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

by
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for
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1. Introduction

This Corrective Measures Assessment Addendum (CMA Addendum) was prepared by Haley & Aldrich, Inc. (Haley & Aldrich) on behalf of South Carolina Public Service Authority (Santee Cooper) to incorporate radium into the analysis of corrective action alternatives for the Bottom Ash Pond at the Cross Generating Station (CGS; Site) which is located in Berkeley County near the communities of Cross and Pineville, South Carolina. The original CMA was completed in accordance with 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) on September 11, 2019 as required.

1.1 BACKGROUND

Assessment monitoring conducted in 2018 to support the original CMA evaluation 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). 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 and initiated an assessment of corrective measures. 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 accordance with the CCR Rule semiannual assessment monitoring and statistical evaluations continued in 2019 and in December 2019 Santee Cooper held a public meeting to present the results of the CMA and to give the public an opportunity to provide input. While Santee Cooper considered the public input received and prepared for remedy selection, an additional semiannual assessment monitoring sampling round was conducted followed by completion of the statistical analysis. In addition to beryllium, cobalt, and lithium, the statistical analysis identified an SSL for radium in one of the downgradient wells. As a result, radium is subject to the corrective action requirements in the CCR Rule. This document summarizes the evaluation of radium with respect to the corrective measures requirements in light of the existing CMA for the Site dated September 2019. In preparing this CMA Addendum and consistent with our previous CMA, Haley & Aldrich considered the following: presence and distribution of radium, 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.

Consistent with the original CMA prepared to address beryllium, cobalt, and lithium, the remedial alternatives evaluated in this CMA Addendum for radium 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, which were presented to the public in December 2019, 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.

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 CMA Addendum:

- **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 radium concentrations, along with beryllium, cobalt, and lithium are expected to decline below their GWPS through the chemical and physical processes of natural attenuation that occur without human intervention. 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.
- **Groundwater Treatment:** In order to implement a groundwater alternative that includes treatment, laboratory testing would be required to demonstrate effective treatability of radium using either ex-situ treatment methods, such as co-precipitation, 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 for radium to evaluate the timeframes to achieve GWPS for the various alternatives compared to the worst case cleanup timeframes for cobalt modeled previously. Cobalt was previously chosen as the worst case Appendix IV SSL because it was the Appendix IV constituent detected at that time with the highest concentration in groundwater, because it was the Appendix IV constituent that had migrated furthest from the unit, and because it had the lowest attenuation factor of the detected Appendix IV constituents. 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.

It should be noted that 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*).

1.2 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.

1.3 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)(iii) 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)(iv) 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)(iii) 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.

1.4 GROUNDWATER PROTECTION STANDARDS

Haley and Aldrich completed a statistical evaluation of groundwater samples using the methods and procedures outlined in the *Statistical Data Analysis Plan* to develop site-specific GWPS for each Appendix IV constituent. For the CGS, background concentrations for combined radium exceed 5 pCi/L (the MCL for combined radium) and have been measured at concentrations as high as 16.3 pCi/L. Using a non-parametric statistical analysis of the background results the upper tolerance limit was used to set the GWPS for combined radium. As a result, the GWPS for combined radium at the Cross Bottom Ash Pond is 16.3 pCi/L.

1.5 NATURE AND EXTENT OF GROUNDWATER IMPACTS

The first round of assessment monitoring results in 2020 were compared to the GWPS and in addition to beryllium, cobalt, and lithium, which were previously identified as the Appendix IV SSLs, radium was detected at a SSL above its GWPS downgradient of the Cross Bottom Ash Pond. While the nature and extent (N&E) of beryllium, cobalt, and lithium had already been defined and presented to the public, Santee Cooper initiated and completed an evaluation of N&E of radium downgradient of the Bottom Ash Pond. The groundwater monitoring network constructed to define the N&E of beryllium, cobalt, and lithium was relied upon to define the N&E of radium. This monitoring network includes two wells located at the downgradient property line (CCMAP-1 and CCMAP-2) between the Bottom Ash Pond and potable water wells that supply drinking water to nearby residences and one well at the boundary of the Ash Pond (CCMAP-3). CCMAP-3 was relied upon to evaluate the vertical extent of impacts at the Ash Pond. The groundwater monitoring network for the Bottom Ash Pond is shown on Figure 1.

