# Cross Generating Station Bottom Ash Pond

## Periodic (5-Yr) Structural Stability Assessment

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07 Nov 2021

One Meridian Boulevard,
Suite 2C02, Wyomissing, PA, 19610
USA

T: +1 610 855 2000
Worley

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## Appendices





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# 1. Introduction

The United States Environmental Protection Agency (EPA) promulgated regulations regarding Coal Combustion Residuals (CCRs). These regulations (40 CFR Part 257) were published in the Federal Register on April 17, 2015. One of the requirements of the regulations (§257.73(d)(1)) is to conduct initial and periodic structural stability assessments on existing CCR surface impoundments and obtain a certification from a qualified professional engineer that the requirements of this section are met.

Two sets of revisions to 40 CFR Part 257 have been published in the Federal Register since the 2015 CCR Rule was first published. The first set of revisions was published on July 30, 2018 and the second on November 12, 2020. However, neither set of revisions included any changes to the §257.73(d)(1) requirements addressing initial and periodic structural stability assessments.

§257.73(f)(3) requires that periodic structural stability assessments are completed every five years. The date of completing the initial assessment is the basis for establishing the deadline to complete the first subsequent periodic assessment. The initial structural stability assessment of the Bottom Ash Pond at Cross Generating Station was placed in the operating record on October 17, 2016 (Rev. 0), with an update (Rev. 1) published on November 3, 2016 [Ref. 1]. The first periodic structural stability assessment therefore must be completed and placed in the operating record on or before October 17, 2021.

This report presents the first periodic structural stability assessment of the Bottom Ash Pond at the Cross Generating Station in Pineville, South Carolina and provides the required certification by a qualified professional engineer.

# 2. Discussion

## 2.1 General

Cross Generating Station consists of four generating units and is located between Lakes Marion and Moultrie, in Pineville, South Carolina. All four units have undergone dry conversion, with bottom ash dewatered and stacked out locally in a containerized bunker adjacent to each of the four units, where it is either hauled offsite for beneficial reuse, or hauled to the onsite Class Three Landfill. Prior to dry conversion, bottom ash from all four units was sluiced to the existing onsite Bottom Ash (BA) Pond.

The BA Pond is a diked CCR surface impoundment covering approximately 87 acres, with its perimeter dike comprising the CCR Unit boundary. Portions of the south and east dikes of the BA Pond are shared with the adjacent Wastewater Decant (WD) Pond, which lies outside the CCR Unit boundary.

BA Pond closure by removal of waste was initiated in August 2020. All wastewater inflows to the BA Pond were terminated at that time and the BA Pond trapezoidal weir spillway (previously located within the shared dike to convey BA Pond effluent to the WD Pond) was removed. As part of the spillway removal, the shared dike in this area was restored to its original design elevation.

At the time of the initial structural stability assessment in 2016 [Ref. 1], an extensive desktop review of site history and engineering reports, a subsurface investigation, and a laboratory testing program were performed to document the construction history, characterize the dike and subsurface soils, and evaluate the existing condition of the BA Pond. This information, along with subsequent annual inspection reports published since the initial structural stability assessment, and weekly inspection reports prepared in 2021, all were reviewed as part of this current assessment.

Worley visited Cross Generating Station on June 22, 2021 to inspect the condition of the BA Pond. Prior to the inspection, the team met in a site conference room to discuss current pond operating procedures and the maintenance history with plant personnel. The inspection team then performed a detailed inspection of the pond, including upstream embankment slopes (above the water line), downstream embankment slopes, embankment penetrations, and hydraulic structures. The impoundment dikes were observed to be in satisfactory condition, with the impoundment generally operated and maintained in accordance with commonly accepted good engineering practice. The inspection did not observe evidence of a deficiency to the structural integrity of the surface impoundment. The results of the periodic structural stability assessment with respect to each requirement listed in §257.73(d)(1)(i)-(vii) are documented in detail in the sections below.

