Liner Evaluation Report
Coffeen GMF Pond

Illinois Power Generating Company
Coffeen Power Station
Montgomery County, Illinois

October 2016

Engineering | Planning | Allied Services

COFFEEN GMF POND
ILLINOIS POWER GENERATING COMPANY
LICENSED PROFESSIONAL ENGINEER CERTIFICATION

As a Qualified Professional Engineer as defined by 40 CFR 257.53 and being a Professional Engineer licensed in the State of Illinois, I certify that I have personally examined and am familiar with the information in the Coffeen GMF Pond Liner Evaluation Report and the Coffeen GMF Pond Liner Documentation Report in the operating record and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate and complete.

As required by 40 CFR 257.71(b), the Coffeen GMF Pond Liner Evaluation Report and the Coffeen GMF Pond Liner Documentation Report in the operating record are accurate and the **Coffeen GMF Pond** meets the requirements set forth in 40 CFR 257.71(a)(1)(ii) as published on April 17, 2015.

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1. Summary

The Coffeen GMF Pond (GMF Pond) was constructed to retain wet-sluiced gypsum produced in the flue-gas scrubber at the Coffeen Power Station. Construction of the GMF Pond began in July 2008 and was completed in October 2010. It encompasses about 43.3 acres within the northwest quarter of Section 11, Township 7 North, Range 3 West of the Third Principal Meridian, just north of the Coffeen Power Station.

The composite liner system in the GMF Pond was designed to comply with Illinois Environmental Protection Agency rules for solid waste landfills. Liner system performance criteria is contained in 35 Illinois Administrative Code (IAC) Part 811 as follows:

35 IAC 811.306 Liner Systems

d) Compacted Earth Liner Standards

1) The minimum allowable thickness shall be 1.52 meters (5 feet).

2) The liner shall be compacted to achieve a maximum hydraulic conductivity of $1X10^{-7}$ centimeters per second.

3) The construction and compaction of the liner shall be carried out in accordance with the construction quality assurance procedures of Subpart E so as to reduce void spaces and allow the liner to support the loadings imposed by the waste disposal operation without settling that causes or contributes to the failure of the leachate collection system.

4) The liner shall be constructed from materials whose properties are not affected by contact with the constituents of the leachate expected to be produced.

5) Alternative specifications, using standard construction techniques, for hydraulic conductivity and liner thickness may be utilized under the following conditions:

A) The liner thickness shall be no less than 1.52 meter (5 feet) unless a composite liner consisting of a geomembrane immediately overlying a compacted earth liner is installed. The following minimum standards shall apply for a composite liner:

i) the geomembrane shall be no less than 60 mils in thickness and meet the requirements of subsection (e); and

ii) the compacted earth liner shall be no less than 0.91 meter in thickness (3 feet) and meet the requirements of subsection (d)(2) through (d)(4).

B) The modified liner shall operate in conjunction with a leachate drainage and collection system to achieve equivalent or superior performance to the requirements of this subsection. Equivalent performance shall be evaluated at maximum annual leachate flow conditions.

In accordance with 35 IAC 811.306(d)(5)(A)(i) and (ii), the GMF Pond composite liner was designed and constructed with 3-feet of compacted clay with a maximum permeability of 1×10^{-7} cm/sec, overlain by a 60-mil textured HDPE geomembrane.

In April 2015, the United States Environmental Protection Agency published rules at 40 CFR Part 257, Subpart D, regulating the disposal of coal combustion residuals (CCR) in landfills and surface impoundments located in association with electrical utilities utilizing coal as the primary fuel source. Liner system performance criteria for existing CCR surface impoundments is specified in 40 CFR Part 257, Subpart D, as follows:

257.71 Liner design criteria for existing CCR surface impoundments.

(a)(1) No later than October 17, 2016, the owner or operator of an existing CCR surface impoundment must document whether or not such unit was constructed with any one of the following:

(i) A liner consisting of a minimum of two feet of compacted soil with a hydraulic conductivity of no more than 1 × 10^{-7} cm/sec;

(ii) A composite liner that meets the requirements of §257.70(b); or

(iii) An alternative composite liner that meets the requirements of §257.70(c).