Existing groundwater monitoring wells around the Cross Bottom Ash Pond (CAP-4 and CAP-6 as shown in Figure 1) 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. However, groundwater samples from monitoring wells CAP-4 and CAP-6, located on either side of CAP-5 were also collected in July 2020 as part of the N&E study of radium. Groundwater sampling results from the from the wells relied upon to define the N&E of radium are presented in Table 1.

Given the fate and transport characteristics of radium, radium is not anticipated to migrate from the Ash Pond and extend off-site at concentrations above the GWPS and should remain in the uppermost aquifer in the vicinity of the waste boundary of the Cross Bottom Ash Pond. This condition was confirmed by the July 2020 groundwater sampling event, which showed that radium was not present in the underlying Santee Limestone or in the downgradient wells screened in the uppermost aquifer. As a result of the radium SSL determination, radium will be added to long term, post closure performance groundwater monitoring program in accordance with § 257.94 and § 257.95.

2. Corrective Measures Alternatives

2.1 CORRECTIVE MEASURES ASSESSMENT GOALS

The overall goal of this CMA Addendum is to identify and evaluate the appropriateness of potential corrective measures to prevent further releases of radium 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 Addendum 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 2 and 3). 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.

2.2 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 A. 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.

Originally, timeframes to achieve GWPS were evaluated using cobalt as a surrogate for beryllium and lithium. For this CMA addendum, timeframes to achieve GWPS were evaluated using radium. Cobalt is considered a worst 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 for radium so that the addition of radium as an Appendix IV SSL can be compared to the risks and remediation timeframes predicted previously for beryllium, cobalt, and lithium. The solute transport model was set up using the February 2020 semiannual groundwater sampling results and the July 2020 N&E evaluation to simulate groundwater concentrations for radium.

As provided in Appendix A, the remediation timeframes associated with radium are comparable to those predicted for cobalt due to the high adsorption coefficient and therefore low mobility. As a result, radium will not migrate an appreciable distance from the Bottom Ash Pond. Therefore, CBR with MNA will continue to achieve 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.

2.3 CORRECTIVE MEASURES ALTERNATIVES

The corrective measures alternatives being evaluated were described in detail in the CMA completed in September 2019. In accordance with §257.97, the groundwater corrective measures alternatives evaluated in 2019 met 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.

This CMA addendum incorporates radium into the evaluation of the six groundwater remediation alternatives presented in the September 2019 CMA which are described below and presented on Table 2 and evaluated against the threshold and balancing criteria on Table 3, 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.

The September 2019 CMA, this CMA Addendum, and the input received during the December 2019 public comment period, will be used to identify a final corrective measure for implementation at the Bottom Ash Pond.

3. Comparison of Corrective Measures Alternatives

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

3.1 EVALUATION CRITERIA

In accordance with §257.97, remedial alternatives that satisfy the threshold criteria are 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 received in December 2019 will be considered in the remedy selection process, as required.

3.2 COMPARISON OF ALTERNATIVES

This section compares the alternatives to each other based on evaluation of the balancing criteria listed above. This comparative analysis was completed in September 2019 for beryllium, cobalt, and lithium and has been updated to include radium in the analysis. The goal of this analysis remains 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 for each of the balancing criteria to provide a visual snapshot of the favorability of each alternative, where green represents favorable, yellow represents less favorable, and red represents least favorable.

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

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.

3.2.1.1 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. The analysis conducted in September 2019 for beryllium, cobalt, and lithium, updated in this CMA Addendum for radium, concluded that there was no unacceptable risk to human health and the environment exists with respect to the Cross Bottom Ash Pond. Therefore, none of the remedial alternatives were necessary to reduce risks because no such exposure to Appendix IV constituents currently existed. However, other types of impacts were considered that may be posed by the various remedial alternatives considered at that time. Alternative 4 (Closure by Removal and MNA) was the most favorable option because the source was 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 was considered less favorable because the source was left in place. Alternatives 3 and 6, which incorporate hydraulic containment and ex--situ treatment) had 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.