## 2.2 §257.73(d)(1)(i) Stable Foundations and Abutments

The BA Pond was constructed over Pleistocene sediments of the Atlantic Coastal Plain. These sediments typically consist of soft to stiff sandy lean clay and fat clay with a few layers of silty sand. The thickness of the soil layer varies from approximately 17 to 36 feet. The underlying Santee Limestone is variably weathered and, in many locations, can be sampled with a split-spoon sampler. The limestone surface elevation varies. Groundwater levels fluctuate seasonally from approximately Elevation 70 to Elevation 78 feet.

Based on the boring and CPT data from the 2015 Terracon subsurface exploration, the location between monitoring wells CAP 7 and CAP 8 was determined to be the critical cross section for the 2016 initial safety factor assessment [Ref. 2]. The assessment demonstrated that both static and seismic factors of safety exceeded the minimum requirements set forth in §257.73(e). Although some localized soil zones have the potential to exhibit a reduced strength during a seismic event, they are not considered liquefiable in the classic sense. Also, these zones are not laterally continuous, so widespread loss of strength is unlikely.

Ongoing closure activities in the BA Pond will include pond dewatering and removal of all waste. It is recognized that this activity, in conjunction with current normal operating conditions within the adjacent WD Pond, may influence the location of the critical cross section from a safety factor assessment standpoint as pond closure progresses. Therefore, an additional critical cross section through the shared dike between the BA Pond and the WD Pond was analyzed as part of the 2021 Periodic (5-Yr) Safety Factor Assessment [Ref. 3]. This assessment demonstrated that both static and seismic factors of safety exceed the minimum requirements set forth in §257.73(e).

In the thirty years since the Cross Generating Station BA Pond was constructed, there has been no documented instability within the BA Pond area. Modelling of the BA Pond stability, using conservative soil properties, resulted in acceptable safety factors. Therefore, there is no evidence to suggest that the foundations of the BA Pond are not stable.

## 2.3 §257.73(d)(1)(ii) Upstream Slope Protection

The upstream (interior) slopes of the BA Pond are covered with a three-inch thick layer of concrete revetment mat, except the small area of the shared dike between the BA Pond and the WD Pond associated with the former trapezoidal weir spillway location (which was removed during the recent onset of BA Pond closure activities). While no erosion was observed at the former spillway location, this area of the slope is not fully stabilized with vegetation and is discussed further in Section 3.

Around the rest of the impoundment, the revetment is anchored just above the top slope of the embankment and extends down to four feet beyond the toe of the upstream embankment slope inside the BA Pond. This concrete revetment mat provides protection to the embankment from surface erosion, wave action, and adverse effects associated with rapid drawdown.

## 2.4 §257.73(d)(1)(iii) Dike Compaction

Compaction test reports from the construction of the BA Pond are not available. Earthwork specifications (included in Ref. 4) indicate the embankments were constructed of on-site excavated soil with the maximum particle size not exceeding 1/2 of the lift thickness (12 inches). The specifications required the subgrade to be compacted to a minimum density of 90 percent of modified Proctor (or 95 percent of standard Proctor) in areas receiving fill. Fill was to be placed in maximum 12-inch loose lifts and compacted to either 90 percent of maximum density as determined by the Modified Proctor test, or 95 percent of the maximum density as determined by the Standard Proctor test. According to personnel involved with the design and construction of the BA Pond, all work was verified by third party monitoring, testing, and inspection services.

Proctor compaction data from the Woodward-Clyde and Law geotechnical reports [Ref. 5 and 6] are presented in Table 1. The TP-200 series test pits were excavated under Law's direction, and modified Proctors were performed. These test pits were located across the generating station area. The other test pits were excavated under Woodward-Clyde's direction and standard Proctors were performed. These test pit locations were primarily in the area of the BA Pond. The Proctor tests were performed on remolded soils obtained from shallow depths.

