complete a low permeability cap to limit infiltration of surface water to groundwater. Continue to monitor groundwater until natural attenuation reduces concentrations downgradient.	**Meets criteria.** No current unacceptable risk to human health or the environment. Closure by capping will reduce constituents of concern entering the subsurface and MNA will reduce constituents of concern in groundwater over time.	**Meets criteria.** High degree of ability to attain the GWPS. Relies on MNA to attain the GWPS with time.	**Meets criteria.** The source of releases of groundwater constituents from the regulated unit should decrease after capping due to a reduction in infiltration of surface water and leaching via precipitation infiltration. Contaminants in concern will diminish due to MNA and source depletion.	**Meets criteria.** Isolation of mass at the waste boundary followed by in place closure of regulated unit will result in reduction of groundwater constituents migrating downgradient of the regulated unit over time.	**Meets criteria.** Regulated unit will be closed in place; RCRA wastes resulting from alternative will not be generated.	**Effective short-term** due to containing the source of contaminants and groundwater through capping. The low permeability cap will reduce the flux of water moving through source material. **Effective long-term** as natural attenuation, which requires limited management, will address groundwater contamination, after the unit is capped, through processes of CCR source leaching and depletion. **Full protection** already achieved under existing conditions, risk to community during construction will be minimal, and periodic MNA sampling poses no risk. Institutional controls can be easily enforced because the Bottom Ash Pond located on property owned by Santee Cooper. CIP is considered permanent but to **demonstrate success,** groundwater monitoring will be used to verify MNA. Potential exists for the need to replace remedy if CIP with MNA isn't successful long-term.	**Moderate degree of effectiveness to control further releases** due to isolation of the waste through capping. Capping expected to reduce infiltration of surface water and concentrations of constituents of concern in groundwater. Leaching and depletion of CCR constituents expected to reduce groundwater concentrations longer-term. **No groundwater treatment technologies,** other than natural attenuation, will be used.	**Remedy easy to implement** assuming cap materials readily available and since capping construction is common industry practice. **Remedy will be considered reliable** because closure in place and monitored natural attenuation are acceptable and reliable practices for long-term waste management. **Permitting** is expected to be straightforward and easily obtained. **No specialty contractors, laboratories, or equipment required.** Because the Bottom Ash Pond will be closed in place, **treatment, storage, and disposal services will not be needed**.
2	**Capping with CIP and Hydraulic Containment through Groundwater Pumping.** Hydraulic containment with direct discharge to surface water as an interim remediation measure, then close unit in place by capping. Continue to operate hydraulic control with pumping until concentrations are reduced downgradient.	**Meets criteria.** No current unacceptable risk to human health or the environment. Capping and hydraulic containment will reduce additional leaching of constituents to groundwater and downgradient migration.	**Meets criteria**. Attainment of the GWPS will be achieved because groundwater constituents will be removed through extraction, followed by closure in place by constructing a cap over CCR material, which will result in reducing the ability for constituents to enter the groundwater system. Downgradient concentrations will decrease to below the GWPS over time.	**Meets criteria.** The source of releases of groundwater constituents from the regulated unit should decrease after capping due to a reduction in infiltration of surface water and leaching via precipitation infiltration. Constituents in groundwater will be further addressed by hydraulic containment and pumping well effluent discharged directly to surface water.	**Meets criteria.** Removal of mass at the waste boundary followed by in place closure of regulated units will result in reduction of groundwater constituents migrating downgradient of the regulated unit over time.	**Meets criteria.** Regulated unit will be closed in place; RCRA wastes resulting from alternative will not be generated.	**Effective short-term** due to containing the source of constituents and groundwater. The low permeability cap will reduce the flux of water moving through source material. Treatment system would require **long-term operation and maintenance. Full protection** already achieved under existing conditions, **risk to community** during construction will be minimal, and periodic sampling poses no risk. Once completed, the **long-term reliability** of the hydraulic containment and direct discharge is expected to be high because this is proven technology. **Institutional controls** can be easily enforced because the Bottom Ash Pond is located on property owned by Santee Cooper. Potential exists for the need to replace remedy if hydraulic containment isn't successful long-term.	**Moderate degree of effectiveness to control further releases** due to isolation of the waste through capping, hydraulic containment, and direct discharge to surface water. The hydraulic containment system with direct discharge will direct contaminents to surface water, however, capping is expected to reduce infiltration of surface water and concentrations of constituents of concern in groundwater. **Treatment technology** will include groundwater pumping wells, associated pipework, and a direct discharge system.	Hydraulic containment remedy **easy to implement** because hydraulic control technology is readily available, well understood and construction is relatively straightforward. **Easy to implement** cap assuming cap materials readily available and since capping construction is common industry practice. More difficult to implement than passive remedies. **Remedy will be considered reliable** because technology known and accepted. **Permitting** will likely be required for groundwater discharge. **No specialty contractors, laboratories, or equipment required.** Because the Bottom Ash Pond will be closed in place, **treatment, storage, and disposal services will not be needed for CCR material**.
3	**Capping with CIP and Hydraulic Containment through Groundwater Pumping.** Hydraulic containment with ex-situ treatment as an interim remediation measure, then close unit in place by capping. Continue to operate hydraulic control with treatment until concentrations are reduced downgradient.	**Meets criteria.** No current unacceptable risk to human health or the environment. Capping and hydraulic containment will reduce additional leaching of constituents to groundwater and downgradient migration.	**Meets criteria**. Attainment of the GWPS will be achieved because groundwater constituents will be removed through extraction, followed by closure in place by constructing a cap over CCR material, which will result in reducing the ability for constituents to enter the groundwater system. Downgradient concentrations will decrease to below the GWPS over time.	**Meets criteria.** The source of releases of groundwater constituents from the regulated unit should decrease after capping due to a reduction in infiltration of surface water and leaching via precipitation infiltration. Constituents in groundwater will be further addressed by hydraulic containment and ex-situ treatment.	**Meets criteria.** Removal of mass at the waste boundary followed by in place closure of regulated units will result in reduction of groundwater constituents migrating downgradient of the regulated unit over time.	**Meets criteria.** Regulated unit will be closed in place; RCRA wastes resulting from alternative will not be generated.	**Effective short-term** due to containing the source of constituents and groundwater. The low permeability cap will reduce the flux of water moving through source material. Treatment system would require **long-term operation and maintenance. Full protection** already achieved under existing conditions, **risk to community** during construction will be minimal, and periodic sampling poses no risk. Once completed, the **long-term reliability** of the hydraulic containment and ex-situ treatment system is expected to be high because this is proven technology. **Institutional controls** can be easily enforced because the Bottom Ash Pond is located on property owned by Santee Cooper. Potential exists for the need to replace remedy if hydraulic containment isn't successful long-term.	**Moderate degree of effectiveness to control further releases** due to isolation of the waste through capping, hydraulic containment, and ex-situ treatment. Capping expected to reduce infiltration of surface water and concentrations of constituents of concern in groundwater, and hydraulic containment with ex-situ treatment will treat groundwater at the unit boundary. **Treatment technology** will include groundwater pumping wells, associated pipework, and an ex-situ treatment system.	Hydraulic containment remedy **easy to implement** because hydraulic control technology is readily available, well understood and construction is relatively straightforward. Easy to implement cap assuming cap materials readily available and since capping construction is common industry practice. More difficult to implement than passive remedies. **Remedy will be considered reliable** because technology known and accepted. **Permitting** will likely be required for treated groundwater discharge. **No specialty contractors, laboratories, or equipment required.** Because the Bottom Ash Pond will be closed in place, **treatment, storage, and disposal services will not be needed for CCR material.** The ex-situ treatment system may generate a concentrated waste stream which would likely require off-site transportation and disposal.

Alternative	Remedial Alternative Synopsis	THRESHOLD CRITERIA					BALANCING CRITERIA		
		§ 257.97(b)(1) Be Protective of Human Health and the Environment	§ 257.97(b)(2) Attain the groundwater protective standard	§ 257.97(b)(3) Control the Source of Releases	§ 257.97(b)(4) Remove as much material from the environment released from the CCR unit as is feasible	§ 257.97(b)(5) Management of waste all applicable RCRA requirements	§ 257.97(c)(1) Long- and Short Term Effectiveness, Protectiveness, and Certainty of Success[1]	§ 257.97(c)(2) Effectiveness to Control Further Releases[2]	§ 257.97(c)(3) Difficulty of Implementation[3]
4	**CBR with MNA.** Continue to monitor groundwater until natural attenuation reduces concentrations downgradient.	**Meets criteria.** No current unacceptable risk to human health or the environment. Remedy by removal will eliminate constituents of concern from entering the subsurface.	**Meets criteria**. High degree of ability to attain the groundwater protection standard (GWPS). Removing CCR material will eliminate additional constituents of concern entering the subsurface longer-term. Relies on MNA to address the existing plume and attain the GWPS with time.	**Meets criteria.** High degree of ability to control source because the remedy includes removal of the source of contaminants.	**Meets criteria.** High ability to remove material from the environment. Following removal of source, contamination to surrounding environment not expected.	**Meets criteria.** High degree of ability to meet RCRA waste management requirements during implementation.	Remedy by removal provides a **high degree of long- term effectiveness** due to eliminating the source of contamination; **success of remedy certain**. **Moderate degree of short-term** risk to the community associated with removal project due to design, permitting, and construction, but eliminates source material and therefore constituents of concern will not migrate beyond waste boundary longer-term. **Full protection** already achieved under existing conditions and periodic MNA sampling poses no risk. **Institutional controls** can be easily enforced because the Bottom Ash Pond located on property owned by Santee Cooper. CBR is considered permanent but requires groundwater monitoring to verify MNA. Potential exists for the need to replace remedy if CBR with MNA isn't successful long-term.	**Moderate degree of effectiveness short-term** since beneficial reuse has already begun. **High degree of effectiveness to control further releases long-term** due to removal of the source of contaminants once construction is complete. No groundwater treatment technologies, other than natural attenuation, will be used.	**Difficult to implement remedy** by removal due to estimated haul volume (1.5 MM tons) of CCR. Logistical and safety challenges of extracting and transporting waste material for beneficial reuse or to an existing third-party landfill.P**ermitting** anticipated to be straight forward for completing the closure by removal and s**pecialty remediation/dewatering contractors** are not anticipated.
5	**CBR with Hydraulic Containment through Groundwater Pumping.** Hydraulic containment with direct discharge to surface water as an interim remediation measure, then close unit. Continue to operate hydraulic control with pumping until concentrations are reduced downgradient.	**Meets criteria.** No current unacceptable risk to human health or the environment. Remedy by removal will eliminate constituents of concern from entering the subsurface. Hydraulic containment will reduce additional leaching of constituents to groundwater and downgradient migration.	**Meets criteria**. High degree of ability to attain the groundwater protection standard (GWPS). Removing CCR material will eliminate additional constituents of concern entering the subsurface longer-term. Attainment of the GWPS will be achieved because groundwater constituents will be removed through extraction. Downgradient concentrations will decrease to below the GWPS over time.	**Meets criteria.** High degree of ability to control source because the remedy includes removal of the source of contaminants. The source of releases of groundwater constituents from the regulated unit should decrease after capping due to a reduction in infiltration of surface water and leaching via precipitation infiltration. Constituents in groundwater will be further addressed by hydraulic containment and pumping well effluent discharged directly to surface water.	**Meets criteria.** High ability to remove material from the environment. Following removal of source, contamination to surrounding environment not expected. Removal of mass at the waste boundary will result in reduction of groundwater constituents migrating downgradient of the regulated unit over time.	**Meets criteria.** High degree of ability to meet RCRA waste management requirements during implementation.	Remedy by removal provides a **high degree of long- term effectiveness** due to eliminating the source of contamination; **success of remedy certain**. **Moderate degree of short-term** risk to the community associated with removal project due to design, permitting, and construction, but eliminates source material and therefore constituents of concern will not migrate beyond waste boundary longer-term. **Full protection** already achieved under existing conditions and periodic MNA sampling poses no risk. **Institutional controls** can be easily enforced because the Bottom Ash Pond located on property owned by Santee Cooper. CBR is considered permanent but requires groundwater monitoring to verify MNA. Potential exists for the need to replace remedy if CBR with hydraulic containment isn't successful long-term.	**Moderate degree of effectiveness short-term** since beneficial reuse has already begun. **High degree of effectiveness to control further releases long-term** due to removal of the source of contaminants once construction is complete. In addition, hydraulic containment with direct discharge to surface water treatment will be used.	**Difficult to implement remedy** by removal due to estimated haul volume (1.5 MM tons) of CCR. Logistical and safety challenges of extracting and transporting waste material for beneficial reuse or to an existing third-party landfill.P**ermitting** anticipated to be straight forward for completing the closure by removal and s**pecialty remediation/dewatering contractors** are not anticipated.
6	**CBR with Hydraulic Containment through Groundwater Pumping.** Hydraulic containment with ex-situ treatment as an interim remediation measure, then close unit in place. Continue to operate hydraulic control with treatment until concentrations are reduced downgradient.	**Meets criteria.** No current unacceptable risk to human health or the environment. Remedy by removal will eliminate constituents of concern from entering the subsurface. Hydraulic containment will reduce additional leaching of constituents to groundwater and downgradient migration.	**Meets criteria**. High degree of ability to attain the groundwater protection standard (GWPS). Removing CCR material will eliminate additional constituents of concern entering the subsurface longer-term. Attainment of the GWPS will be achieved because groundwater constituents will be removed through extraction. Downgradient concentrations will decrease to below the GWPS over time.	**Meets criteria.** High degree of ability to control source because the remedy includes removal of the source of contaminants. The source of releases of groundwater constituents from the regulated unit should decrease after capping due to a reduction in infiltration of surface water and leaching via precipitation infiltration. Constituents in groundwater will be further addressed by hydraulic containment and ex-situ treatment.	**Meets criteria.** High ability to remove material from the environment. Following removal of source, contamination to surrounding environment not expected. Removal of mass at the waste boundary will result in reduction of groundwater constituents migrating downgradient of the regulated unit over time.	**Meets criteria.** High degree of ability to meet RCRA waste management requirements during implementation.	Remedy by removal provides a **high degree of long- term effectiveness** due to eliminating the source of contamination; **success of remedy certain**. **Moderate degree of short-term** risk to the community due to transporation, but eliminates source material. Once completed, the **long-term reliability** of the hydraulic containment and ex-situ treatment is expected to be high because this is proven technology. **Full protection** already achieved under existing conditions and periodic MNA sampling poses no risk. **Institutional controls** can be easily enforced. CBR is considered permanent but requires groundwater monitoring to verify MNA. Potential exists for the need to replace remedy if CIP with MNA isn't successful long-term.	**Moderate degree of effectiveness short-term** since beneficial reuse has already begun. **High degree of effectiveness to control further releases long-term** due to removal of the source of contaminants once construction is complete. In addition, hydraulic containment with ex-situ treatment will be used.	**Difficult to implement remedy** by removal due to estimated haul volume (1.5 MM tons) of CCR. Logistical and safety challenges of extracting and transporting waste material for beneficial reuse or to an existing third-party landfill.P**ermitting** anticipated to be straight forward for completing the closure by removal and s**pecialty remediation/dewatering contractors** are not anticipated.