Because there is no current exposure risk to groundwater impacted by radium and based on the modeling results indicating that radium will not migrate an appreciable distance from the Bottom Ash Pond, incorporating radium does not change the outcome of this analysis. Alternative 4 (Closure by Removal and MNA) remains the most favorable option because the source will be 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 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						

3.2.2 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.

3.2.2.1 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.

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, lithium, and radium 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, lithium, and radium 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, lithium, and radium in groundwater migrating downgradient and are considered less favorable with respect to this criterion. 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 Effectiveness in controlling the source to reduce further releases						

3.2.3 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.

3.2.3.1 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.

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. To facilitate closure within 5 years, the current removal 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, lithium, and radium 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 Treatment
CATEGORY 3 Ease of implementation						

4. Summary

This CMA Addendum has been prepared to incorporate radium into the evaluation of the following alternatives previously evaluated for SSLs of beryllium, cobalt, and lithium:

- 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.

The addition of radium as an SSL at the Site as summarized in this addendum does not alter the conclusions of the CMA.

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.

The September 2019 CMA, this CMA Addendum, and the input received during the December 2019 public comment period, will be used to select a final corrective measure for implementation at the Bottom Ash Pond.

References

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TABLES

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TABLE I
SUMMARY OF ANALYTICAL RESULTS
SANTEE COOPER
CROSS GENERATING STATION
CROSS, SOUTH CAROLINA

	CAP-1 6/25/2020	CAP-3 6/30/2020	CAP-4 7/29/2020	CAP-5 2/27/2020	CAP-5 6/30/2020	CAP-5 7/29/2020	CAP-6 7/30/2020	CAP-7 6/30/2020	CAP-9 6/29/2020	CCMAP-1 7/29/2020	CCMAP-2 7/29/2020	CCMAP-3 7/29/2020
Radiological (pCi/L)												
Radium-226	**1.02**	**0.535**	**0.913**	**7.04**	**7.27**	**6.18**	**1.26**	**0.92**	**0.96**	**0.622**	**0.491**	**1.17**
Radium-228	**1.14**	**1.31**	**1.44**	**12**	**12.4**	**9.61**	**1.15**	**0.671**	**3.23**	**0.403**	**0.143**	**0.801**
Radium-226 & 228	**2.16**	**1.85**	**2.35**	**19**	**19.7**	**15.8**	**2.41**	**1.59**	**4.19**	**1.03**	**0.634**	**1.97**

Notes:
1. Results in **bold** are detected.

TABLE 2
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

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

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 implemen**t 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 implemen**t 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.

Green	**Most favorable when compared to other alternatives**
Yellow	**Less favorable when compared to other alternatives**
Red	**Least favorable when compared to other alternatives**

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

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 2020

FIGURE 1

GIS FILE PATH: \\haleyaldrich.com\share\grn_common\131539 - Santee Cooper\GIS\Maps\2020_08\132892_004_00MB_ASH_POND_WELLS.mxd — USER: hwachholz — LAST SAVED: 9/16/2020 11:18:00 AM

APPENDIX A

Groundwater Model Output

HALEY ALDRICH

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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
August 2020

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1. Groundwater Flow Modeling

A groundwater flow and solute transport model was constructed to evaluate and compare radium to the previously completed 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 backbarrier 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 8.9×10^{-3} centimeters per second (cm/s)
- Raysor Formation – 57.6 ft/day or 2.0×10^{-2} cm/s
- Santee Limestone – 17.7 ft/day or 6.0×10^{-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 radium 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.

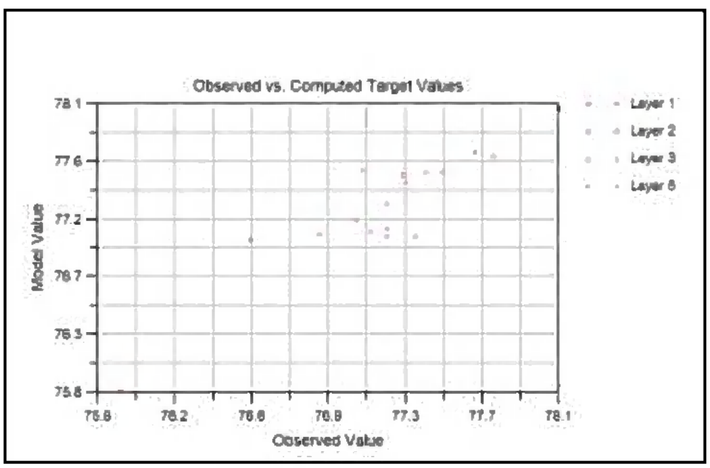

Figure A-1: Calibration scatter plot.