Table 2 presents the unit weights and moisture contents of undisturbed samples that were obtained of the BA Pond embankment during Terracon's 2015 subsurface exploration. Although the densities shown in Table 2 cannot be directly correlated to the Proctor values provided in Table 1 due to differences in grain size distributions and Atterberg Limits, the general range of dry density and moisture content is similar, particularly when compared with standard Proctor data. The average dry density of the undisturbed samples is higher than the average density of the Standard Proctor samples, and the average moisture contents differ by less than a percent. While this observation does not confirm the embankments meet the required Proctor percentages, it, along with the specifications, does provide additional assurance that compaction was performed during construction.

**Table 1: Proctor Compaction Data**

| Test Pit | Depth (ft) | USCS Soil Classification | Proctor Type | Maximum Dry Density (pcf) | Optimum Moisture (%) |
|---|---|---|---|---|---|
| TP-12 & TP-24 | 0 - 1.4 | CL | Standard | 120.3 | 12.5 |
| TP-16, TP-24, & TP-29 | 2.0 - 4.0 | CH | Standard | 99.1 | 21.4 |
| TP-6, TP-24, & TP-29 | 6.0 - 7.0 | SC | Standard | 101.7 | 21.0 |
| TP-7 | 4.0 - 5.0 | CH | Standard | 97.7 | 24.3 |
| TP-12 | 2.0 - 4.0 | CH | Standard | 103.8 | 19.6 |
| | | | Average: | 104.5 | 19.8 |
| TP-223 | 2.5 - 5.0 | SC | Modified | 125.9 | 10.7 |
| TP-228 | 0.9 - 2.0 | SC | Modified | 127.4 | 8.9 |
| TP-229 | 1.0 - 3.0 | SM | Modified | 131.3 | 7.5 |
| TP-242 | 2.5 - 5.0 | SC | Modified | 122.0 | 11.8 |
| TP-243 | 2.0 - 4.5 | SM-SC | Modified | 121.3 | 12.6 |
| TP-246 | 0.8 - 2.5 | SM-SC | Modified | 133.0 | 8.2 |
| TP-248 | 2.5 - 5.0 | SM-SC | Modified | 123.4 | 11.6 |
| | | | Average: | 126.3 | 10.2 |

**Table 2: Undisturbed Sample Density**

| Boring | Depth (ft) | USCS Soil Classification | Average Dry Density (pcf) | Average Moisture (%) |
|---|---|---|---|---|
| B-734 | 2 - 4 | CL | 110.0 | 16.4 |
| | 6 - 8 | SC | 111.3 | 15.7 |
| B-735 | 4 - 6 | SC | 97.8 | 25.1 |
| | 8 - 10 | SC | 107.7 | 20.8 |
| | | Average: | 106.7 | 19.5 |

In addition to the data, visual observations indicate that the embankments were sufficiently compacted during construction to withstand the range of loading conditions in the CCR Unit. There is no evidence of subsidence or settlement of the embankments. There have been no reported instances of any instability or other conditions since the BA Pond was constructed that would indicate insufficient compaction.

## 2.5 §257.73(d)(1)(iv) Slope Vegetation

At the time of the inspection, vegetation on the exterior slopes of the BA Pond typically was not more than six inches in height and no woody vegetation was observed. The vegetation appeared to be well-maintained. No areas of significantly distressed vegetation were observed. Only very minor areas of thin or bare vegetation and shallow rutting were observed and are discussed further in Section 3.

## 2.6 §257.73(d)(1)(v) Spillway

Prior to BA Pond closure by removal of waste, which was initiated in August 2020, water from the BA Pond discharged into the WD Pond via a trapezoidal weir spillway located within the dike shared by the two ponds. This trapezoidal weir represented the sole spillway for the BA Pond, but was removed upon the initiation of BA Pond closure and fill was compacted to raise the former weir area level with the top of the rest of the shared dike, restoring this portion of the dike to its original design elevation and configuration [Ref. 4].

With the BA Pond undergoing closure, there are no longer any inflows to the pond other than direct rainfall, and no gravity outflows from the pond. Evaporation from the pond offsets the direct rainfall into the pond over the long term, maintaining a naturally low pool within the BA Pond. Over the short term, a temporary pump is positioned near the former spillway location and is available to convey water from the BA Pond to the WD Pond to maintain the naturally low pool elevation in the BA Pond after prolonged periods of wet weather, if necessary. This pump is not used to manage or control the design flood. The entire volume (and therefore the peak flow) of the design flood is now managed using the significant storage capacity available within the BA Pond [Ref. 8].