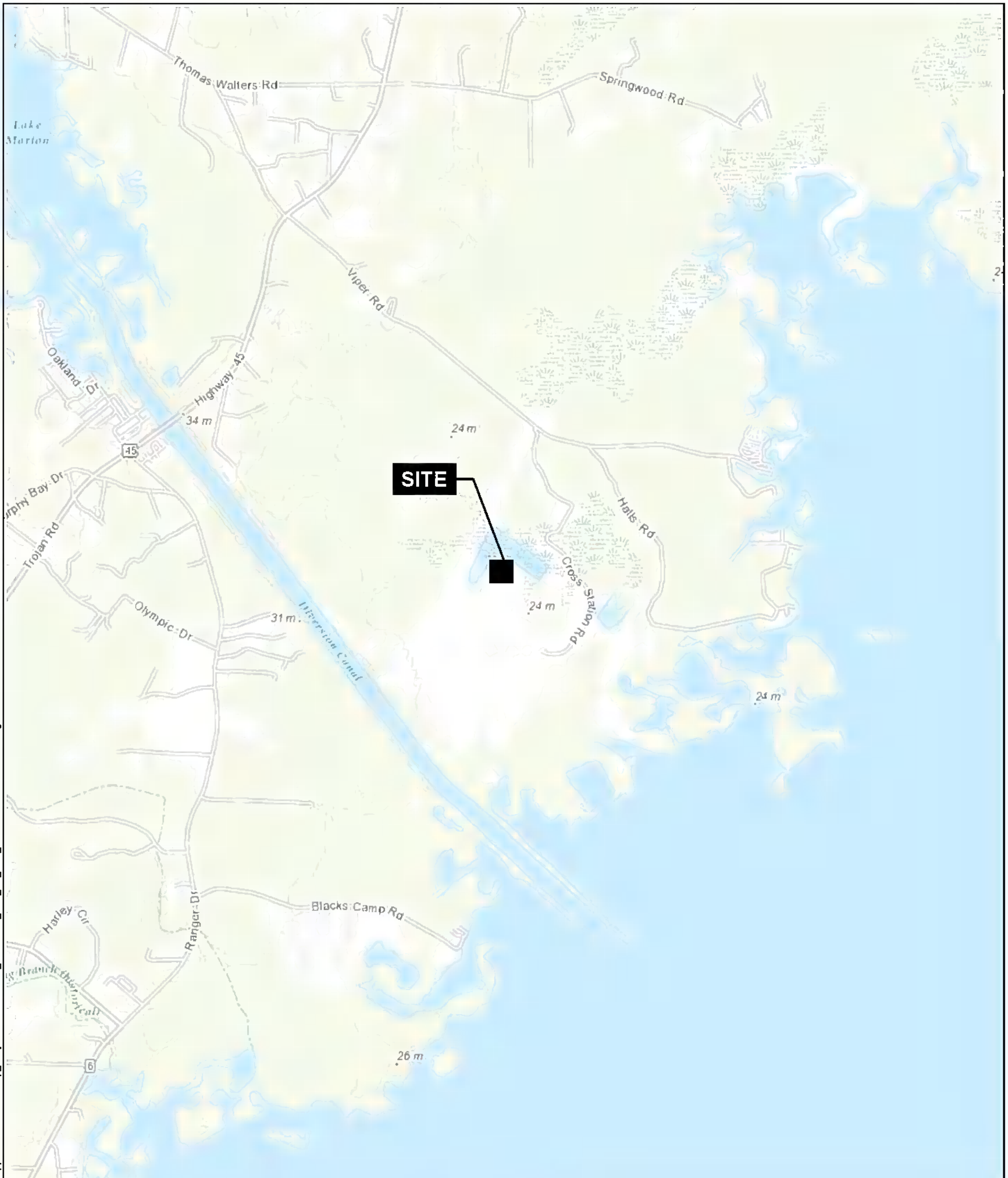
Most favorable when compared to other alternatives (green)
Less favorable when compared to other alternatives (yellow)
Least favorable when compared to other alternatives (red)

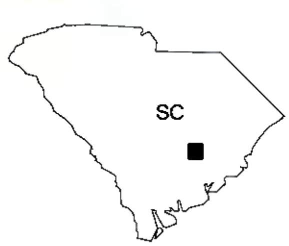
1 The long- and short- term effectiveness evaluation considered the following criteria:
(i) Magnitude of reduction of existing risks;
(ii) Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy;
(iii) The type and degree of long-term management required, including monitoring, operation, and maintenance;
(iv) Short-term risks that might be posed to the community or the environment during implementation of such a remedy, including potential threats to human health and the environment associated with excavation, transportation, and re-disposal of contaminant;
(v) Time until full protection is achieved;
(vi) Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment;
(vii) Long-term reliability of the engineering and institutional controls; and
(viii) Potential need for replacement of the remedy.

2. The effectivness in controlling the source ot reduce further releases considered the following criteria:
(i)The extent to which containment practices will reduce further releases.
(ii)The extent to which treatment technologies may be used.

3. The ease or difficulty of implmentation considered the following criteria:
(i)Degree of difficulty associated with constructing the technology.
(ii)Expected operational reliability of the technologies.
(iii)Need to coordinate with and obtain necessary approvals and permits from other agencies.
(iv) Availability of necessary equipment and specialists.
(v) Available capacity and location of needed treatment, storage, and disposal services.

FIGURES





MAP SOURCE: ESRI

HALEY ALDRICH

SANTEE COOPER
CROSS GENERATING STATION
CROSS, SOUTH CAROLINA

SITE LOCATION MAP

APPROXIMATE SCALE: 1 IN = 2000 FT
JULY 2019

FIGURE 1

GIS FILE PATH: G:\Projects\42122_Santee_Cooper\Global\GIS\Map_Projects\Cross\2015_08\42122_000_01_Site_Location.mxd — USER: gcarson — LAST SAVED: 9/8/2015 2:28:34 PM

LEGEND

- ASH POND WELL
- BACKGROUND WELL

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. AERIAL IMAGERY SOURCE: ESRI

0 1,000 2,000
SCALE IN FEET

HALEY ALDRICH

SANTEE COOPER
CROSS GENERATING STATION
CROSS, SOUTH CAROLINA

LOCATION OF GROUNDWATER MONITORING WELLS FOR CCR COMPLIANCE - BOTTOM ASH POND

SEPTEMBER 2019

FIGURE 2

LEGEND

- APPENDIX III SSI
- ASH POND WELL
- BACKGROUND WELL

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. AERIAL IMAGERY SOURCE: ESRI

0 1,000 2,000
SCALE IN FEET

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CROSS GENERATING STATION
CROSS, SOUTH CAROLINA

LOCATION OF APPENDIX III SSIS

SEPTEMBER 2019

FIGURE 3

GIS FILE PATH: \\haleyaldrich.com\share\gm_common\131539 - Santee Cooper\GIS\Maps\2019_07\132892_004_00MB_ASH_POND_WELLS.mxd — USER: ajospe — LAST SAVED: 7/31/2019 1:19:04 PM

LEGEND

- APPENDIX IV SSL
- ASH POND WELL
- BACKGROUND WELL

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. AERIAL IMAGERY SOURCE: ESRI

0 1,000 2,000
SCALE IN FEET

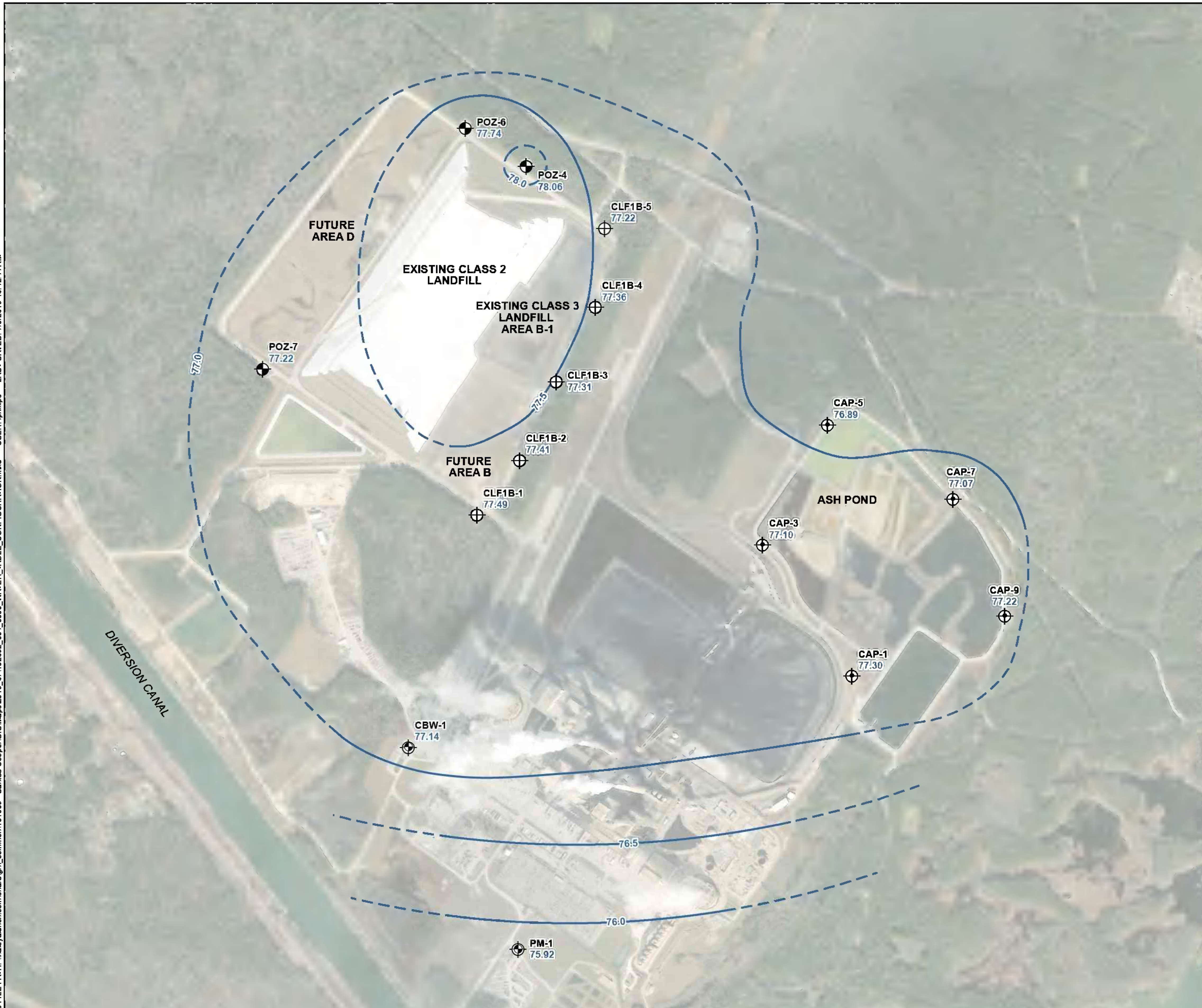
HALEY ALDRICH

SANTEE COOPER
CROSS GENERATING STATION
CROSS, SOUTH CAROLINA

LOCATION OF APPENDIX IV SSLS

SEPTEMBER 2019

FIGURE 4



LEGEND

ASH POND WELL

BACKGROUND WELL

CLASS 2 LANDFILL WELL

CLASS 3 LANDFILL AREA B WELL

GROUNDWATER ELEVATION CONTOUR, IN FT (DASHED WHERE INFERRED)

NOTES

1. GROUNDWATER ELEVATION DATA COLLECTED IN FEBRUARY 2019.
2. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
3. AERIAL IMAGER SOURCE: ESRI

N

0 1,000 2,000

SCALE IN FEET

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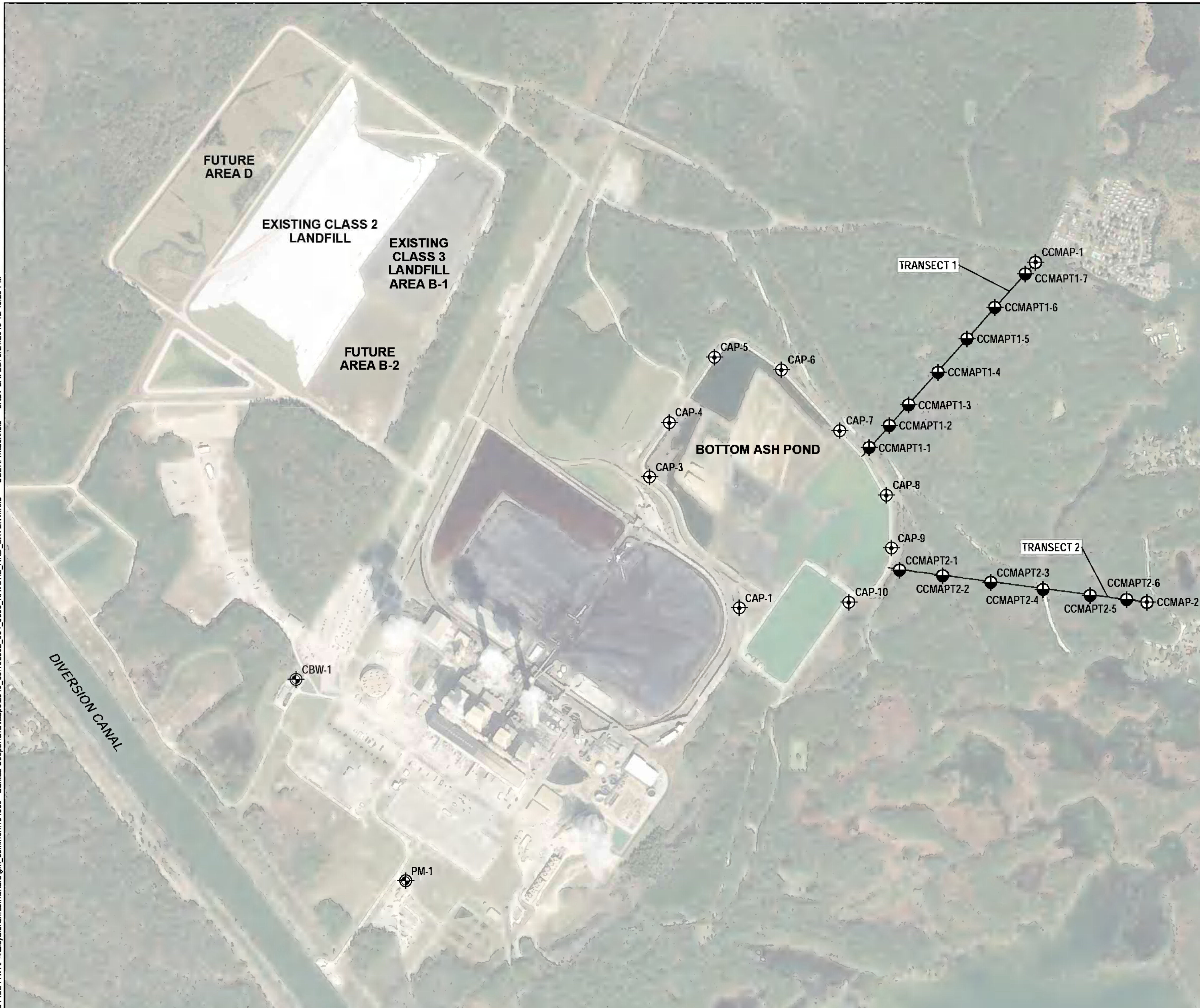
CROSS GENERATING STATION
CROSS, SOUTH CAROLINA