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

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[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 radium. 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 radium 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 radium. 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 radium 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 radium 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 radium. This rate constant was utilized to simulate the radioactive decay of radium-226 which is represented as having a half-life of 1,600 years. This rate constant does not factor in effects of advection, sorption or dispersivity (dispersion). This degradation rate was chosen for radium-226 to provide a conservative estimate for radium decay given the Site has detections of radium-226 and radium-228.

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 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 radium based on its 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 Radium on Aquifer Solids

Radium (atomic number 88) is an alkaline earth element in the periodic classification of the elements. Radium can only exist in nature in the +2 oxidation state and due to its proximity to barium within the alkaline group, reacts similarly to barium.

The aqueous speciation of radium is there for limited to the +2 oxidation state, however the results of measurements conducted with solutions containing dissolved sulfate, carbonate, and bicarbonate indicated that significant concentrations of aqueous radium complexes can be observed (Benes et al., 1982). However, within the pH range of 3 to 10, the uncomplexed ion Ra^{2+} is expected to be the dominant species. 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.

2.2.5.1 K_d value used for radium 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 6.7 L/Kg is considered to be a representative, yet conservative (in terms of not underestimating its mobility) value for evaluation of radium transport in the saturated zone (EPA, 2004).

2.2.6 Source Initial Concentration Data

To conservatively predict the transport of radium 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 radium was generated based on current groundwater concentrations in the monitoring well network.

Concentrations of radium above detection are present at the Site within the vicinity of the pond, the zones are depicted in Figure 9. Initial concentrations ranged from 1 picocurie per liter (ρCi/L) to 19 pCi/L.

2.3 TRANSPORT MODEL RESULTS- RADIUM

The concentration of radium does not exceed the USEPA MCL of 5 ρCi/L less than 350 feet down gradient of the pond in over 900 years. A detailed discussion of each option is presented in the CMA report.

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

HALEY ALDRICH

LEGEND

Monitor Well Locations

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 DOMAIN

AUGUST 2020

FIGURE 1

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

LEGEND

Monitor Well Locations

Model Grid

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

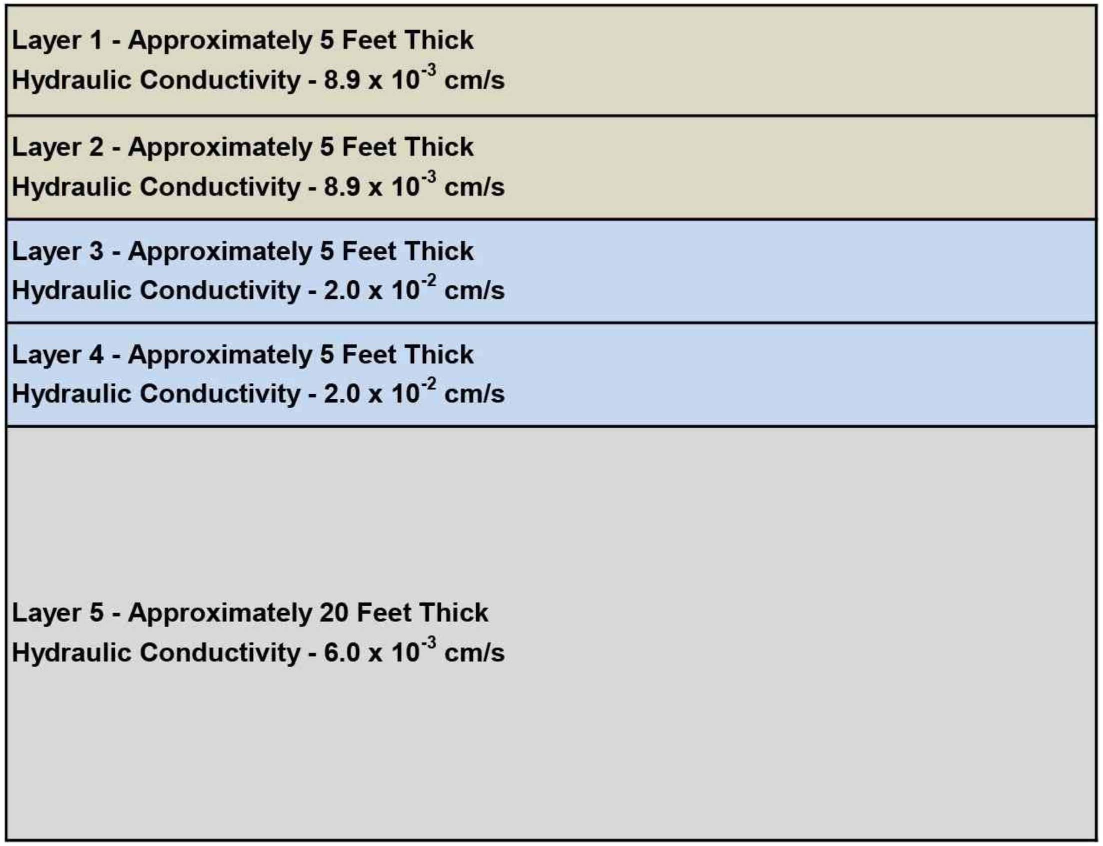
SANTEE COOPER
CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH MODEL GRID

