Five-Year Periodic Structural Stability Assessment

Fly Ash Reservoir II
Brilliant, Ohio

October 2021

Prepared For:

Cardinal Operating Company
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Objective

This report was prepared by TRC Engineers, Inc. (TRC) to fulfill requirements of Title 40 Code of Federal Regulations (40 CFR) 257.73(d) and document whether the design, construction, operations, and maintenance of the CCR unit is consistent with recognized and generally accepted good engineering practices. The initial structural stability assessment was completed and uploaded to the operating record on October 9, 2016. This is the first 5-year periodic assessment as required per 40 CFR 257.73(d).

To develop the periodic assessment review, TRC performed the following scope:

- Reviewed historical documents including the initial Structural Stability Assessment prepared by American Electric Power (2016),
- Reviewed the Initial Safety Factor Assessment (S&ME, 2015),
- Reviewed previous annual dam inspection reports for 2019 and 2020,
- Reviewed current monitoring data for piezometers and deformation instrumentation for FAR II,
- Performed a site visit on September 1, 2021 to visually observe current conditions, and
- Developed observations related to the updated structural stability assessment review.

1.0 Name and Description of CCR Surface Impoundment

The Cardinal Power Plant (Plant) is located in Wells Township, Jefferson County, near the town of Brilliant in eastern Ohio. It is owned by Buckeye Power and AEP Generation Resources (GENCO) and is operated by Cardinal Operating Company (Operator). The Plant currently operates two surface impoundments for storing coal combustion residuals (CCR): the Bottom Ash Complex and Fly Ash Reservoir II (FAR II). This assessment addresses the FAR II only.

The FAR II is a valley filled dam whose current configuration is the result of the original earth fill dam and two separate raisings. The original earth fill dam (Stage 1) consisted of an approximate 180-foot high, arched earth embankment incorporating a zoned cross section. The Stage 1 dam was approximately 70 feet wide by approximately 1,055 feet long at the crest with a top of berm elevation of approximately 925 feet National Geodetic Vertical Datum of 1929 (NGVD). The maximum operating pool that could be achieved with the original configuration was approximately 913 feet NGVD. In 1997, the Stage 1 FAR II was raised, referred to as Stage 2. The Stage 2 dam was approximately 237 feet high with an approximate 30-foot wide crest. In 2013, the dam was raised 13 feet using back-to-back mechanically stabilized earth (MSE) walls, bringing the FAR II into its current configuration, Stage 3. The principal features of the Stage 3 typical section are the MSE wall structures and a vinyl sheet pile wall that provides seepage cutoff for the probable maximum flood (PMF) event by extending through the MSE backfill into the existing clay core.

2.0 Stable Foundation and Abutments [257.73(d)(1)(i)]

Was the facility designed for and constructed on stable foundations and abutments? Describe any foundation improvements required as part of construction.

During design and construction of the Stage 1 dam, the overburden was observed to be saturated and appeared to be heterogeneous, with some material having a softer consistency than that of the samples tested with the geotechnical explorations. Therefore, the overburden material was determined to be unsuitable for the foundation material, and based on our understanding was removed in the area beneath the dam and along the valley slopes up to approximately elevation 800 feet NGVD.

Based on the design drawings, a foundation key was constructed along the centerline of the dam. The key was excavated 6 to 8 feet into the bedrock beneath the dam and along the valley slopes up to approximately elevation 800 feet NGVD.

At the abutment locations, a cut that extended to bedrock was made. The trimmed faces were oriented so that the upstream core of the dam intersects the abutments at right angles. This symmetrical configuration resulted in balanced seating of the clay core against the bedrock which reduces interface seepage and minimizes the potential for cracking of the core.

A grout curtain was provided in the abutments of the dam. The dam was arched in the upstream direction and camber was provided to compensate for settlement. Slope protection consisted of roller compacted concrete (RCC) Facing for Stage 2 construction in the upstream and grass and riprap on the downstream for Stage 1 and 2 slopes with riprap in the groin of the dam. Stage 3 construction did not require additional slope protection. Based on recent subsurface investigations, the density and description of the foundation materials appear to be adequate for this CCR unit.