WATER TABLE CONFIGURATION MAP

SEPTEMBER 2019

FIGURE 5

GIS FILE PATH: \\haleyaldrich.com\share\grn_common\131539 - Santee Cooper\GIS\Maps\2019_07\132692_004_0005_WATER_TABLE_CONFIGURATION.mxd — USER: lphillips — LAST SAVED: 7/5/2019 10:42:44 AM



LEGEND

- ASH POND WELL
- BACKGROUND WELL
- NATURE AND EXTENT EVACUATION TEMPARARY LOCATION
- TRANSECT

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. AERIAL IMAGERY SOURCE: ESRI

0 1,000 2,000
SCALE IN FEET

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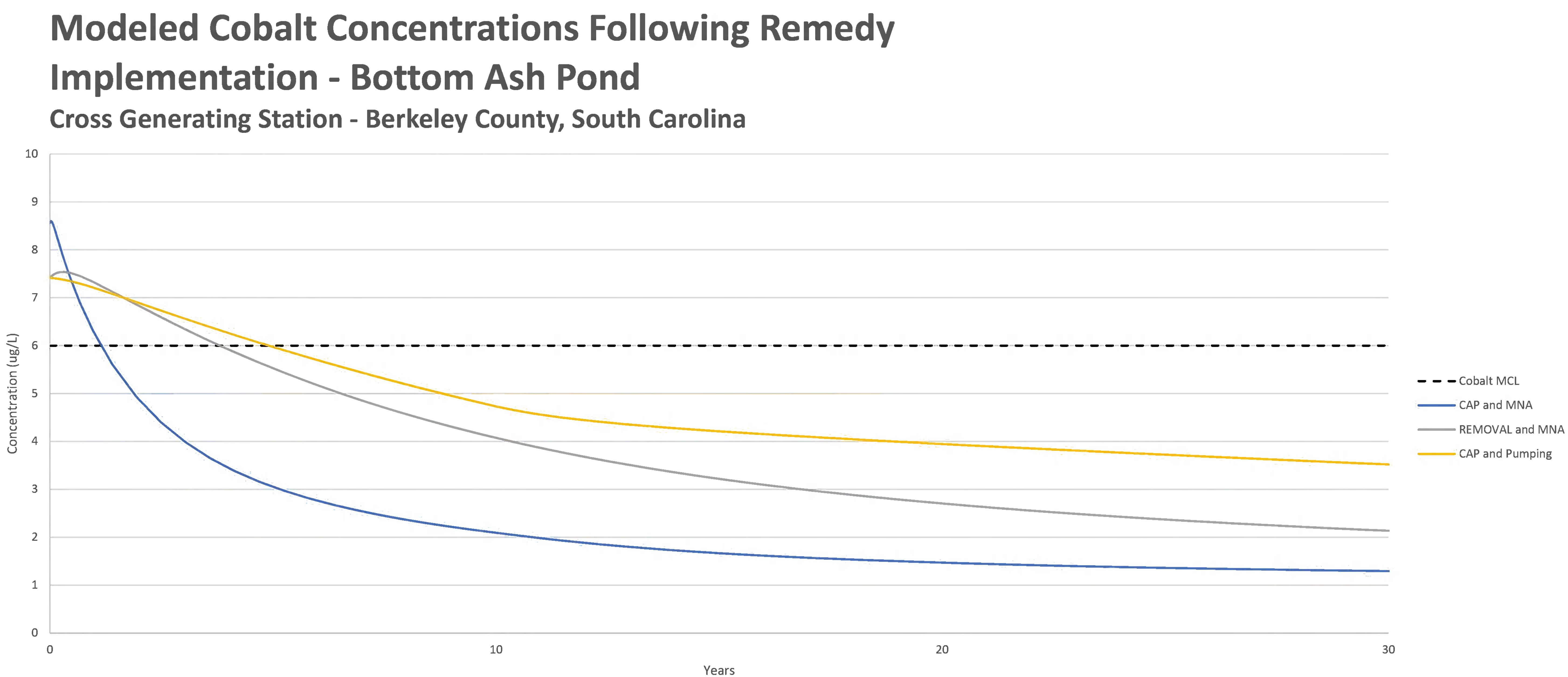
NATURE AND EXTENT
EVALUATION LOCATIONS

SEPTEMBER 2019

FIGURE 6



NOTES:

1.) ug/L - Micrograms per liter

2.) GWPS - Groundwater Protection Standard.

3.) Concentrations are representative of monitoring point approximately 600 feet downgradient

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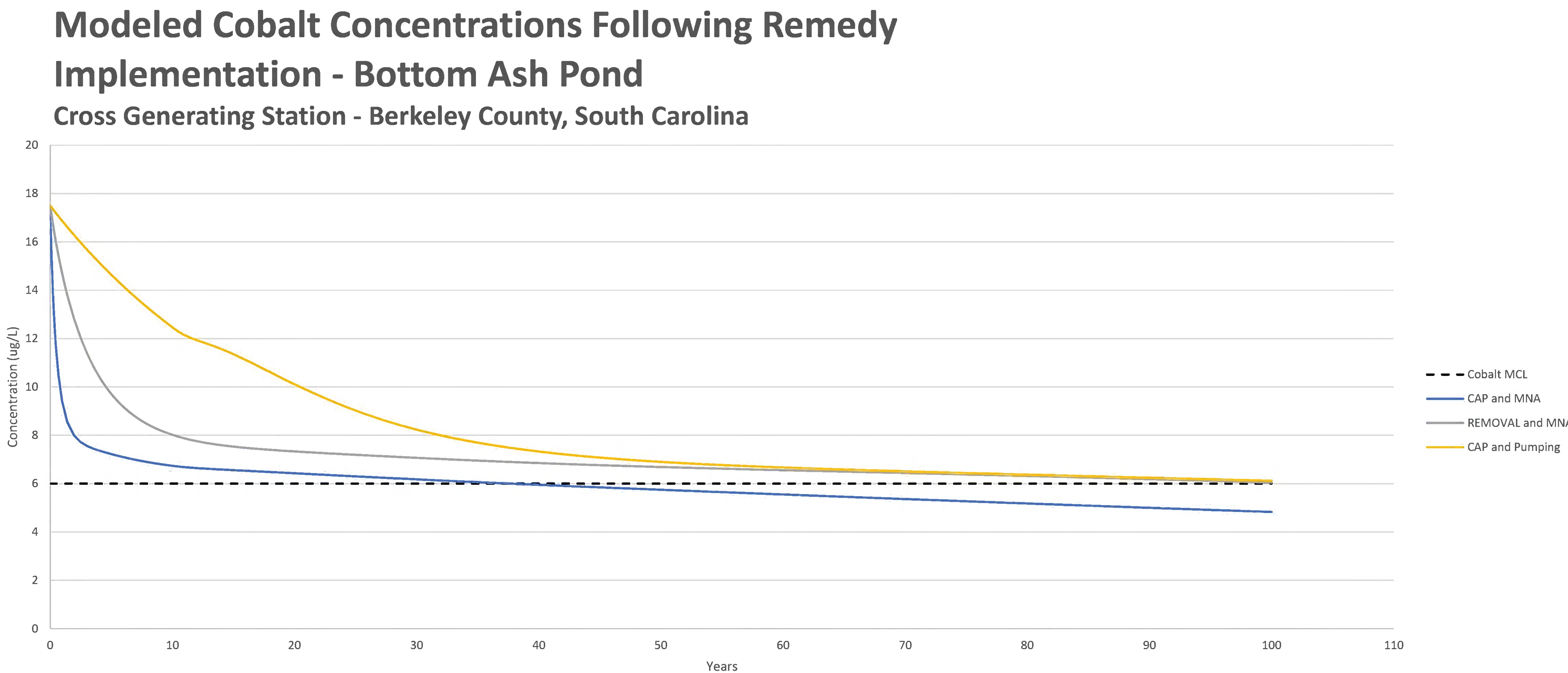
MODELED COBALT CONCENTRATIONS FOLLOWING REMEDY IMPLEMENTATION - BOTTOM ASH POND

September 2019

Figure 7



NOTES:
1.) ug/L - Micrograms per liter
2.) GWPS - Groundwater Protection Standard.
3.) Concentrations are representative of monitoring point approximately 1,200 feet downgradient

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CROSS, SOUTH CAROLINA

MODELED COBALT CONCENTRATIONS FOLLOWING REMEDY IMPLEMENTATION - BOTTOM ASH POND

September 2019

FIGURE 7A

APPENDIX A

Boring Logs

Cross Generating Station
CCR Assessment of Corrective Measures and Nature & Extent
Ash Pond Transect
Transect 1

Sample Location	Transect	Screen Intervals (ft, bgs)	GW Depth (feet)	Sample Date	Sample Time	Temp round 1 (celcius)	pH round 1 (units)	Eh ORP (mV)	Spec Cond round 1 (uS/cm)	Turbidity (NTU)	Dissolved Oxygen (ppm)	Comments
CCMAPT1-1S	start	26-30	22.4	5/17/2019	1115	22.7	4.38	146	3420	>1000	2.17	tan, very turbid, cleans up some, but still >1000 NTU
CCMAPT1-1S Soil	start	25-30	-----	5/17/2019	1050	-----	-----	-----	-----	-----	-----	top 2 ft, fine to medium mottled tan, orange and gray sand with some silt, then clayey/silty lenses toward the end of the run.
CCMAPT1-2S	500 ft	16-20	13.55	5/17/2019	1600	25.54	4.99	197	362	455	3.37	Started out very turbid and chalky, tan color.
CCMAPT1-2S soil	500 ft	15-20	-----	5/17/2019	1540	-----	-----	-----	-----	-----	-----	Clay from 10 to 15 ft, so had to push down another 5 ft . Still clay, silty clay, banded tan, gray and orange to first 4 ft. Then same colored medium to coarse sand with lenses of that clayey silt from above. Saturated, but not runny.
CCMAPT1-3S	approx. 1000 ft	15-19	5.04	5/17/2019	1725	27.69	4.97	187	527	155	0.96	chalky tan, but cleaned up and cleared up fairly quickly
CCMAPT1-3S soil	approx. 1000 ft	14-19	-----	5/17/2019	1700	-----	-----	-----	-----	-----	-----	lt gray clay at the top 2.5 ft. then lt gray fine grained soupy, running sand that grades to less saturated, but wet, and more consolidated tan, orange and lt gray medium to coarse sand with some silt and clay lenses.
CCMAPT1-4S	1180 ft	15-19	6.88	5/24/2019	1000	17.95	5.14	120	77	>1000	2.06	tan to orange, silts out, but still high turbidity. Lots of water
CCMAPT1-4S Soil	1180 ft	14-19	-----	5/24/2019	952	-----	-----	-----	-----	-----	-----	tan to orange medium to coarse grained with pebbles, saturated with clay and silt so consolidated the first 1 ft.,then orange soupy coarse to very coarse with pebbles, lots of water for 2.5 ft. grades to more silt and clay and coarse to medium consolidated sand. starts getting lt gray lenses toward the end of the run.
CCMAPT1-5S	1600 ft	15-19	2.46	5/24/2019	1102	19.78	5.67	32	96	300	6.37	lt gray color. Still high turbidity.
CCMAPT1-5S Soil	1600 ft	14-19	-----	5/24/2019	1045	-----	-----	-----	-----	-----	-----	tan to orange, medium to coarse sand, moist to saturated but consolidated at top 2.4 ft. Then grades to lt gray to greenish gray sand, more coarse and flowing for 2 ft, then grades to more cohesive, silty clayey medium sand at bottom of the run.
CCMAPT1-6S	2000 ft	14-18	9.11	5/30/2019	1325	25.33	5.73	100	138	>1000	6.27	gray to white color. Still high turbidity.
CCMAPT1-6S Soil	2000 ft	13-18	-----	5/30/2019	1240	-----	-----	-----	-----	-----	-----	17-22 ft run--gray to greenish gray fine to medium silty sand, running sand at top 0.6 ft. Then grades to more clay to silty/sandy gray clay, dry. So ran a soil sample from 13 to 18 ft--alternates from the gray silty, clayey sand (saturated) to dry silty, sandy clay.
CCMAPT1-7S	2500	11-15	7.78	5/30/2019	1636	33.95	5.81	181	11	>1000	6.33	tan to gray color. Still high turbidity.
CCMAPT1-7S Soil	2500	17-22	-----	5/30/2019	1600	-----	-----	-----	-----	-----	-----	17-22 ft run- lt gray to greenish gray silty/sandy clay with lenses of organic material. then at 3.5 ft, more sandy, clayey silt but is wet. Not much to get water so did another run. 22- 26 ft - top 3 inches, as above, then tan to orange soupy/running medium to coarse grained sand with some silt and clay. Then some drier, more sonsolidated layers with shell fragments in it until 3 ft, then more silty/fine to medium tan sand with clay, dry, consolidated.
CCMAP-1 23	boundary well	13-23	-----	5/29/2029	1725	-----	-----	-----	-----	-----	-----	13 to 18 ft run, brown to tan fine to silty sand with clay, moist but consolidated with organic material that grades to gray/greenish gray silty, sandy clay for last foot. 18 to 23 ft run, orange fine to medium sand with some silt, saturated to running, gets coarser at 3.5 ft with coarse to very coarse and pebbles, grades to white shell hash material, silty fine to coarse grained with shell fragments, moist, but not running, consolidated, but comes apart when you handle it.
CCMAP-1	boundary well	13-23		5/29/2019	-----	-----	-----	-----	-----	-----	-----	screen from 13 to 23 ft, sand to 11 ft, bentonite chips to 8.5 ft

CCR ACM and Nature & Extent----Sulfide, Total and Bicarbonate Alkalinity, TOC (Total Organic Carbon), DOC (Dissolved Organic Carbon), Total and Dissolved Metals (Fe, Mg, Mn, Ca, Na, K, Be, Li and Co), Cl, SO4, TDS

Comments/Conditions: "S" is Shallow" and "D" is Deep

Samples were collected by Melanie Goings

Cross Generating Station
CCR Assessment of Corrective Measures and Nature & Extent
Ash Pond Transect
Transect 2