The BA Pond is classified as a low hazard potential CCR surface impoundment based on the hazard potential classification assessment [Ref. 7]. For a low hazard potential CCR surface impoundment, the design flood event is the 100-year flood. The inflow design flood control system plan [Ref. 8] demonstrates how the available storage capacity available within the BA Pond will adequately manage and retain the entire volume (and therefore the flow) associated with this design flood event. The entire volume of the design flood event can be retained within the BA Pond itself above the typical pool elevation maintained during pond closure activities, with at least four feet of freeboard.

## 2.7 §257.73(d)(1)(vi) Hydraulic Structures

The only known hydraulic structure underlying the base of the BA Pond is the underdrain system that was installed at the time of original BA Pond construction. This system, described in the History of Construction Report [Ref. 4], was abandoned in place, and the outfall manhole grouted.

In preparation for BA Pond closure, all wastewater inflow pipes entering the BA Pond were intercepted and diverted directly to the WD Pond during the recent CCR-ELG project. Several of these pipes were intercepted and diverted just inside the south embankment of the BA Pond, with the new piping routed along the south embankment to the WD Pond. Where these pipes cross over the south embankment of the BA Pond, they are routed through existing concrete pipe trenches that are surfaced with steel grating, allowing for traffic along the top of the perimeter dike to safely pass over them. Construction drawings indicate that the concrete trenches have 18-inch thick bottom slabs and one foot thick walls. The invert elevations of the trenches are approximately 88 feet, which corresponds to the historic normal operating pool elevation (but is approximately four feet higher than the current typical pool during ongoing closure). A concrete wall extends around the pond end of the trenches from the invert to the top of the dike at approximately Elevation 91 feet, thus preventing the flow of pond water back through the trenches should the water level in the pond ever approach the top of the dike. The bentonite geocomposite liner extends to the top of the pipe trench foundation slabs.

An abandoned six-inch diameter steel outfall pipe from the Coal Pile Runoff (CPRO) Pond extends through the embankment at Elevation 89.0 feet. This pipe also penetrates the liner and erosion control revetment. This pipe was grouted shut in 2016. Operationally, this pipe was previously replaced by a six-inch diameter HDPE pipe prior to the time of the initial stability assessment in 2016, and lean concrete was placed around the pipe where it penetrated the concrete revetment. Since that time, this pipe was intercepted outside of the BA Pond dike and all CPRO was diverted to a dedicated CPRO treatment system as part of the CCR-ELG project. Where this pipe was intercepted, the existing pipe was capped to seal off the remaining pipe that enters the BA Pond.

The only other hydraulic structure is a 16-inch diameter HDPE pipe that previously conveyed leachate from the Class 3 Landfill Leachate Collection Pond into the BA Pond. This pipe was installed in July 2015, and enters over the top of the liner system at invert EL 90. Lean concrete also was placed around the end of the pipe where it penetrates the revetment. This pipe was intercepted outside of the BA Pond dike and all leachate was diverted to the WD Pond as part of the CCR-ELG project. Similar to the CPRO pipe, the remaining pipe that enters the BA Pond was capped off when this pipe was intercepted.

None of these structures showed any indication of significant deterioration, deformation, distortion, bedding deficiencies, sedimentation, or debris that would negatively affect their operation where they enter the BA Pond. The integrity of these hydraulic structures (in this case their abandonment) appeared to be adequate with respect to a continued safe condition of the impoundment during ongoing closure. However, erosion around the pipe supports outside the south embankment of the BA Pond was observed for some of the piping routed to the WD Pond that passes through the existing concrete pipe trenches. This is discussed in more detail in Section 3.