During the 2021 site visit, the abutment showed no signs of global instability or apparent changes in geometry as compared to the descriptions provided in the 2020 inspection. The FAR II dam abutments, downstream slope, and downstream floor area visible at the time of the inspection appeared stable with no visible signs of slumping, seepage, or significant erosion. TRC reviewed recent instrumentation results that confirmed visual observations that no significant movement of the earthen dam has occurred. Based on these items, the foundation and abutments of the FAR II dam continue to meet the criteria of CFR 257 (d)(1)(i) and no further action must be taken at this time, other than to continue regularly scheduled inspections, maintenance, and monitoring.

3.0 Slope Protection [257.73(d)(1)(ii)]

Describe the slope protection measures on the upstream and downstream slopes.

Slope protection consisted of RCC Facing for the upstream Stage 2 face and grass on the downstream Stage 1 and 2 slopes with riprap in the groin of the dam. Stage 3 slope protection is provided by the concrete MSE wall panels. Based on conversations with the Operator, erosion identified during weekly inspections is repaired within a timely period in accordance with the Operating and Maintenance Plan.

Per the 2020 inspection performed by others, the crest of the dam, the groin areas, the flow line, the left groin ditch, the downstream slopes, the western exterior slope and the inboard and outboard slopes showed no significant signs of erosion. The downstream slope also appears to have a good stance of vegetation with no large areas of stressed vegetation.

Due to recent precipitation within the last few days, erosion rills have developed as observed at the time of TRC's September 1, 2021 site visit, within the gravel access drive located on the east side of the dam along the downstream slope. The erosion appeared to be contained within the access road gravel layer and did not extend into the underlying subgrade (e.g., dam surface). The Operator indicated at the time of the inspection that the erosion rills would be repaired as soon as feasible. The riprap material within the rock letdowns was observed to be in fair condition. The rock fragments are continuing to weather and deteriorate in some cases, but the material appears to be protecting the surface of the dam. The Operator should continue to monitor the riprap and replace, as needed, to continue protection within the letdowns.

4.0 Embankment Construction [257.73 (d)(1)(iii)]

Describe the specifications for compaction and/or recent boring to give a relative comparison of density.

The design drawings indicate that the embankment materials were to be compacted to a minimum of 100% of the maximum dry density as determined by Standard Proctor (ASTM D698) method or 90% of the maximum dry density as determined by Modified Proctor (ASTM D1557). Previous soil borings drilled by others through the embankment for design of the Stage 3 dam indicate that the material is stiff based on the results of the Standard Penetration Tests (SPT) (ASTM D1586) and representative of compacted earthen materials. Daily field reports, compaction quality assurance testing, or other as-built documentation was not available for TRC's review as part of this assessment.

Since the completion of Stage 3 construction, the FAR II has been monitored for signs of deformation or instability. A deformation report (Amanda Graphics, LLC, 2021) was provided to TRC with monitoring updated as of June 2021. This report presents data from a series of 6 inclinometers to measure relative displacement. Of these six, five reported little to no deformation. SI-5 reported moderate deformation (0.16 inches over a 1-month period) and should be monitored closely to identify if future trends indicate excess deformation. In addition, foundation piezometer P-11b gained approximately 7 feet of head from 2002-2021 as groundwater levels have responded to increases with water levels in FAR II. Over the past 6-years, the reported elevations in P-11b have varied by less than 1 foot. This piezometer should be closely monitored for future changes in head in comparison to the action levels identified in the Initial Safety Factor Assessment (S&ME, 2015).

5.0 Vegetation Control [257.73 (d)(1)(iv)]

Describe the maintenance plan for vegetative cover.

The vegetative areas are mowed to facilitate inspections, inhibit rodent burrowing, and maintain the growth of the vegetative layer; and prevent the growth of woody vegetation. As previously discussed, at the time of TRC's September 1, 2021 site visit, the downstream slope appears to have a good stance of vegetation with no large areas of stressed vegetation.

6.0 Spillway System [257.73(d)(1)(v)]

Describe the spillway system and its capacity to pass the Inflow Design Flood as per its Hazard Classification.

The spillway system consists of a primary weir box and pipe for normal operations and an open channel spillway to pass flood events. The CCR unit has a high Hazard rating and is designed to safely pass the PMF flood without overtopping the dam crest.