Sample Location	Transect	Screen Intervals (ft, bgs)	GW Depth (feet)	Sample Date	Sample Time	Temp round 1 (celcius)	pH round 1 (units)	Eh ORP (mV)	Spec Cond round 1 (uS/cm)	Turbidity (NTU)	Dissolved Oxygen (ppm)	Comments
CCMAPT2-1S	start	26-30	9.52	5/16/2019	1841	26.23	4.11	206	336	>1000	1.3	
CCMAPT2-1S Soil	start	25-30	-----	5/16/2019	1813	-----	-----	-----	-----	-----	-----	First 8 inches is gray clay. Next 1 foot 5 inches is silty sandy with some coarse sand particles. Remaining is light gray tight packed clay. Water is evident especially in coarse sandy section.
CCMAPT1-2S	500 ft	16-20	12.4	5/23/2019	1730	28.72	6.86	135	159	>1000	6.31	tan and kept going dry. Took almost 2 hours to fill sample bottles
CCMAPT2-2S	500 ft	15-20	-----	5/23/2019	1656	-----	-----	-----	-----	-----	-----	tan clay , medium to coarse sand in lenses to approx 19 ft bls, then greenish gray, silty/clayey fine to medium sand . Was moist, but hole caved in to 14 ft. Took another soil sample in another hole fiom 10 to 15 ft. even drier, It gray to tan silty clay with some sand lenses.
CCMAPT2-3S	1000 ft	15-19	11.21	5/22/2019	1649	34.09	7.46	23	355	682	4.57	tan went dıy
CCMAPT2-3S Soil	1000 ft	15-20	-----	5/22/2019	1620	-----	-----	-----	-----	-----	-----	medium to coarse grained, saturated sand but still consolidated with very little clay or silt, tan to orange for first 1.1 ft. Then grades to tan to orange coarser sand, very coarse and even pebbles, super saturated, and running. At 3.11 ft, green fine grained silt with some clay, still saturated, mushy.
CCMAPT2-4S	1500 ft	15-19	1.05	5/22/2019	1500	31.48	6.74	28	2500	>1000	2.81	tan. Went dıy
CCMAPT2-4S Soil	1500 ft	15-20	-----	5/22/2019	1437	-----	-----	-----	-----	-----	-----	Top 3.5 ft, lt gray, Coarse to very coarse grained, saturated sand with little clay and silt stringers--pretty clean sand, almost running . Starts gradeing to more silt and clay and more medium to coarse grained. Color also gets more tan and orange. dıyer and more consolidated.
CCMAPT2-5S	2000 ft	15-19	7.75	5/22/2019	1151	21.46	5.3	107	184	752	3.9	tan to orange color. Went dıy.
CCMAPT2-5S Soil	2000 ft	14-19	-----	5/22/2019	1131	-----	-----	-----	-----	-----	-----	very coarse to coarse white to lt gray sand with little silt. Saturated bu cohesive for 3.4 ft. Then grades more silt and clay, less coarse, tan to reddish sand.
CCMAPT2-6S	2280 ft	15-19	2	5/22/2019	1043	19.93	5.08	94	76	508	6.42	tan or brown color. Turbidity better
CCMAPT2-6S Soil	2280 ft	15-20	-----	5/22/2019	1027	-----	-----	-----	-----	-----	-----	tan to orange, medium to coarse sand, very saturated sand at top 2.2 ft. Then grading to less coarse (medium to fine) sand to silt, with silty clay lenses, more cohesive. At 4 ft, backto tan sand with red, some silty tomedium and coarse sand. Not as saturated.
CCMAP-2 23	boundary well	13-23	-----	5/29/2019	1126	-----	-----	-----	-----	-----	-----	first run, 13-18 ft--mottled tan, orange, red and lt gray fine to medium sand with some silt, saturated but cohesivee to 3.4 ft, then grades to medium to coarse sand, very saturated sand, tan to orange. next run of 18 to 23 was tan sand as above but running to 4 ft then grades more silt and consolidated and not as running.
CCMAP-2	boundary well	13-23		5/29/2029								Screen from 13 to 23, sand from 11 to 13 ft, and bentonite chips to 8.5 ft. neat cement to surface

CCR ACM and Nature & Extent----Sulfide, Total and Bicarbonate Alkalinity, TOC (Total Organic Carbon), DOC (Dissolved Organic Carbon), Total and Dissolved Metals (Fe, Mg, Mn, Ca, Na, K, Be, Li and Co), Cl, SO4, TDS
Comments/Conditions: "S" is Shallow" and "D" is Deep
Samples were collected by Melanie Goings

APPENDIX B

Laboratory Analytical Reports

HALEY ALDRICH

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Analytical Services

Sample ID	Location Code	Description	Sample Date	Alkalinity	Beryllium	Beryllium Dissolved	Bicarbonate Alkalinity	Calcium	Calcium Dissolved	Chloride	Cobalt	Cobalt Dissolved	Depth	Dissoloved Organic Carbon	Dissolved Oxygen	Dissolved Oxygen Rep 1	Dissolved Oxygen Rep 2	Elevation
				mg/L	ug/L	ug/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	Feet	mg/L	ppm	ppm	ppm	Feet
				SM 2320B	EPA 6020B	EPA 6020B	SM 2320B	EPA 6020B	EPA 6020B	EPA 300.0	EPA 6020B	EPA 6020B		SM 5310B				
AE43246	CAP-1		5/21/19	25.8	11.1	9.4	25.8	291	297	256	24.0	22.7	6.78	6.57	0.670	0.790	0.730	75.92
AE43247	CAP-3		5/21/19	333	<0.50	<0.50	333	514	550	634	27.3	23.8	16.05	3.58	0.540	0.610	0.590	75.44
AE43336	CAP-5		5/22/19	<4.00	4.6	4.4	<4.00	149	139	578	14.0	13.5	18.01	3.23	0.69	0.72	0.7	73.77
AE43337	CAP-7		5/22/19	52.1	<0.50	<0.10	52.1	887	786	1680	9.1	9.1	16.82	3.67	0.790	0.960	0.870	74.82
AE43338	CAP-9		5/22/19	<4.00	15.7	15.0	<4.00	518	472	1070	38.3	36.5	16.56	2.04	0.660	0.660	0.650	75.03
AE43339	CAP-9	DUP	5/22/19	<4.00	17.9	14.8	<4.00	509	477	1060	37.2	37.2		1.93				
AE44585	CCMAP-1		6/4/19	176	<0.500	<0.500	176	79.9	58.6	6.50	1.19	<1.00	8.39	1.75	0.57	0.62	0.6	71.82
AE44586	CCMAP-1	Duplicate	6/4/19	194	<0.500	<0.500	194	72.8	54.6	6.31	1.03	<1.00		3.70				
AE44587	CCMAP-2		6/4/19	45.9	<0.500	<0.500	45.9	11.2	11.7	4.95	<1.00	<1.00	8.28	1.67	0.51	0.59	0.55	72.96

Iron	Iron - Dissolved	Lithium	Lithium Dissolved	Magnesium	Magnesium Dissolved	Manganese	Manganese Dissolved	Oxidation Reduction Potential	Oxidation Reduction Potential 1	Oxidation Reduction Potential 2	pH	pH Round 1	pH Round 2	Potassium	Potassium Dissolved	Sodium	Sodium Dissolved	Spec. Cond.	Spec. Cond. Round 1	Spec. Cond. Round 2
ug/L	**ug/L**	**ug/L**	**ug/L**	**mg/L**	**mg/L**	**ug/L**	**ug/L**	**mv**	**mv**	**mv**	**SU**	**SU**	**SU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**uS**	**uS**	**uS**
EPA 6020B	EPA 6020B	EPA 6010D	EPA 6010D	EPA 6020B	EPA 6020B	EPA 6020B	EPA 6020B	SM2580	SM2580	SM2580				EPA 6020B	EPA 6020B	EPA 6020B	EPA 6020B			
42400	42300	120	110	8.2	8.1	131	148	98.0	92.0	95.0	4.73	4.74	4.73	0.57	0.56	66.7	67.0	1770	1720	1750
1360	692	11	<10	59.1	56.5	2770	2440	84.0	91.0	85.0	6.35	6.31	6.33	3.9	3.5	91.7	87.4	3250	3320	3240
11800	94600	12	13	3.7	3.5	57.6	57.3	104	98.0	102	3.96	4	3.97	0.72	0.66	87.0	78.6	1970	1970	1960
218000	214000	<10	<10	183	225	7540	7110	81.0	87.0	84.0	5.47	5.47	5.47	15.3	14.1	188	163	6880	6960	6980
94600	84300	65	62	55200	49.9	937	903	252	246	249	3.86	3.87	3.87	7.2	6.9	156	136	4020	3980	3990
89300	82200	60	59	52300	47.9	904	890							6.8	6.7	155	131			
267	229	11	<10	2.33	2.0	309	177	-55	-54	-55	7.28	7.29	7.28	0.965	0.912	9.39	8.51	341	341	342
362	153	<10	<10	2.17	2.01	248	176							0.943	0.916	8.8	9.09			
<100	<100	<10	<10	0.357	0.37	23.5	23.2	37	33	36	6.31	6.31	6.3	1.02	1.01	9.55	9.45	111	111	112

Sulfate	Sulfide	Temp	Temp Round 1	Temp Round 2	Total Dissolved Solids	Total Organic Carbon	Turbidity	Turbidity Rep 1	Turbidity Rep 2
mg/L	**mg/L**	**C**	**C**	**C**	**mg/L**	**mg/L**	**NTU**	**NTU**	**NTU**
EPA 300.0	EPA 9034				SM 2540C	SM 5310B			
704	<0.100	25.59	25.58	25.61	1392	7.50	64.0	122	82.4
907	<0.100	28.90	28.43	28.95	3080	3.54	1.40	5.70	3.00
<2.0	<0.100	21.99	22.00	21.89	1624	2.34	3.80	2.5	1.6
1700	<0.100	23.34	22.85	22.83	5512	4.56	0	0	0
541	<0.100	24.63	24.78	24.67	3359	1.90	0	0	0
518	<0.100				3422	3.11			
<2.0	<0.100	26.17	25.92	26.04	231.2	1.83	44.7	44.2	46.7
<2.0	<0.100				263.8	3.82			
<2.0	<0.100	19.97	20.2	19.96	71.25	1.69	0	6.1	3.4

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Sample ID	Location Code	Description	Sample Date	Antimony	Arsenic	Barium	Boron	Cadmium	Calcium	Chloride	Chromium	Cobalt	Depth	Dissolved Oxygen	Dissolved Oxygen Rep 1	Dissolved Oxygen Rep 2	Elevation	Fluoride
				ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	mg/L	ug/L	ug/L	Feet	ppm	ppm	ppm	Feet	mg/L
				EPA 6020B	EPA 6020B	EPA 6020B	EPA 6010D	EPA 6020B	EPA 6020B	EPA 300.0	EPA 6020B	EPA 6020B						EPA 300.0
AE35558	CLF1B-5D		2/13/19		<5.0	17.4	<15	<0.50		5.47	<5.0		4.38	1.31	1.45	1.40	76.55	
AE35563	CLF1B-1		2/12/19		<5.0	155	<15	<0.50	176	36.3	<5.0		6.27	1.22	1.43	1.32	77.49	<0.10
AE35564	CLF1B-1	DUP	2/12/19		<5.0	158	<15	<0.50	181	36.8	<5.0							<0.10
AE35565	CLF1B-2		2/12/19		<5.0	190	16	<0.50	152	80.1	<5.0		4.63	0.820	0.870	0.840	77.41	<0.10
AE35566	CLF1B-3		2/12/19		<5.0	134	44	<0.50	198	29.0	<5.0		5.44	0.760	0.790	0.760	77.31	<0.10
AE35567	CLF1B-4		2/12/19		<5.0	48.1	18	<0.50	110	54.4	<5.0		5.38	1.80	2.20	1.99	77.36	<0.10
AE35568	CLF1B-5		2/13/19		<5.0	104	18	<0.50	257	134	<5.0		3.87	0.670	0.700	0.670	77.22	<0.10
AE35569	CBW-1		2/12/19	<5.0	<5.0	42.7	<15	<0.50	24.4	2.68	<5.0	0.84	8.66	0.990	1.16	1.05	77.14	0.18
AE36203	CLF1B-5	Cobolt Only	2/13/19									3.2						
AE36204	CLF1B-5D	Cobolt Only	2/13/19									<0.50						

Iron	Lead	Lithium	Mercury	Molybdenum	Nitrate	Oxidation Reduction Potential	Oxidation Reduction Potential 1	Oxidation Reduction Potential 2	pH	pH Round 1	pH Round 2	Radium 226	Radium 226/228 Combined Calculation	Radium 228	Selenium	Spec. Cond.	Spec. Cond. Round 1	Spec. Cond. Round 2	Sulfate	Temp
ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	mv	mv	mv	SU	SU	SU	pCi/L	pCi/L	pCi/L	ug/L	uS	uS	uS	mg/L	C
EPA 6020B	EPA 6020B	EPA 6010D	EPA 7470	EPA 6010D	EPA 300.0	SM2580	SM2580	SM2580				EPA 903.1 Mod	EPA 903.1 Mod	EPA 904.0	EPA 6020B				EPA 300.0	
206	<1.0				<0.10	42.0	50.0	45.0	7.32	7.32	7.33				<10.0	352	353	351	<2.00	16.41
92.6	<1.0				0.26	118	126	121	6.82	6.83	6.83				<10.0	946	946	947	139	17.62
114	<1.0				0.31										<10.0				137	
221	<1.0				<0.10	44.0	52.0	48.0	7.07	7.07	7.07				<10.0	720	723	719	13.5	19.87
1110	<1.0				0.30	19.0	28.0	22.0	6.82	6.82	6.82				<10.0	975	986	979	191	20.00
<50.0	<1.0				0.24	37.0	35.0	36.0	7.38	7.39	7.38				<10.0	507	506	506	13.7	23.25
1670	<1.0				0.29	36.0	44.0	37.0	6.71	6.71	6.71				<10.0	1370	1370	1370	203	15.86
87.3	2.5	<10	<0.20	<10	0.14	111	103	107	4.50	4.50	4.50	<1.00	0.346	<3.00	<10.0	202	201	202	69.1	18.04

Temp Round 1	Temp Round 2	Thallium	Total Dissolved Solids	Total Organic Carbon	Turbidity	Turbidity Rep 1	Turbidity Rep 2	Zinc
C	C	ug/L	mg/L	mg/L	NTU	NTU	NTU	ug/L
		EPA 6020B	SM 2540C	SM 5310B				EPA 6020B
16.38	16.40		198.8	<1.00	0.900	0.800	0.800	<10.0
17.54	17.55		617.5	2.14	0	0	0	<10.0
			617.5	2.28				<10.0
19.48	19.69		476.2	1.35	0	0	0	<10.0
19.78	20.02		651.2	3.93	0	0	0	<10.0
23.17	23.18		331.2	1.17	0	2.40	0.800	<10.0
15.99	15.87		921.2	1.44	1.80	4.00	1.60	<10.0
17.67	17.84	<1.0	135.0	2.69	0.500	1.00	0	<10.0