## 2.8 §257.73(d)(1)(vii) Downstream Slopes

The crest of the BA Pond is approximately 11 feet higher than the typical site grade surrounding the pond, and is not located near any bodies of water. However, the embankment at the southeast corner of the impoundment is common to the WD Pond. Since both the WD Pond and the BA Pond have bentonite liners, rapid drawdown of the WD Pond would have minimal effect on the structural stability of the common embankment. Some erosion was observed on the downstream slope of the common embankment (i.e. within the WD Pond) at the discharge location of the temporary pump effluent hose. This is discussed in more detail in Section 3.

# 3. Structural Deficiencies

There are no known structural deficiencies of the BA Pond at this time. The inspection did note some areas of interest that should be monitored to minimize the potential for future deterioration. In some cases, repairs are recommended to ensure the structural stability of the impoundment will be maintained during ongoing closure activities. Repair recommendations and procedures are described in Section 4. Refer to Appendix A for the location of each observation.

1. **Observations MR1 through MR5:** There are five areas along the outer slope of the pond embankment where some very small areas of thin vegetation or bare soil, and minor rutting, was observed. These areas appear to be caused by rutting from tractor tires as a result of routine mowing operations. Two such areas (MR1 and MR2) are located near the northwest corner of the pond, west of monitoring well CAP 6. A third area (MR3) is located about 70 feet west of monitoring well CAP 7. A fourth area (MR4) is located about 80 east of monitoring well CAP 8. The fifth area (MR5) is located about 130 feet south of monitoring well CAP-9. Weekly monitoring of these areas should be continued, and the areas re-seeded if conditions worsen.
2. **Observations TD1 and TD2:** The top surface of the dike in one area (TD1) near CAP 7 appears to exhibit a slight inverse crown that slopes to a low point along the outer edge of the dike that currently collects and concentrates more runoff than would otherwise be present from a well-distributed sheet flow off the dike alone. This low point is directly above the area of minor rutting observed near monitoring well CAP 7 (Observation MR3). The additional surface runoff in this area of the slope may be contributing to the conditions responsible for the minor rutting observed in this area of the slope. The top surface of the dike in another area (TD2) near the southeast corner of the BA Pond exhibits an erosion rill within the aggregate surfacing that is concentrating runoff over the outside edge of the dike.
3. **Observation BS1:** A larger area of bare soil (BS1) was observed on the north slope (i.e. within the BA Pond) of the shared dike between the BA Pond and the WD Pond. This area is about 70 feet long measured at the top of the dike, extends down to the ash surface inside the BA Pond, and is associated with the work performed in 2020 to remove the former trapezoidal weir spillway that previously connected the two ponds hydraulically, prior to the initiation of closure by removal. This area did not appear to exhibit erosion at the time of the inspection, but the lack of fully-established vegetation on this slope may be susceptible to erosion in the future.
4. **Observation OF1:** The temporary pump occasionally used to maintain the normal pool within the BA Pond was observed to sit on top of the dike between the BA Pond and the WD Pond, with the suction hose extending down into the BA Pond, and the discharge hose extending partially down the side slope into the WD Pond. At the time of the inspection, the water level in the WD Pond was lowered well below its normal pool to provide additional surge capacity in advance of wet weather. Some erosion of the WD Pond liner protective cover soil was observed around the hose discharge location. If left in its current configuration, this may result in further erosion of the protective cover soil, the underlying bentonite liner, and ultimately the downstream slope of the embankment.
5. **Observations PT1 and PT2:** Erosion was observed in the vicinity of the cast-in-place concrete pipe trenches located along the southern embankment of the BA Pond, including the two westernmost pipe trenches

(PT1) and the eastern pipe trench (PT2). The erosion near the easternmost pipe trench has undermined at least one of the existing pipe support foundations located beyond the outside toe of the embankment, causing the pipes to separate from the supports. Existing grade along inside edge of the BA Pond dike near the pipe trenches is at or above the top surface of the dike, and local area stormwater runoff from the top of the dike is directed into or alongside the pipe trenches and allowed to concentrate as it runs off the exterior slope of the embankment, causing some erosion of the downstream slope of the embankment. While the ash pond embankment itself is intact, continued erosion in this area and additional undermining of the pipe supports could cause pipe failure and result in rapid erosion of the embankment and/or surrounding soils, or undermining of the pipe trenches themselves.