AUGUST 2020

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



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

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CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

Model Layers 1 Through 5
With Hydraulic Conductivities

AUGUST 2020 **Figure 3**

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 1

AUGUST 2020

FIGURE 4

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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CROSS, SOUTH CAROLINA

SITE PLAN WITH BOUNDARY CONDITIONS LAYER 2

AUGUST 2020

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

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CROSS GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH BOUNDARY CONDITIONS LAYER 3

AUGUST 2020

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

N

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

AUGUST 2020

FIGURE 7

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

AUGUST 2020

FIGURE 8

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

Initial Concentration

- 1 pCi/L
- 10 pCi/L
- 19 pCi/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 GENERATION STATION
CROSS, SOUTH CAROLINA

SITE PLAN WITH INITIAL RADIUM CONCENTRATIONS LAYER 3

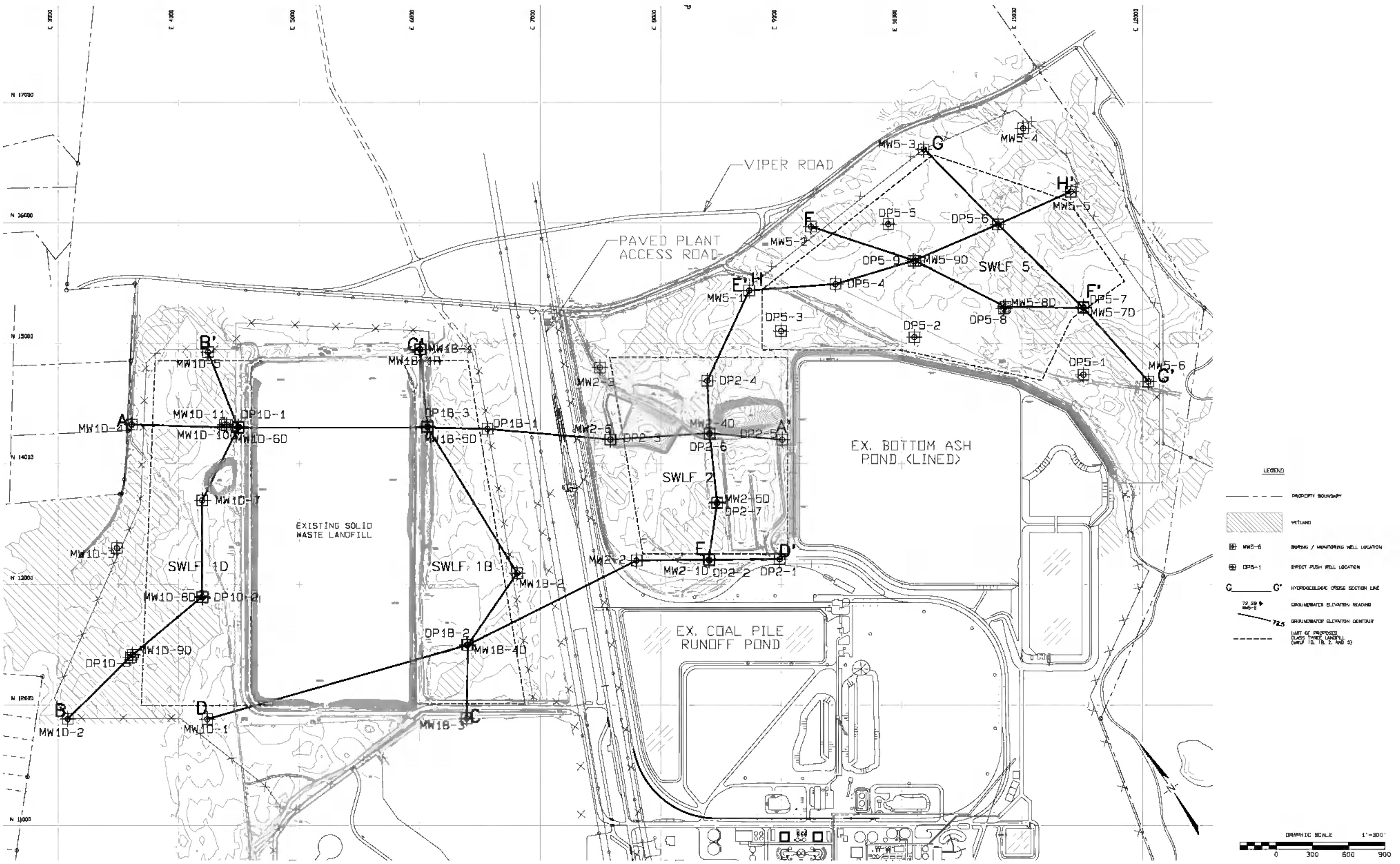
AUGUST 2020

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: 7/29/2020 3:53:49 PM

APPENDIX A

Cross Sections



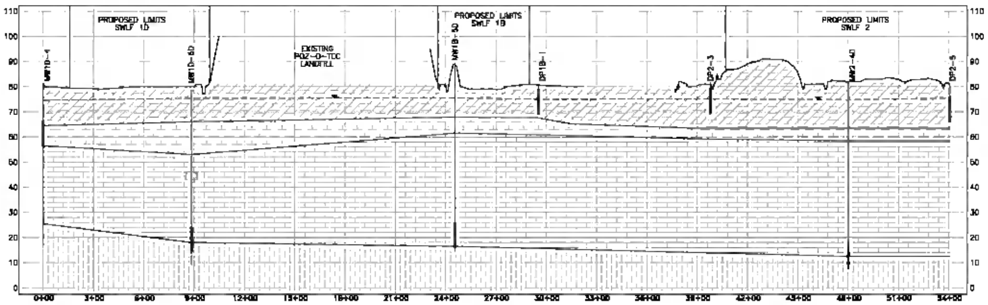
REVISION	DATE
1)	
2)	
3)	
4)	