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Sample ID	Location Code	Description	Sample Date	Alkalinity	Beryllium		Beryllium Dissolved		Bicarbonate Alkalinity	Calcium		Calcium Dissolved		Chloride	Cobalt	Cobalt Dissolved	Depth	Dissoloved Organic Carbon
				mg/L	ug/L		ug/L		mg/L	mg/L		mg/L		mg/L	ug/L	ug/L	Feet	mg/L
				SM 2320B	EPA 6010D	EPA 6020B	EPA 6010D	EPA 6020B	SM 2320B	EPA 6010D	EPA 6020B	EPA 6010D	EPA 6020B	EPA 300.0	EPA 6020B	EPA 6020B		SM 5310B
AE42849	GW_MISC	CLMAPT 2-1S	5/16/19	<4.00		12.0		11.0	<4.00		373		338	991	36.5	29.2	9.52	1.87
AE42993	GW_MISC	CCMAPTI 1-1S	5/17/19	<4.00		4.2		3.1	<4.00		494		490	887	27.7	24.0	22.40	1.18
AE42994	GW_MISC	CCMAPTI 1-2S	5/17/19	4.02		2.3		2.2	4.02		34.5		32.9	97.2	32.3	28.2	13.55	1.05
AE42995	GW_MISC	CCMAPTI 1-3S	5/17/19	11.1		15.8		2.0	11.1		75.0		67.7	165	72.6	20.4	5.04	1.18
AE43325	GW_MISC	CCMAPT2-6S	5/22/19	35.6		0.87		<0.50	35.6		3.3		3.1	7.13	4.0	0.84	2.00	1.25
AE43326	GW_MISC	CCMAPT2-5S	5/22/19	38.2		10.1		0.61	38.2		10.4		10.9	43.8	62.8	59.8	7.75	1.00
AE43327	GW_MISC	CCMAPT2-4S	5/22/19	193		75.3		<0.50	193		499		46.0	568	149	130	1.05	1.90
AE43328	GW_MISC	CCMAPT2-3S	5/22/19	183		6.4		2.1	183		81.0		72.3	15.9	15.6	2.1	11.21	1.39
AE43641	GW_MISC	CCMAPT 2-2S	5/23/19	67.6		1.3		<0.50	67.6		18.9		14.7	6.10	4.5	0.84	12.40	1.47
AE43642	GW_MISC	CCMAPT 1-4S	5/24/19	29.6		13.3		<0.50	29.6		11.6		5.9	12.1	102	3.6	6.88	<1.00
AE43643	GW_MISC	CCMAPT 1-5S	5/24/19	29.8		0.79		<0.50	29.8		1.5		1.6	6.47	6.1	4.4	2.46	1.22
AE44091	CCMAPT1-6	CCMAPT1-6	5/30/19	21.1	<4.0	<2	<4.0	<2	21.1	7.0		5.9		9.90	<10	<10	9.11	1.98
AE44092	CCMAPT1-7	CCMAPT1-7	5/30/19	978	<4.0	<2	<4.0	<2	978	120		84		<2.0	<10	<10	7.78	2.84

Dissolved Oxygen	Elevation	Iron		Iron - Dissolved	Lithium	Lithium Dissolved	Magnesium		Magnesium Dissolved	Magnesium Dissolved	Manganese		Manganese - Dissolved	Manganese Dissolved	Oxidation Reduction Potential	pH	Potassium		Potassium Dissolved	
ppm	**Feet**	**ug/L**		**ug/L**	**ug/L**	**ug/L**	**mg/L**		**mg/L**	**mg/L**	**ug/L**		**ug/L**	**ug/L**	**mv**	**SU**	**mg/L**		**mg/L**	
		EPA 6010D	EPA 6020B	EPA 6020B	EPA 6010D	EPA 6010D	EPA 6010D	EPA 6020B	EPA 200.7	EPA 6020B	EPA 6010D	EPA 6020B	EPA 200.7	EPA 6020B	SM2580		EPA 6010D	EPA 6020B	EPA 6010D	EPA 6020B
1.30	80.76		178000	135000	47	43		47.8		46.4		774		698	206	4.11		6.3		5.3
2.17	67.46		36100	2420	17	18		32.8		31.8		805		746	146	4.38		9.4		7.5
3.37	65.08		3480	663	<10	<10		6.0		5.8		230		219	197	4.99		3.9		3.5
0.960	72.21		147000	2800	15	13		14.2		7.6		405		172	187	4.97		7.6		3.7
6.42	75.22		32900	1290	<10	<10		0.95		0.59		124		59.9	94.0	5.08		2.0		0.77
3.90	61.75		2890	2580	<10	<10		3.8		3.8		515		511	107	5.30		2.9		2.6
2.81	75.09		8740	1930	<10	<10		20.0		18.6		1780		1800	28.0	6.74		4.3		3.1
4.57	53.58		38400	3000	18	10		1.9		1.1		493		168	23.0	7.46		1.9		0.80
6.31	63.92		18900	666	<10	<10		2.5		0.66		40.4		16.6	135	6.86		2.9		1.1
3.64	71.16		107000	77.0	13	<10		5.3		0.44		1130		93.4	120	6.88		5.1		0.81
2.87	75.54		19900	11500	<10	<10		1.2		0.58		149		124	32.0	2.46		1.5		0.60
6.27	67.54	7800	6520	3490	11	11	1.3	1.08	0.75	0.703	46	38	26	23	100	5.73	1.5	1.29	0.83	0.786
6.33	69.32	6200	6110	460	<10	<10	3.9	3.70	3.1	2.91	530	509	470	452	181	5.81	2.2	2.33	1.8	2.04

Sodium		Sodium Dissolved		Spec. Cond.	Sulfate	Sulfide	Temp	Total Dissolved Solids	Total Organic Carbon	Turbidity
mg/L		mg/L		uS	mg/L	mg/L	C	mg/L	mg/L	NTU
EPA 6010D	EPA 6020B	EPA 6010D	EPA 6020B		EPA 300.0	EPA 9034		SM 2540C	SM 5310B	
	143		136	336	683	<0.100	26.33	2746	1.84	>1000
	98.2		95.9	3420	385	<0.100	22.70	3201	<1.00	>1000
	17.9		17.6	362	13.3	<0.100	25.54	377.5	<1.00	455
	20.2		22.5	527	18.7	<0.100	27.69	595.0	1.01	155
	3.8		4.2	76.0	<2.0	<0.100	19.93	58.75	1.03	508
	10.1		9.6	184	<2.0	<0.100	21.46	142.5	<1.00	752
	75.3		69.9	2500	489	<0.100	31.48	2534	1.69	>1000
	6.4		6.4	355	<2.0	<0.100	34.09	438.8	<1.00	682
	4.0		3.8	159	2.65	<0.100	28.72	348.8	<1.00	>1000
	4.7		4.9	77.0	<2.0	<0.100	17.95	136.2	<1.00	>1000
	5.8		5.2	96.0	<2.0	<0.100	19.78	76.25	<1.00	300
9.0	9.45	8.8	9.83	138	<2.0	<0.100	25.33	423.8	<2.00	>1000
11	11.0	12	10.8	11.0	<2.0	<0.100	33.95	273.8	3.71	>1000

santee cooper

Analytical Services

Sample ID	Location Code	Description	Sample Date	Beryllium	Calcium	Cobalt	Iron	Lithium	Magnesium	Manganese	Potassium	Sodium	SPLP Beryllium	SPLP Calcuim	SPLP Cobolt	SPLP Iron	SPLP Lithium	SPLP Magnesium
				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/Kg	mg/kg	mg/kg	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
				SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 1312/6010 D	SW846 1312/6010 D	SW846 1312/6010 D	SW846 1312/6010	SW846 1312/6010 D	SW846 1312/6010 D
AE42850	GW_MISC	CLMAPT 2-1S Soil	5/16/19	1.16	3100	<0.833	1320	<6.7	361	6.06	508	43.1	<0.05	29.9	<0.05	32.2	<0.050	6.14
AE42996	GW_MISC	CCMAPTI 1-1S	5/17/19	<0.659	976	<0.659	12900	<6.6	208	9.98	298	40.2	<0.05	11.2	<0.05	<1.0	<0.050	<3.0
AE42997	GW_MISC	CCMAPTI 1-2S	5/17/19	<0.648	355	2.2	6250	<5.4	330	18.4	329	<32.4	<0.05	<2.0	<0.05	<1.0	<0.050	<3.0
AE42998	GW_MISC	CCMAPTI 1-3S	5/17/19	<0.562	599	1.97	5560	<6.3	245	5.97	248	<28.1	<0.05	8.37	<0.05	60.2	<0.050	3.54
AE43329	GW_MISC	CCMAPT2-6S Soil	5/22/19	<0.592	33.6	<0.592	3640	<6.4	49.8	5.53	57.7	<29.6	<0.05	<2.0	<0.05	<1.0	<0.050	<3.0
AE43330	GW_MISC	CCMAPT2-5S Soil	5/22/19	<0.574	<28.7	0.885	340	<5.4	<34.4	4.7	45.7	<28.7	<0.05	<2.0	<0.05	<1.0	<0.050	<3.0
AE43331	GW_MISC	CCMAPT2-4S Soil	5/22/19	<0.583	140	1.14	111	<5.5	<35	1.5	<29.2	<29.2	<0.05	4.49	<0.05	<1.0	<0.050	<3.0
AE43332	GW_MISC	CCMAPT2-3S Soil	5/22/19	<0.599	356	1.08	1520	<6.4	36.9	44.7	44.3	<29.9	<0.05	5.48	<0.05	26.8	0.078	<3.0
AE43644	GW_MISC	CCMAPT 2-2S Soil	5/23/19	2.81	3630	28	5680	<7.4	802	24	927	39.5	<0.05	8.96	<0.05	18.5	0.089	3.74
AE43645	GW_MISC	CCMAPT 1-4S Soil	5/24/19	0.749	546	8.81	9280	<6.2	335	35.4	310	<29.5	<0.05	2.36	<0.05	7.54	<0.050	<3.0
AE43646	GW_MISC	CCMAPT 1-5S Soil	5/24/19	0.583	45	1.02	3700	<6.4	262	9.91	262	<29.1	<0.05	<2.0	<0.05	32.1	<0.050	<3.0
AE44093	GW_MISC	POZ 854	5/28/19		355000	2.42	4320		4540	426	1420	222		10.3	<0.05	<1.0		<3.0
AE44094	GW_MISC	CCMAP-223	5/29/19	<0.669	185	0.781	3080	<6.3	94.8	14.6	136	<33.5	<0.05	<2.0	<0.05	<1.0	<0.050	<3.0

SPLP Manganese	SPLP Potassium	SPLP Sodium	Total Organic Carbon
mg/L	mg/L	mg/L	mg/L
SW846 1312/6010 D	SW846 1312/6010 D	SW846 1312/6010 D	SM 5310B
<0.1	7.95	18.6	1740
<0.1	<1.5	3.63	770
<0.1	<1.5	<3.0	560
<0.1	3.37	9.91	620
<0.1	<1.5	<3.0	680
<0.1	<1.5	<3.0	<500
<0.1	<1.5	<3.0	<500
0.243	<1.5	4.84	<500
<0.1	3.05	25	2780
<0.1	<1.5	21.6	530
<0.1	2.04	8.32	<500
<0.1	<1.5	<3.0	205000
<0.1	<1.5	<3.0	640

Sample ID	Location Code	Description	Sample Date	Beryllium	Calcium	Cobalt	Iron	Lithium	Magnesium	Manganese	Potassium	Sodium	SPLP Beryllium	SPLP Calcuim	SPLP Cobolt	SPLP Iron	SPLP Lithium	SPLP Magnesium
				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/Kg	mg/kg	mg/kg	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
				SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 6010D	SW846 1312/6010 D	SW846 1312/6010 D	SW846 1312/6010 D	SW846 1312/6010	SW846 1312/6010 D	SW846 1312/6010 D
AE44095	GW_MISC	CCMAP-123	5/29/19	1.61	17200	8.94	16200	8.8	940	311	909	55.3	<0.05	8.84	<0.05	2.49	0.18	<3.0
AE44096	GW_MISC	CCMAPT 1-6	5/30/19	<0.622	1360	1.6	1700	<6.0	469	12.7	492	59.5	<0.05	<2.0	<0.05	5.11	<0.050	<3.0
AE44097	GW_MISC	CCMAPT 1-7	5/30/19	<0.668	378000	3.09	3860	92	3670	286	734	186	<0.05	7.52	<0.05	<1.0	<0.050	<3.0
AE44098	GW_MISC	CBW-120	5/30/19	<0.541	126	<0.541	425	<5.8	<32.4	2.35	56	<27	<0.05	2.04	<0.05	<1.0	<0.050	<3.0
AE44099	GW_MISC	PM-120	5/30/19	<0.654	1270	<0.654	744	<6.5	155	4.54	211	<32.7	<0.05	5.87	<0.05	4.32	<0.050	<3.0

SPLP Manganese	SPLP Potassium	SPLP Sodium	Total Organic Carbon
mg/L	**mg/L**	**mg/L**	**mg/L**
SW846 1312/6010 D	SW846 1312/6010 D	SW846 1312/6010 D	SM 5310B
<0.1	<1.5	18.5	11300
<0.1	<1.5	16.2	870
<0.1	<1.5	<3.0	158000
<0.1	<1.5	<3.0	<500
<0.1	<1.5	20.6	1610

APPENDIX C

Groundwater Model Output

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APPENDIX A:
GROUNDWATER FLOW MODELING
SANTEE COOPER BOTTOM ASH POND
CROSS, SOUTH CAROLINA

by
Haley & Aldrich of New York
Rochester, New York

for
Santee Cooper
Moncks Corner, South Carolina

File No. 131539-003
September 2019

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1. Groundwater Flow Modeling

A groundwater flow and solute transport model was constructed to evaluate and compare potential corrective measures in support of the Corrective Measures Assessment (CMA) for the Santee Cooper Bottom Ash Pond in Cross, South Carolina. The following text describes the model construction, calibration and subsequent simulations of remedy alternatives for Appendix IV constituents above the Groundwater Protection Standard (GWPS).

The numerical model MODFLOW-2005 (Harbaugh, 2005) was selected for the modeling effort and is a three-dimensional, finite difference groundwater flow model capable of simulating the groundwater conditions under various scenarios including pumping and changes to infiltration over time.

1.1 MODEL DOMAIN

The model domain was established to encompass the Santee Cooper Cross Generating Station (Site) and surrounding areas that represented model boundaries including the nearby and unnamed surface water channel located to the south of the landfill and Lake Moultrie to the east. Given its distance from the Site, it was not necessary to encompass Lake Marion to the west within the model domain.

MODFLOW uses a rectangular grid within the domain and allows for establishing irregular groundwater flow boundary conditions that represent actual and Site-specific features in the study area. The setup is facilitated by assigning boundary types and values to specific grid cells. Figure 1 depicts the model domain boundary overlain on an aerial photograph of the Site.