# 4. Corrective Measures

Several areas of the BA Pond were observed to have conditions that could potentially lead to some form of future damage to the impoundment structure if not repaired. At the time of the inspection, none of these areas represented a significant or imminent hazard to the structural integrity of the impoundment that warranted immediate repairs. The repair recommendations and procedures are described as follows:

1. **Observations TD1 and TD2:** Limestone aggregate base course should be placed in these areas and the areas re-graded and compacted to re-establish the normal crown of the dike and restore well-distributed sheet flow conditions over the edge of the dike.
2. **Observation BS1:** The area of bare soil should be stabilized by permanently seeding the area as required to achieve a full stand of grass. The application of topsoil and erosion control blanket may be necessary to achieve final stabilization.
3. **Observation OF1:** The temporary pump effluent hose configuration should be modified to ensure non-erosive conditions at the hose discharge location.
4. **Observations PT1 and PT2:** Pipe support foundations that have moved or otherwise settled as a result of erosion either should be restored to their design condition, or the existing pipe saddles should be modified in a manner to re-establish support for the pipes. Eroded areas around the pipe supports and pipe trenches should be backfilled with compacted fill, and the ground surface in the general area downslope from the pipe trenches should be stabilized. To alleviate the condition responsible for the erosive concentrated flow, diversion ditches should be installed just inside and along the north edge of the embankment (above the revetment) to collect local runoff and redirect it towards the lower areas within the BA Pond.

# 5. Conclusions

Based on available data, discussions with Santee Cooper personnel, and inspection of the CCR surface impoundment, the BA Pond at Cross Generating Station was designed and constructed using recognized and generally accepted good engineering practices. Likewise, the operation and maintenance of the facility also follow recognized and generally accepted good engineering practices. At the time of the inspection, there were no observations that would indicate instability of the structure or preclude the continued safe ongoing beneficial reuse operation and closure of the impoundment.

The inspection noted some areas of interest that should be monitored to minimize the potential for future deterioration. In some cases, repairs are recommended to ensure the structural stability of the impoundment will be maintained during ongoing closure activities.

Based on the evaluations presented in this report, the BA Pond at Cross Generating Station satisfies the structural stability requirements for existing CCR surface impoundments in accordance with §257.73(d)(1).

# 6. Certification

I, the undersigned Professional Engineer registered in good standing in the State of South Carolina, do hereby certify under penalty of law that I have personally examined and am familiar with the information submitted in this demonstration, and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. I certify, for the Cross Generating Station Bottom Ash Pond CCR impoundment, that the periodic structural stability assessment as specified in 40 CFR §257.73(d)(1) was conducted in accordance with the requirements of the section.



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email=fletcher.wood@worley.com
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Fletcher Wood

Printed Name of Professional Engineer

# 7. References


1. WorleyParsons, Santee Cooper Cross Generating Station Bottom Ash Pond Initial Structural Stability Assessment, Rev. 1, November, 2016
2. WorleyParsons, Santee Cooper Cross Generating Station Bottom Ash Pond Initial Safety Factor Assessment, October, 2016
3. Worley, Santee Cooper Cross Generating Station Bottom Ash Pond Periodic (5-Yr) Safety Factor Assessment, October, 2021
4. Santee Cooper, Bottom Ash Pond History of Construction, April, 2021.
5. Woodward-Clyde Consultants, Unit 1 Subsurface Investigation Cross Generating Station, January 26, 1981.
6. Law Engineering Testing Company, Final Report Cross Generating Station, February 9, 1979.
7. Worley, Santee Cooper Cross Generating Station Bottom Ash Pond Periodic (5-Yr) Hazard Potential Classification Assessment, October, 2021
8. Worley, Santee Cooper Cross Generating Station Bottom Ash Pond Periodic (5-Yr) Inflow Design Flood Control System Plan, October, 2021

## Appendix A. Observation Location Plan


BA Pond Observation Location Plan [Ref. Google Earth]