GARRETT & MOORE

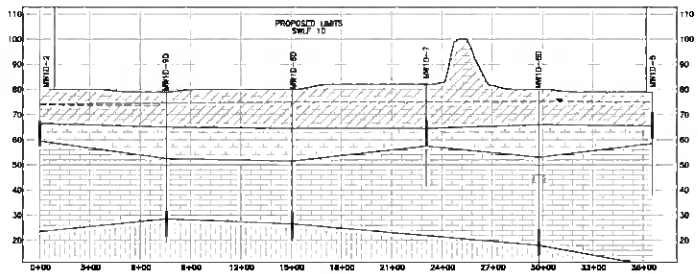
SANTEE COOPER CROSS GENERATING STATION
CLASS THREE LANDFILL PROJECT

SITE HYDROGEOLOGICAL CHARACTERIZATION STUDY
SITE INVESTIGATION MAP

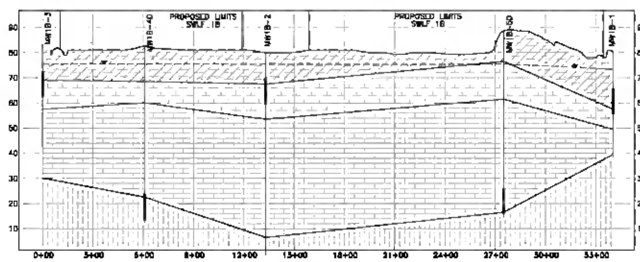
JOB NUMBER
SHEET
FIGURE 3



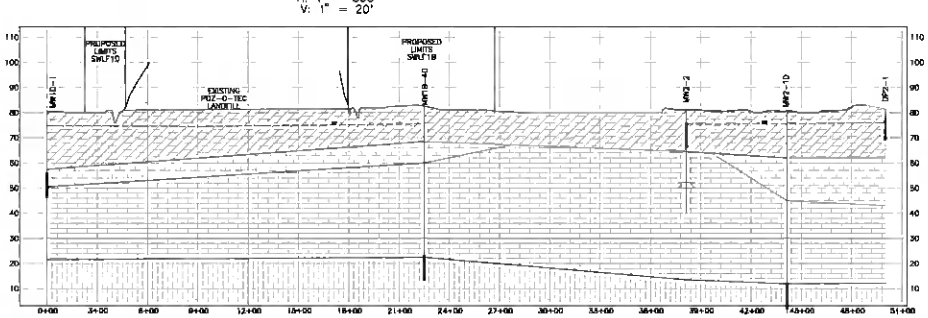
SECTION AA
H: 1" = 300'
V: 1" = 20'



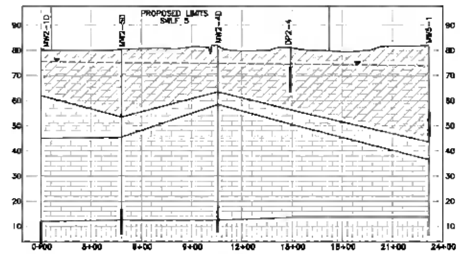
SECTION BB
H: 1" = 300'
V: 1" = 20'



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



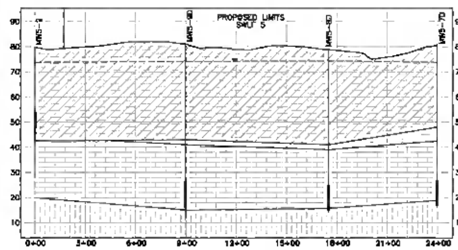
SECTION DD'
H: 1" = 300'
V: 1" = 20'



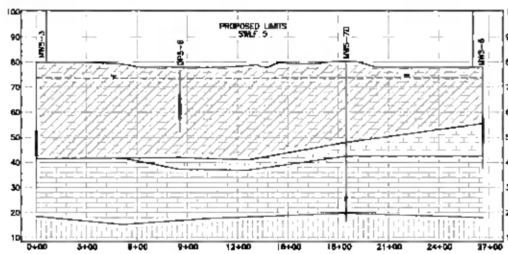
SECTION EE
H: 1" = 300'
V: 1" = 20'

LEGEND

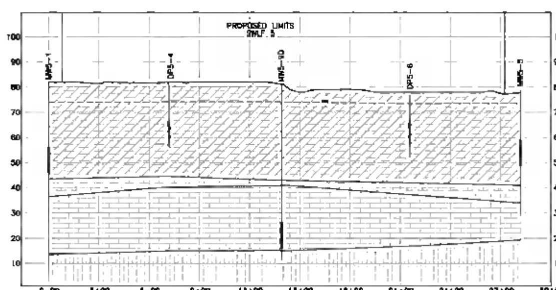
- APPROXIMATE GROUNDWATER ELEVATION (VARIES SEASONALLY)
- UNIT 1: PLEISTOCENE WICOMICO FORMATION
- UNIT 2: PLIOCENE RAYSOR FORMATION
- UNIT 3: EOCENE SANTEE LIMESTONE
- UNIT 4: PALEOCENE BLACK MINGO GROUP
- WELL SCREEN



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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SANTEE COOPER CROSS GENERATING STATION
CLASS THREE LANDFILL PROJECT

GEOLOGIC CROSS SECTIONS

JOB NUMBER

SHEET
FIGURE 5