Figure 2 depicts the model domain with the grid spacing selected for the model. The three-dimensional finite difference groundwater flow model domain covers a length of 11,710 feet in the x-direction (west to east), 14,330 feet in the y-direction (north to south), and approximately 50 feet in the z-direction (vertical). The grid layers were set to a minimum thickness of 0.1 feet to avoid model inconsistencies associated with pinch outs and rapid cell drying. The model consists of 413 rows 450 columns, and 5 layers for a total of 929250 cells covering an approximate area of 3852 acres. In MODFLOW, the groundwater-flow system is subdivided laterally and vertically into rectilinear blocks called cells. The hydraulic properties of the material in each cell are assigned and assumed to be uniform within each cell. The row and column dimension of each cell is variable based on proximity to the Site. This variability was created to allow for finer resolution within the vicinity of the primary flow pathway for the Site.

A Digital Elevation Model (DEM) was obtained from the USGS website to create the surface of the model for the Site. Lithologic descriptions contained in the boring logs generated during various phases of environmental investigations as well as cross-sections prepared as part of the 2011 Site Hydrogeologic Characterization report were used to develop formation geometry and hydraulic properties. The cross-sections that were utilized to build the model are provided in Appendix A. The Site was divided into three vertical lithologic units to represent geologic conditions underlying the Site and to account for vertical heterogeneities within the model.

A summary of each geologic unit is as follows:

- Wicomico Formation – Unconsolidated, upward-fining sequences of poorly sorted sand, silt, and clay deposited in a near-shore marine depositional setting that includes barrier islands and back-barrier depositional environments. This depositional setting produces soil types that grade laterally and vertically from more sandy types to more clayey soil types.

- Raysor Formation – Unconsolidated or weakly cemented discontinuous layer of sandy limestone that contains abundant weathered mollusk shells deposited in a shallow marine-shelf environment.

- Santee Limestone – Thin highly weathered layer consisting of relatively dense partially indurated, shelly, fine to medium sand. This thin layer is underlain by a thick consolidated layer of variably weathered crystalline, soft to hard, medium to light gray, shelly to muddy limestone.

Elevations used in the model were determined from digital elevation models for the area. The topography of the ground surface is mimicked in the subsequent lower layers; however, the elevation has been reduced by the layer thickness. Layer thicknesses were determined through the review of the above-mentioned Site geology.

Figure 3 depicts the two-dimensional views of the model layer elevations. The surfaces shown in Figure 3 represent the model top (i.e., land surface), the flat model bottom, and all the lithologic interfaces between.

1.2 BOUNDARY CONDITIONS

Boundary conditions define the locations and manner in which water enters and exits the active model domain. The conceptual model for the groundwater system that forms the basis for the model boundaries are as follows:

1. Nearby lakes Marion (used to estimate western boundary elevations) and Moultrie in addition to the nearby connection canal between the two lakes control groundwater flow on three sides of the model,
2. Recharge at the Site creates radial flow away from the Site toward the nearby water bodies,
3. There is an easterly component of flow from Lake Marion to Lake Moultrie.

The specified boundaries of the model coincide with predicted natural hydrologic boundaries. To recreate observed groundwater flow, two types of model boundaries were used: specified head boundaries, and the Modflow River package. The locations of these boundary conditions in the model are illustrated in Figure 4 through Figure 8.

1.2.1 Specified Head Boundaries

The MODFLOW Time Variant Specified Head Package (Harbaugh, 2005), also known as the Constant Head Package, was used to simulate boundaries presented in Figure 4 through Figure 8. The package is used to fix the head values in selected grid cells regardless of the conditions in the surrounding grid cells. The cell with the assigned constant head acts either as a source of water entering or a sink of water leaving the system. The values for this boundary are referenced to datum NAVD 88 and range from 76 to 71 feet for Layer 1 through Layer 5. These values were estimated based on topography, the depths to water in wells at the Site, the pattern of groundwater flow, elevations of nearby water bodies, and through calibration of the groundwater flow model as described in Section 1.3 below.

1.2.2 River Boundaries

River boundaries in Modflow are a special form of the head-dependent boundary condition. In a head-dependent boundary, the model computes the difference in head between the boundary and the model cell to calculate the amount of water flowing into or out of the model through the boundary. Figure 4 represents the river boundary condition representing the canal between the two lakes near the Site. The head assigned to this boundary was calibrated based on the water levels observed in nearby wells, however, the elevation was restricted to elevations observed between the two lakes.

1.3 HYDRAULIC MODEL PROPERTIES

Hydraulic properties were initially assigned consistent with data presented in the 2011 Site Hydrogeologic Characterization Report. Values were assigned for horizontal hydraulic conductivity and vertical hydraulic conductivity. These parameters were iteratively varied during model calibration to achieve the best fit to observed hydraulic patterns including head elevations, hydraulic gradients, and flow directions.

For calibration, uniform hydraulic properties were applied within discrete model layers. Results of the initial calibration indicated that hydraulic conductivities in the range of those values determined from slug tests were representative with regard to groundwater flow observed at the Site. The hydraulic conductivity values used in the model are presented below for the three hydrogeologic units underlying at the Site:

- Wicomico Formation – 25 feet per day (ft/day) or 8.9 x 10-3 centimeters per second (cm/s)
- Raysor Formation – 57.6 ft/day or 2.0 x 10-2 cm/s
- Santee Limestone – 17.7 ft/day or 6.0 x 10-3 cm/s

1.3.1 Calibrated Horizontal and Vertical Hydraulic Conductivity

The calibrated horizontal (K_X and K_Y) and vertical (K_Z) hydraulic conductivity values in Model layer 1 through 5 were distributed uniformly across the model domain. Vertical hydraulic conductivity values were estimated at $1/10^{th}$ of the horizontal hydraulic conductivity values. As previously stated, hydraulic conductivity from slug test data presented in the 2011 Site Hydrogeologic Characterization Report were utilized in the calibration process for hydraulic conductivity in the model.

1.3.2 Porosity, Storage, and Yield

Effective porosity values are needed for particle tracking and solute transport simulations. The effective porosity values were conservatively estimated based on the soil type through the examination of boring logs. Due to the generally sandy aquifer make-up a porosity of 0.25 was utilized for the model. This value is slightly higher than clean sand as most logs depict some amount of fine-grained material. As such, specific storage and specific yield were estimated as being 0.02 and 0.23, respectively.

1.4 METHODS OF EVALUATING MODEL CALIBRATION QUALITY

Model calibration is the process of refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to minimize the difference between the simulated heads and fluxes to the measured data. Construction of a complex model with more parameters than the data support may reduce the residuals (difference between measured and simulated values) but does not ensure a more accurate model. Therefore, calibrated model parameters also need to be checked for their validity. Throughout the calibration process, no adjustments were made that conflicted with the general understanding of the groundwater system and previously documented information.

The iterative calibration process of "trial and error" was used for model calibration. It involves making changes to the input values, running MODFLOW, and assessing the impact of the changes. Beside the trial and error approach, a model independent parameter optimization software tool – PEST was used to adjust selected input values to further improve model calibration (Doherty, 2010).

The quality of model fit can be assessed from many statistical and graphical methods. One method is based on the difference between simulated and observed heads and flows, or residuals. The overall magnitude of the residuals is considered, but the distribution of those residuals, both statistically and spatially, can be equally important. The magnitude of residuals can initially point to gross errors in the model, the data (measured quantity), or how the measured quantity is simulated (Hill, 1998). A useful graphical analysis is a simple scatter plot of all simulated values as a function of all observed values.

For the flow calibration, the statistics of the mean error (ME), mean absolute error (MAE), and the root mean square (RMS) error were used to assess the calibration quality. They are defined as follows:

$$ME = \frac{\sum_{i=1}^{n}(O_i - C_i)}{n}$$

$$MAE = \frac{\sum_{i=1}^{n}|O_i - C_i|}{n}$$

$$RMS = \frac{\sum_{i=1}^{n}(O_i - C_i)^2}{n}$$

Where:
Oi = Observed head at observation point i
Ci = Calculated head at observation point i
n = Number of observation points

The mean error is the average of the differences between the observed and calculated heads (or residuals) and can indicate the overall comparison between computed and observed data. Negative and positive residuals can cancel each other out, resulting in a mean error close to zero even when the calibration is not good. The sign of the mean error is an indication of the overall comparison of the model to the data (e.g. a positive mean error indicates the model is generally computing heads that are too high).

The mean absolute error is the average of the absolute values of the residuals. The absolute value prevents positive and negative residuals from canceling each other, providing a clearer picture of the magnitude of errors across the model, without an indication of the direction (high or low) of the errors. The RMS error is the square root of the average of the squares of the residuals. The RMS adds additional weight to points where the residual is greatest. If the residuals at all points are very similar, the RMS will be close to the mean absolute error. Alternatively, a few points with high errors can add significantly to the RMS for an otherwise well calibrated model. For all three of these criteria the optimal value is zero.

The numerical goals for the groundwater flow model calibration are to (1) minimize the ME and MAE errors and (2) achieve the ratio of the root mean square (RMS) error of the head residuals to the range of observed heads (i.e., normalized RMS error) to be at least less than 10 percent.[1]

Groundwater flow field calibration for the Site has been conducted to provide a reasonable representation of the groundwater flow field in the vicinity of the Site, which forms the basis of assessing cobalt migration potential through the fate and transport process. To accomplish this objective, a MODFLOW numerical model was developed to simulate observed groundwater conditions at the Site through calibrating a representative steady-state flow field. The decision of using a steady-state flow field for the flow model calibration was made through an evaluation of the available groundwater elevation data for the Site. Most importantly is that historical flow patterns have been relatively consistent at the Site; therefore, a steady-state flow model was deemed reasonable to represent average flow conditions.

The evaluation of gauging data resulted in the selection of 12-14 February 2019 as the observed heads for the flow model calibration for representing Site conditions (Table 1).

The numerical calibration goals have been achieved. The mean error in head was -0.04 feet or 1.8 % of the head observation range, 2.14 feet. The absolute residual is +0.16 feet. The RMS error for the calibrated model was +0.20 feet and the normalized RMS error was 9.5%. Presented below is the scatter plot of the observed versus simulated heads, which generally fall along the theoretical slope of 1 to 1. Table 1 provides the observed heads on 12-14 February 2019, as discussed above, used to generate the plot below (Figure A-1). The quality of the flow model calibration meets the calibration goals as described herein.

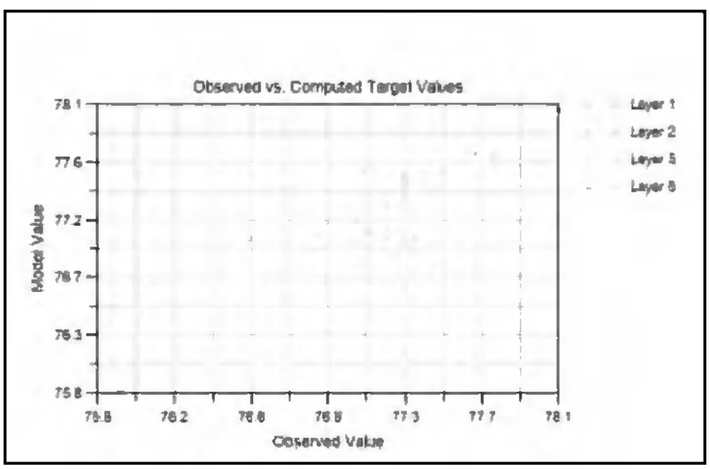

Figure A-1: Calibration scatter plot.

Because the calibration has met the acceptable calibration goals, the groundwater flow model is considered to be usable for the development of the cobalt fate and transport models described in Section 2.0.

[1] Anderson, M.P., Woessner. WW (1992) Applied Groundwater Modeling. Simulation of Flow and Advective Transport.

2. Fate and Transport Modeling

Contaminant fate and transport modeling was conducted utilizing the three-dimensional, numerical model MT3DMS (Version 5 of MT3D) (Zheng, 1990). MT3DMS simulates advection, dispersion, adsorption and decay of dissolved constituents in groundwater using a modular structure similar to MODFLOW to permit simulation of transport components independently or jointly. MT3D interfaces directly with MODFLOW for the head solution and supports all the hydrologic and discretization features of MODFLOW. The MT3D code has a comprehensive set of solution options, including the method of characteristics (MOC), the modified method of characteristics (MMOC), a hybrid of these two methods (HMOC), and the standard finite-difference method (FDM). MT3D was originally released in 1990 as a public domain code from the United State Environmental Protection Agency (USEPA) and has been widely used and accepted by federal and state regulatory agencies.

For this modeling effort, the MT3DMS model utilized the flow regime from the steady-state, calibrated Site groundwater flow model presented in Section 1.0 to simulate transport of cobalt. The steady state model was transformed into a transient model so various CMA options could be evaluated with respect to time. The strength and locations of the potential cobalt sources specified in the transport models were based on current dissolved-phase concentration distributions from groundwater monitoring data at the Site.

In addition to the MODFLOW groundwater flow field discussed in Section 1.0, the fate and transport models require inputs of effective porosity values, dispersivity coefficients, and adsorption rate constants for cobalt. In the modeling effort, input parameter values were defined from Site data, whenever possible, or through the use of conservative literature values.

2.1 TRANSPORT MODELING APPROACH

The solute transport portion of the modeling effort focused mainly on the future flow pathway for cobalt and lithium at the Site. As such, the initial concentration including the current plume extent and the estimated leachable mass near the existing pond were utilized in place as a constant source. The location and initial concentrations for cobalt and lithium within the model (layer 3) is presented in Figures 9.

The calibrated flow model was allowed to run for 100 years following implementation of the groundwater remedy. Calibration of the concentrations through time was not performed on the predictive model as the starting conditions were the current conditions at the Site and thus represent a conservative estimate of transport through the Site.

2.2 KEY PARAMETERS FOR TRANSPORT MODELING

The following sections describe the key input parameters of the transport model, and how they were derived. Note that these parameters were selected for the purpose of comparative evaluation of relative benefits of various corrective measures. The parameters and conditions used for the modeling are selected based on the data available to date. Therefore, simulated remedial timeframes using the parameters described in this section should not be construed as absolute predictions of remedial time frames for various corrective measures.

2.2.1 Effective Porosity

The effective porosities used in the model were presented in previous Section 1.3.2.

2.2.2 Dispersivity

Dispersion incorporates the effects of fluid mixing that result from heterogeneities within the groundwater system and molecular diffusion, which is the random movement of ions or molecules. If the molecules of water and dissolved constituents traveled at the average seepage velocity, there would be an abrupt interface and dispersion would be negligible. However, in natural systems water molecules and dissolved contaminants do not all travel at the same rate; some travel faster and some slower. Dispersion in the model accounts for the spreading of the dissolved plume. Diffusion is time dependent and is significant at low velocities. In general, dispersion acts to decrease the contaminant concentration on the leading edge of the plume, while increasing the size and rate of transport of the dissolved plume. Longitudinal dispersion occurs in the direction of advective groundwater flow, while transverse dispersion occurs perpendicular to groundwater flow.