6.1 Service Spillway

The existing service spillway is a vertical concrete shaft structure with a side opening for effluent discharge via a weir. This vertical concrete shaft connects into a sloping concrete shaft structure on the upstream face of the FAR II dam with one side opening, four feet wide. The sloping concrete shaft discharges into a 54-inch diameter pre-stressed concrete cylinder pipe (PCCP), designed for 200 feet of internal hydraulic pressure and 200 feet of overburden pressure. During most operating conditions, discharge through the service spillway is controlled by the-weir flow over the side openings in the shaft. The bottom of the sloping concrete shaft and the entire 54-inch concrete pipe was constructed within bedrock during the 1997 raising. Stop logs are utilized to maintain settling action and control the operating pool level. The CCR unit has a high Hazard rating and therefore is designed for a probable maximum flood, which is defined as 26.5 inches of rain for a 6-hour period based on Hydrometeorological Report 51 by the National Weather Service. The facility can pass this flood without overtopping the dam crest utilizing the service spillway and the emergency spillway.

At the time of TRC's September 1, 2021 site visit, the principal spillway appeared to be in good condition, with no obstructions at the stop-log structure and no signs of instability on the riser of the staircase.

6.2 Emergency spillway

During the 2013 construction, the existing emergency spillway was raised using a concrete gravity section in conjunction with reinforced concrete retaining walls. The new walls direct the flow into the existing spillway outlet channel. In accordance with State of Ohio dam safety requirements for Class 1 dams, the new emergency spillway was designed to pass the design PMF without overtopping the dam. The new spillway features a 108-foot-long by 15-foot-wide concrete control section, weir, positioned at an approximate elevation 975.5 feet NGVD, or 1.5 feet above the maximum operating pool. The training walls are located above elevation 975.5 and will consequently not be exposed to a continuous pool reducing corrosion concerns. Based on the flood routing, the calculated peak discharge from the dam is 5,409 cubic feet per second at a maximum pool elevation of 981.9 feet NGVD. The PMF routing was also checked with the service spillway blocked, which resulted in a maximum pool elevation of 982.8 and 0.2 feet of freeboard.

At the time of TRC's September 1, 2021 site visit, the emergency spillway appeared to be in fair condition, with some moderate cracking observed in the concrete sidewalls. The cap of the west concrete sidewall also appears to have adjusted based on a couple inch space between the cap and the wall panel, however, it should be noted that the amount of the adjustment seems to be similar when compared to photographs of the 2019 and 2020 inspections. The surface of the RCC within the surface of the emergency spillways also appears to be degrading and has some erosion rills present. The cracking of the concrete sidewall, adjustment of the west sidewall cap, and erosion of the spillway surface should continue to be monitored and repaired if necessary.

7.0 Buried Hydraulic Structures [257.73 (d)(1)(vi)]

Describe the condition of the sections of any hydraulic structure that in buried beneath and/or in the embankment.

The principal outlet pipe from FAR II passes though the dam near the southwestern side of the dam. The portion of the outlet pipe that passes though the embankment is a 54-inch diameter pre-stressed concrete cylinder pipe (PCCP), designed for 200 feet of internal hydraulic pressure and 200 feet of overburden pressure. The entire 54-inch concrete pipe was constructed within bedrock during the 1997 raising. No performance issues have been reported by the Operator or previous operators with the outlet pipe that would indicate plugging or failure of the pipe. Given that this portion of pipe is reinforced concrete, structural integrity is not considered to be an issue at this time. In general, reinforced concrete pipe has a long service life under a range of conditions and is an appropriate design for this application.

At the time of TRC's September 1, 2021 site visit, this pipe appears to be functioning in good condition. There were no signs of potential structural issues that would negatively affect its stability or safe operation and the inflow and outflow from the principal outlet pipe appeared to be conveyed without restriction.

8.0 Sudden Drawdown [257.73 (d)(1)(vii)]

If the downstream slope is susceptible to inundation, discuss the stability due to a sudden drawdown.

The downstream slope of the FAR II is not expected to be inundated from adjacent water bodies, such as a river, stream or lake. Therefore, a sudden drawdown assessment to evaluate the

structural stability during low pool of the adjacent water body or sudden drawdown of the adjacent water body is not required.