The groundwater modeling generally accepted longitudinal dispersity value (α_L) estimate is 1 to 100. The horizontal transverse dispersivity (α_T) can be estimated as approximately one-tenth of the α_L, and vertical transverse (α_v) dispersivity can be estimated as one-hundredth of the α_L. The values utilized for dispersivity values are as follows:

- α_L - 100 ft,
- α_T – 10 ft, and
- α_V - 1 ft

2.2.3 First-Order Degradation Rate Constant – Lambda (λ)

Another input parameter for the fate and transport model is the first order degradation rate constant (λ) for cobalt. This rate constant only takes into account degradation of the dissolved constituent during transport, as it leaves the source. This rate constant does not factor in effects of advection, sorption or dispersivity (dispersion). The field-scale degradation rate constant usually can be expressed as a first order decay process. Due to the general lack of decay for metals within the groundwater system, a first-order decay rate was not specified for model simulations.

2.2.4 Retardation Effects

Chemical retardation occurs when a solute (contaminant) reacts with the porous media and its rate of movement is retarded relative the advective groundwater velocity. Retardation can occur by a variety of processes including adsorption and mass transfer in porous media. The effects of retardation are often related to site-specific adsorption isotherms. For this modeling purpose, a liner adsorption isotherm is used to account for the effects of transport retardation that may occur for Site-related contaminants. The effects of retardation on contaminant mobility is usually expressed in terms of a retardation factor (R), which is the ratio of the groundwater velocity to contaminant transport velocity.[2] When a linear adsorption isotherm is used to characterize contaminant mobility, the linear adsorption coefficient (K_d) can be linked to the retardation factor with the the mathematical relationship below:

$$R = \frac{v_{gw}}{v_c} = 1 + \frac{\rho_b}{n} \times K_d$$

[2] Bedient, P.B., Rifai, H.S. and Newell, C.J., 1994. *Ground water contamination: transport and remediation*. Prentice-Hall International, Inc.

where R is the retardation factor, v_{gw} is the groundwater velocity, v_c is contaminant transport, ρ_b is the aquifer solid bulk density, n is the effective transport porosity of the medium, and K_d is the linear adsorption coefficient.

The following describe the adsorption effects of cobalt and lithium based on their geochemical properties and the published empirical data, as well as the choice of the linear adsorption coefficient for each contaminant used for transport modeling.

2.2.5 Adsorption of Cobalt on Aquifer Solids

Cobalt (atomic number 27) is a transition metal in Group VIII of the periodic classification of the elements. The affinity for cobalt to adsorb to the geologic matrix can be affected by factors such as pH, redox conditions, mineral contents of aquifer solids, and the presence of organic ligands in the groundwater system.

The aqueous speciation of cobalt and potential formation of cobalt-related minerals under a spectrum of the electro-potential (Eh) and pH conditions are shown below (Figure A-2). Based on Site groundwater monitoring results, the range of pH is approximately between 4 and 7 and the range of oxidation-reduction potential is approximately between 40 to 170. Since the Site geochemical conditions is not sulfide-genic, the main cobalt species in groundwater is expected to be Co^{2+} related species.

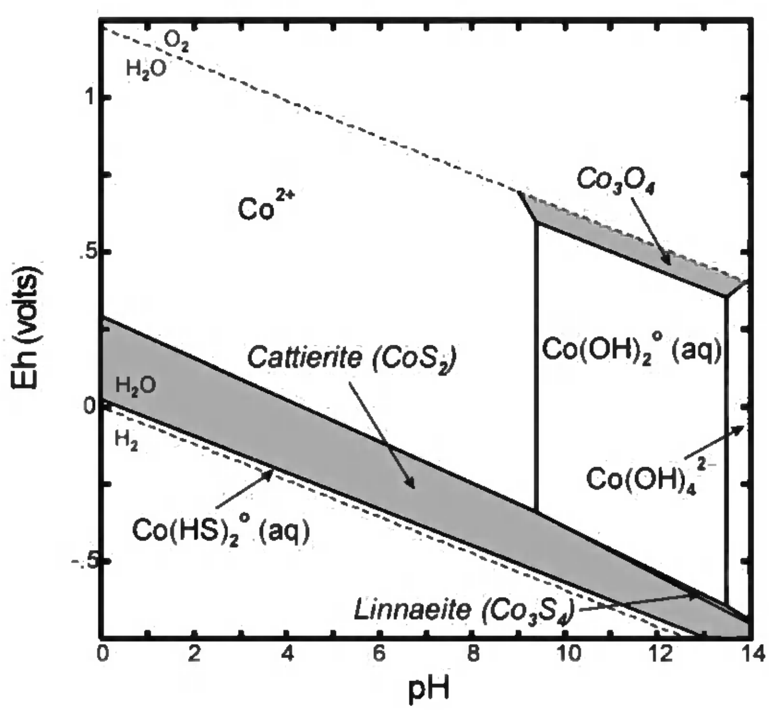

Figure A-2: Eh-pH diagram showing dominant aqueous species of cobalt (Co) and Eh-pH region (shaded areas) where the solubilities of cobalt solids have been exceeded [diagram was calculated at 25 ºC and a concentration of 10^{-12} mol/L total dissolved cobalt in the presence of dissolved chloride, nitrate, carbonate, and sulfate.]

2.2.5.1 Empirical data on adsorption in the absence of organic ligands

The adsorption of cobalt has been studied on a variety of minerals, sediments, soils, and crushed rock materials. Typically, at near neutral and basic pH values, cobalt in the absence of organic complexants exhibits high adsorption affinity for minerals. The K_d values commonly reported in the literature range from 10^3 to 10^5 Liter/Kilogram (L/Kg).[3] Metal oxides (iron, manganese, and aluminum oxides) in aquifer solids are shown to play a major role in cobalt adsorption. The extent of adsorption is greatly influenced by pH. Generally, the degree of adsorption increases with pH. It was also found that the surface-bound humic acid functional moieties on aquifer solids increased cobalt adsorption on all mineral sorbents by 10 to 60%. The largest increase in cobalt adsorption occurred in the pH range from 4.5 to 6.5, where the humic acid adsorption was the greatest; cobalt adsorption due to surface bound humic acid was weak and dominated by ion exchange.[4]

Sheppard et al. evaluated a large set of cobalt sorption and desorption data and summarized the geometric mean K_d values for various soil types and conditions as follows: sand K_d = 260 L/Kg, loam K_d = 810 L/Kg, clay K_d = 3,800 L/Kg, organic matter K_d = 87 L/Kg, and K_d for soils with pH ≤ 5 = 12 L/Kg.[5]

2.2.5.2 Empirical data on adsorption in the presence of organic ligands

The presence of certain natural and synthetic organic ligands is known to reduce the adsorption of cobalt on sediments, soils, minerals, and other geologic materials especially at basic conditions. This decrease in cobalt adsorption is typically caused by the formation of anionic cobalt complexes at near neutral and basic pH conditions, which do not readily adsorb on mineral surfaces at basic pH values. cobalt in the absence of organic complexants normally exhibits cationic adsorption behavior, and the adsorption of cobalt to oxide minerals is low at acidic conditions and then increases with increasing pH. The formation of anionic cobalt complexes (inorganic or organic) reverses this trend in adsorption at basic pH conditions.[3]

Site groundwater exhibits a range of total organic carbon (TOC) concentrations in groundwater between 1 mg/L and 7 mg/L, which is a typical range for groundwater. Because the observed cobalt concentrations do not show a positive correlation with the TOC concentrations, the influence of organic ligands for cobalt sorption to aquifer solids at the Site is not considered to be important.

2.2.5.3 K_d value used for cobalt transport modeling

Because the Site aquifer solids are sandy and the geochemical conditions for Site groundwater is generally acidic (pH< 6), a K_d value of 2 L/Kg is considered to be a representative, yet conservative (in terms of not underestimating its mobility) value for evaluation of cobalt transport in the saturated zone.

2.2.6 Adsorption of Lithium on Aquifer Solids

Lithium is the lightest of all metals, with an atomic weight of 6.939, and an atomic number of 3, and having a density of only half that of water. It does not occur in the metalic state in nature, but it is a common element of nearly all igneous rocks. Lithium is concentrated in the silicates and alumino-silicates of acidic igneous rocks where it often replaces magnesium, ferrous iron, or aluminum. Lithium is also concentrated in clays, in which it correlates strongly with aluminum.[6] Under most pH and

[3] Krupka, K.M. and Serne, R.J., 2002. Geochemical Factors Affecting the Behavior of Antimony, Cobalt, Europium, Technetium, and Uranium in Vadose Zone Sediments (No. PNNL-14126). Pacific Northwest National Lab.(PNNL), Richland, WA (United States).

[4] Zachara J.M., Resch, C.T., and Smith, S.C., 1994. Influence of Humic Substances on Co2+ Sorption by a Subsurface Mineral Separate and Its Mineralogic Components. Geochimica et Cosmochimica Acta, 58:553-566.

[5] Sheppard, S., Long, J., Sanipelli, B. and Sohlenius, G., 2009. *Solid/liquid partition coefficients (Kd) for selected soils and sediments at Forsmark and Laxemar-Simpevarp* (No. SKB-R--09-27). Swedish Nuclear Fuel and Waste Management Co.

[6] Crawley, M.E., 1977. A geochemical model for lithium and boron (Doctoral dissertation, Texas Tech University).

redox conditions in groundwater environments, lithium is generally present in the form of a cation. The extent of adsorption increases with pH.

2.2.6.1 *Empirical data on lithium adsorption onto aquifer solids*

The cation exchange characteristics of a soil are also influential in retaining lithium. This factor is a function of the clay mineral and organic content of the soil material, as well as the chemistry of other mineral components of the soil system. Any lithium attached as an exchangeable cation will be very weakly held.[6] Based on published results for lithium transport field studies[6,7,8,9], Kd may range from 0.03 to 5 L/Kg.

2.2.6.2 *K_d value used for lithium transport modeling*

Because the Site aquifer solids are sandy and the geochemical conditions for Site groundwater is generally acidic (pH< 6), a K_d value of 0.06 L/Kg is considered to be a representative, yet conservative value (in terms of not underestimating its mobility) for evaluation of lithium transport in the saturated zone.

2.2.7 Source Initial Concentration Data

To conservatively predict the transport of cobalt and lithium and preserve the mass transported through the Site, the source area was defined utilizing initial concentration and constant sources in the form of recharge. The current extent of the groundwater plume for cobalt was generated based on current groundwater concentrations in the monitoring well network.

Six discrete areas with concentrations of cobalt above detection are present at the Site within the vicinity of the pond, the zones are depicted in Figure 9. Initial concentrations ranged from 6 mg/L to 130 mg/L. Three discrete areas with concentration of lithium above detection are present at the Site within the vicinity of the pond, the zones are depicted in Figure 10. Initial concentrations ranged from 13 mg/L to 110 mg/L.

2.3 TRANSPORT MODEL RESULTS- COBALT AND LITHIUM

The concentration of cobalt and lithium was monitored approximately 1200 feet down gradient of the pond. A detailed discussion of each option is presented in the CMA report.

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[7] Mojid, M.A. and Vereecken, H., 2005. On the physical meaning of retardation factor and velocity of a nonlinearly sorbing solute. Journal of hydrology, 302(1-4), pp.127-136.

[8] Garabedian, S.P., 1987. Large-scale dispersive transport in aquifers: Field experiments and reactive transport theory (Doctoral dissertation, Massachusetts Institute of Technology).

[9] Akhtar, M.S., Steenhuis, T.S., Richards, B.K. and McBride, M.B., 2003. Chloride and lithium transport in large arrays of undisturbed silt loam and sandy loam soil columns. Vadose Zone Journal, 2(4), pp.715-727.

TABLES

Table 1
February Groundwater Elevations
Santee Cooper
Cross, South Carolina

Well	Easting Feet	Northing Feet	Depth To Water Feet	Groundwater Elevation Feet (NAVD88)
CAP-1	2273089.38	561223.22	5.4	77.3
CAP-3	2272207.61	562513.7	14.39	77.1
CAP-5	2272846.82	563697.1	14.89	76.89
CAP-7	2274081.72	562969.45	14.57	77.07
CAP-9	2274593.46	561813.37	14.37	77.22
PM-1	2269801.59	558532.71	7.32	75.92
POZ-5D	2269944.514	566182.0385	4.84	77.65
CLF-1B-5D	2270721.025	565588.3164	4.38	76.55
POZ-4	2269884.716	566240.5539	4.67	78.06
POZ-6	2269283.405	566617.3156	6.1	77.74
POZ-7	2267285.398	564244.465	4.8	77.22
CLF-1B-1	2269396.353	562812.1258	6.27	77.49
CLF-1B-2	2269816.783	563348.3265	4.63	77.41
CLF-1B-3	2270176.281	564122.1617	5.44	77.31
CLF-1B-4	2270652.222	565630.1312	5.38	77.36
CLF-1B-5	2270493.127	564774.133	3.87	77.22
CBW-1	2268722.248	560522.1348	8.66	77.14

FIGURES

LEGEND

- Monitor Well Locations
- Model Domain

NOTES

1. Aerial Imagery Provided By ESRI
2. All Locations and Extents Approximate

0 1,600 3,200
SCALE IN FEET

HALEY ALDRICH

SANTEE COOPER
CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH MODEL DOMAIN

JULY 2019

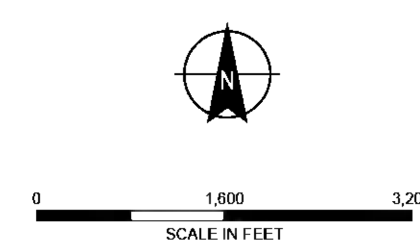
FIGURE 1

LEGEND

- Monitor Well Locations
- Model Grid
- Model Domain

NOTES

1. Aerial Imagery Provided By ESRI
2. All Locations and Extents Approximate



HALEY ALDRICH

SANTEE COOPER
CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH MODEL GRID

JULY 2019

FIGURE 2

GIS FILE PATH: D:\2_GIS\Santee Cooper\Cross Station\Groundwater Flow Model\Santee_Cooper_Cross_Flow_Model.mxd — USER: dquafisi — LAST SAVED: 7/11/2019 7:04:40 AM

Layer 1 - Approximately 5 Feet Thick
Hydraulic Conductivity - 8.9×10^{-3} cm/s

Layer 2 - Approximately 5 Feet Thick
Hydraulic Conductivity - 8.9×10^{-3} cm/s

Layer 3 - Approximately 5 Feet Thick
Hydraulic Conductivity - 2.0×10^{-2} cm/s

Layer 4 - Approximately 5 Feet Thick
Hydraulic Conductivity - 2.0×10^{-2} cm/s

Layer 5 - Approximately 20 Feet Thick
Hydraulic Conductivity - 6.0×10^{-3} cm/s

NOTES:
1. Layer Thicknesses Approximate Due To Variability In Model

HALEY ALDRICH

SANTEE COOPER
CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

Model Layers 1 Through 5
With Hydraulic Conductivities

July 2019 **Figure 3**

LEGEND

- Monitor Well Locations
- Model Domain
- River Boundary

Constant Head Boundary

- 71 Ft
- 74.22 Ft
- 76 Ft

NOTES

1. Aerial Imagery Provided By ESRI
2. All Locations and Extents Approximate

N

0 1,600 3,200
SCALE IN FEET

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SANTEE COOPER
CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH BOUNDARY CONDITIONS LAYER 1

JULY 2019

FIGURE 4

GIS FILE PATH: D:\2_GIS\Santee Cooper\Cross Station\Groundwater Flow Model\Santee_Cooper_Cross_Flow_Model.mxd — USER: dquafisi — LAST SAVED: 7/11/2019 7:08:28 AM

LEGEND

Monitor Well Locations

Model Domain

River Boundary

Constant Head Boundary

71 Ft

74.22 Ft

76 Ft

NOTES

1. Aerial Imagery Provided By ESRI
2. All Locations and Extents Approximate

0 1,600 3,200
SCALE IN FEET

HALEY ALDRICH

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CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH BOUNDARY CONDITIONS LAYER 2

JULY 2019

FIGURE 5

GIS FILE PATH: D:\2_GIS\Santee Cooper\Cross Station\Groundwater Flow Model\Santee_Cooper_Cross_Flow_Model.mxd — USER: dquafisi — LAST SAVED: 7/11/2019 7:08:26 AM

LEGEND

- Monitor Well Locations
- Model Domain
- River Boundary

Constant Head Boundary

- 71 Ft
- 74.22 Ft
- 76 Ft

NOTES

1. Aerial Imagery Provided By ESRI
2. All Locations and Extents Approximate

0 1,600 3,200
SCALE IN FEET

HALEY ALDRICH

SANTEE COOPER
CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH BOUNDARY CONDITIONS LAYER 3

JULY 2019

FIGURE 6

GIS FILE PATH: D:\2_GIS\Santee Cooper\Cross Station\Groundwater Flow Model\Santee_Cooper_Cross_Flow_Model.mxd — USER: dquafisi — LAST SAVED: 7/11/2019 7:08:28 AM

LEGEND

Monitor Well Locations

Model Domain

River Boundary

Constant Head Boundary

71 Ft

74.22 Ft

76 Ft

NOTES

1. Aerial Imagery Provided By ESRI
2. All Locations and Extents Approximate

0 1,600 3,200
SCALE IN FEET

HALEY ALDRICH

SANTEE COOPER
CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH BOUNDARY CONDITIONS LAYER 4

JULY 2019

FIGURE 7

GIS FILE PATH: D:\2_GIS\Santee Cooper\Cross Station\Groundwater Flow Model\Santee_Cooper_Cross_Flow_Model.mxd — USER: dquafisi — LAST SAVED: 7/11/2019 7:08:26 AM

LEGEND

Monitor Well Locations

Model Domain

River Boundary

Constant Head Boundary

71 Ft

74.22 Ft

76 Ft

NOTES

1. Aerial Imagery Provided By ESRI
2. All Locations and Extents Approximate

0 1,600 3,200
SCALE IN FEET

HALEY ALDRICH

SANTEE COOPER
CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH BOUNDARY CONDITIONS LAYER 5

JULY 2019

FIGURE 8

LEGEND

- Monitor Well Locations
- Model Domain

Initial Concentration

- 6 ug/L
- 10 ug/L
- 20 ug/L
- 37 ug/L
- 59.8 ug/L
- 130 ug/L
- River Boundary

NOTES

1. Aerial Imagery Provided By ESRI
2. All Locations and Extents Approximate

N

0 1,600 3,200
SCALE IN FEET

HALEY ALDRICH

SANTEE COOPER
CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH INITIAL COBALT CONCENTRATIONS LAYER 3

JULY 2019

FIGURE 9

GIS FILE PATH: D:\2_GIS\Santee Cooper\Cross Station\Groundwater Flow Model\Santee_Cooper_Cross_Flow_Model.mxd — USER: dquafisi — LAST SAVED: 7/11/2019 8:59:31 AM

LEGEND

Monitor Well Locations

Model Domain

Initial Concentration

13 ug/L

60 ug/L

110 ug/L

River Boundary

NOTES

1. Aerial Imagery Provided By ESRI
2. All Locations and Extents Approximate

0 1,600 3,200

SCALE IN FEET

HALEY ALDRICH

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CROSS, SOUTH CAROLINA

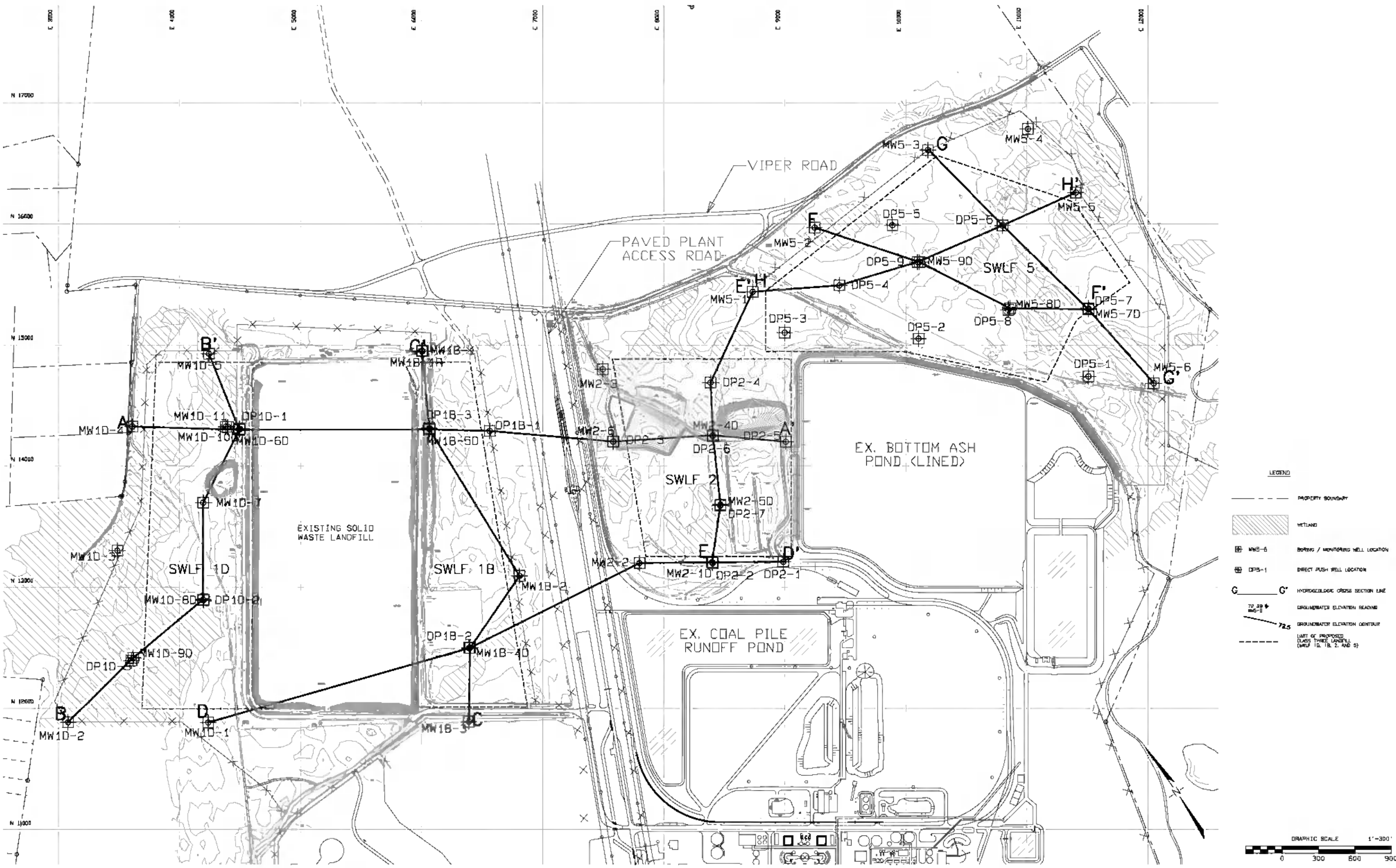
SITE PLAN WITH INITIAL LITHIUM CONCENTRATIONS LAYER 3

JULY 2019

FIGURE 10

APPENDIX A

Cross Sections



REVISION	DATE
1)	
2)	
3)	
4)	

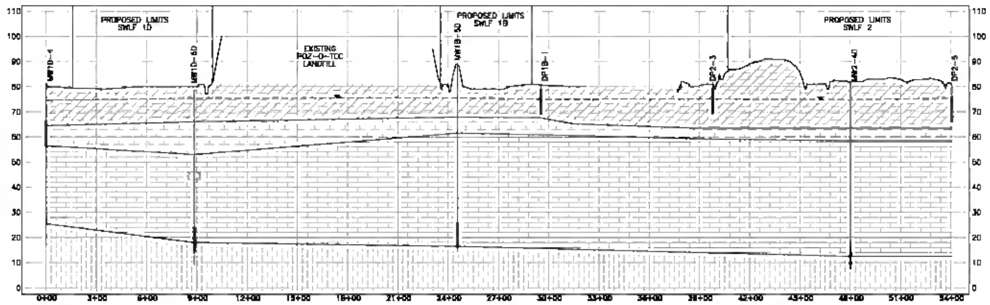
GARRETT & MOORE

SANTEE COOPER CROSS GENERATING STATION
CLASS THREE LANDFILL PROJECT

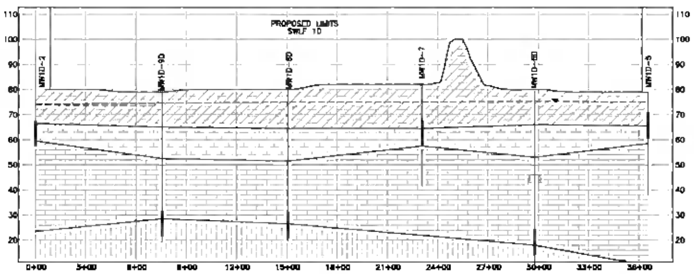
SITE HYDROGEOLOGICAL CHARACTERIZATION STUDY
SITE INVESTIGATION MAP

JOB NUMBER

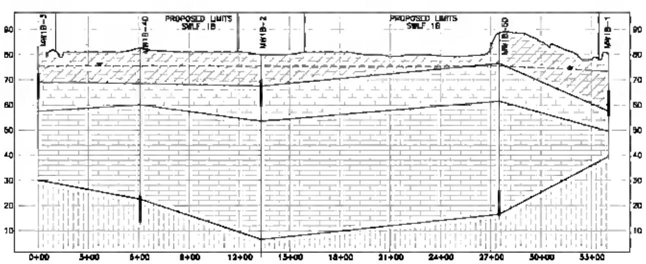
SHEET FIGURE 3



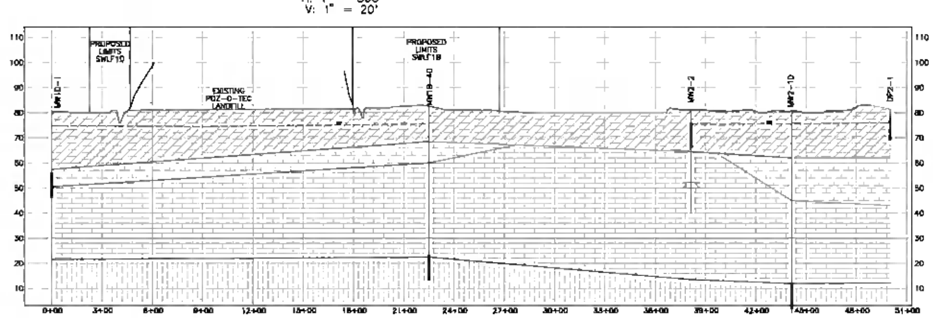
SECTION AA
H: 1" = 300'
V: 1" = 20'



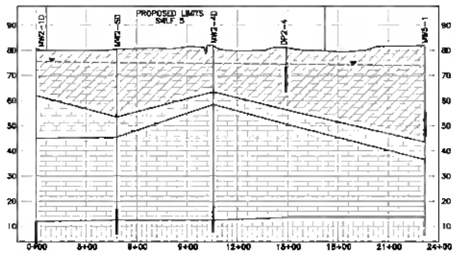
SECTION BB
H: 1" = 300'
V: 1" = 20'



SECTION CC'
H: 1" = 300'
V: 1" = 20'



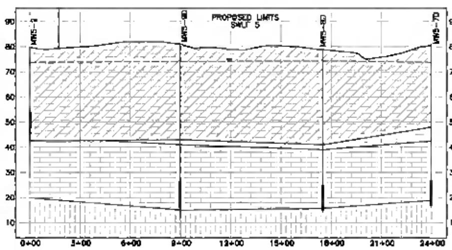
SECTION DD'
H: 1" = 300'
V: 1" = 20'



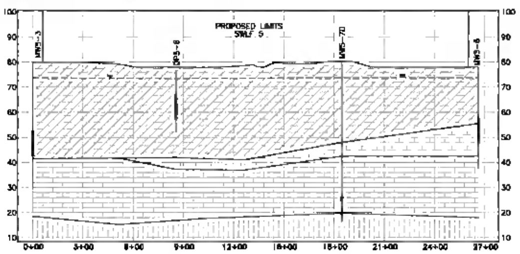
SECTION EE
H: 1" = 300'
V: 1" = 20'

LEGEND

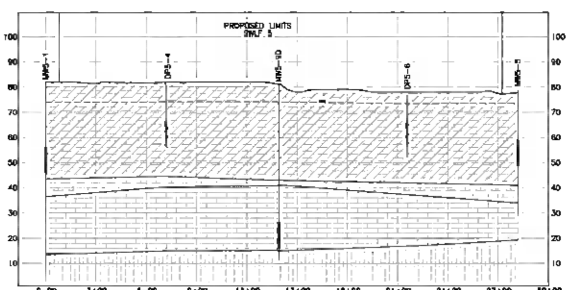
- APPROXIMATE GROUNDWATER ELEVATION (VARIES SEASONALLY)
- UNIT 1: PLEISTOCENE WICOMICO FORMATION
- UNIT 2: PLIOCENE RAYSOR FORMATION
- UNIT 3: EOCENE SANTEE LIMESTONE
- UNIT 4: PALEOCENE BLACK MINGO GROUP
- WELL SCREEN



SECTION FF
H: 1" = 300'
V: 1" = 20'



SECTION GG
H: 1" = 300'
V: 1" = 20'



SECTION HH
H: 1" = 300'
V: 1" = 20'

REVISION	DATE
1	
2	
3	
4	

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CLASS THREE LANDFILL PROJECT

GEOLOGIC CROSS SECTIONS

JOB NUMBER

SHEET
FIGURE 5