9.0 Conclusions and Recommendations

Upon the review of available documentation as previously discussed and the visual observations from TRC's September 1, 2021 site visit, it can be concluded that the FAR II Dam continues to meet of 40 CFR 257.73. Overall, the foundation and abutments appear to be stable, appropriate slope protection measures are in place and are maintained as needed, the embankment was compacted to a sufficient density during initial construction, vegetative overgrowth is cleared and maintained in a timely manner, the spillways can control a PMF, and buried structures are in acceptable condition. TRC recommends a few extra measures be taken after review of the inspection reports and the deformation report.

1. Continue to perform inspections and monitor the dam for erosion and ensure the erosion protection measures are performing satisfactorily, such as the condition of the vegetation and riprap within the letdown. Repair areas of erosion and erosion protection measures, as necessary and as quickly as feasible, as part of routine maintenance.

2. Continue to monitor inclinometer SI-5 for movement that is outside of acceptable bounds, and continue to closely evaluate monument P-11B for future changes in piezometric head. These were the only recent data points in the deformation report that observed substantial changes since construction.

10.0 Limitations

The observations, assessment, and recommendations presented in this Report are based on our limited scope of work and on information disclosed by our visual observations, the conditions of the site at the time of the September 1, 2021 inspection, the design information available at the time of this investigation, and only apply to the Cardinal FAR II Dam. This work has been performed in accordance with our authorized scope of work and is based on the level of effort and investigative techniques using that degree of care and skill ordinarily exercised under similar conditions by reputable members of the profession practicing in the same or similar locality at the time of service. No other warranties, expressed or implied, are made or intended by this Report. These services were intended to provide an indication of the current, observable conditions of the dam at the time of the visual observations on the date indicated in this Report. Such a limited visual review does not account for other non-visible, hidden, subsurface or material condition analyses, and the professional services rendered are not guaranteed to be a representation by TRC of inaccessible and unobservable site conditions or actual conditions subsequent to the date of TRC's site visit. Therefore, the evaluations, conclusions, recommendations and opinions provided in this Report are subject to change as a result of future natural or manmade processes and as a result of an additional comprehensive, intrusive investigation and engineering analyses beyond TRC's visual observations. TRC is not responsible for any conclusions or opinions drawn by others from the data included herein, nor are the recommendations specifically presented in this Report intended for use or reliance as construction specifications.

11.0 Certification

I, the undersigned Ohio Professional Engineer, hereby certify that I am familiar with the technical requirements of 40 CFR 257 Subpart D. I also certify that the information contained in this document was conducted in accordance with 40 CFR 257.73(d) based on the currently available data reviewed, and that the information reviewed is, to the best of my knowledge, accurate and correct.

For the purpose of this document, “certify” and “certification” shall be interpreted and construed to be a “statement of professional opinion.” The certification is understood and intended to be an expression of my professional opinion as a Licensed Professional Engineer, based upon knowledge, information, and belief. The statement(s) of professional opinion are not and shall not be interpreted or construed to be a guarantee or a warranty of the analysis herein.

Shawn D. McGee, P.E.	PE.68761
Name	Engineer License Number
	10/8/2021
Signature of Professional Engineer	Date

12.0 References

Amanda Graphics, LLC. 2020. 2019 Annual Dam and Dike Inspection Report: Cardinal Plant – Fly Ash Dams 1, 2 & Bottom Ash Complex. January 2020.

Amanda Graphics, LLC. 2021. 2020 Annual Dam and Dike Inspection Report: Cardinal Plant – Fly Ash Dams 1, 2 & Bottom Ash Complex. January 2021.

Amanda Graphics, LLC. 2021. Deformation Review Report of Survey: Cardinal Plant – Fly Ash Dam. June 2021.

American Electric Power Service Corporation. 2016. Structural Stability Assessment – CFR 257.73(d): Fly Ash Reservoir II – Cardinal Plant, Brilliant, Ohio. October 2016.

S&ME. 2015. Safety Factor Assessment for the Fly Ash Reservoir II Dam at the Cardinal Power Plant. Brilliant, Ohio.