(2) The hydraulic conductivity of the compacted soil must be determined using recognized and generally accepted methods.

(3) An existing CCR surface impoundment is considered to be an existing unlined CCR surface impoundment if either:

(i) The owner or operator of the CCR unit determines that the CCR unit is not constructed with a liner that meets the requirements of paragraphs (a)(1)(i), (ii), or (iii) of this section; or

(ii) The owner or operator of the CCR unit fails to document whether the CCR unit was constructed with a liner that meets the requirements of paragraphs (a)(1)(i), (ii), or (iii) of this section.

(4) All existing unlined CCR surface impoundments are subject to the requirements of §257.101(a).

(b) The owner or operator of the CCR unit must obtain a certification from a qualified professional engineer attesting that the documentation as to whether a CCR unit meets the requirements of paragraph (a) of this section is accurate.

(c) The owner or operator of the CCR unit must comply with the recordkeeping requirements specified in §257.105(f), the notification requirements specified in §257.106(f), and the Internet requirements specified in §257.107(f).

As referenced in 40 CFR 257.71(a)(1)(ii), 40 CFR 257.70(b), Design criteria for new CCR landfills and any lateral expansion of a CCR landfill, provides:

(b) A composite liner must consist of two components; the upper component consisting of, at a minimum, a 30-mil geomembrane liner (GM), and the lower component consisting of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than 1 × 10^{-7} centimeters per second (cm/sec). GM components consisting of high density polyethylene (HDPE) must be at least 60-mil thick. The GM or upper liner component must be installed in direct and uniform contact with the compacted soil or lower liner component. The composite liner must be:

(1) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeologic forces), physical contact with the CCR or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation;

(2) *Constructed of materials that provide appropriate shear resistance of the upper and lower component interface to prevent sliding of the upper component including on slopes;*

(3) *Placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift; and*

(4) *Installed to cover all surrounding earth likely to be in contact with the CCR or leachate.*

In accordance with 40 CFR 257.70(b)(1) above, the composite liner in the Coffeen GMF Pond was constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeologic forces), physical contact with the CCR or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation. This information is located in Section 4 and Section 5 of the Coffeen GMF Pond Liner Documentation Report located in the operating record.

In accordance with 40 CFR 257.70(b)(2) above, the composite liner in the Coffeen GMF Pond was constructed of materials that provide appropriate shear resistance of the upper and lower component interface to prevent sliding of the upper component, including on slopes. This information is located in Section 4 of the Coffeen GMF Pond Liner Documentation Report located in the operating record.

In accordance with 40 CFR 257.70(b)(3) above, the composite liner in the Coffeen GMF Pond was placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift. This information is located in Section 4 of the Coffeen GMF Pond Liner Documentation Report located in the operating record.

In accordance with 40 CFR 257.70(b)(4) above, the composite liner in the Coffeen GMF Pond was installed to cover all surrounding earth likely to be in contact with the CCR or leachate. This information is located in the "Geosynthetics Quality Assurance Report, Gypsum Stack, AERG (Ameren) Coffeen Power Station, Coffeen, Montgomery County, Illinois. Feezor Engineering, Inc." in the Coffeen GMF Pond Liner Documentation Report located in the operating record.

The purpose of this report is to document that the existing composite liner in the Coffeen GMF Pond meets the minimum requirements of 40 CFR 257.71(a)(1)(ii), i.e., a composite liner that meets the requirements of §257.70(b).

Briefly, in comparison:

35 IAC 811.306(d)(5)(A) requires a compacted clay liner of at least three (3) feet in thickness with a hydraulic conductivity of less than $1x10^{-7}$ cm/sec, overlain by a geomembrane of no less than 60-mils in thickness.

40 CFR 257.71(a)(1)(ii) requires a compacted soil liner of at least two (2) feet in thickness with a hydraulic conductivity of no more than $1x10^{-7}$cm/sec, overlain by a geomembrane of no less than 30-mils in thickness. If the geomembrane is composed of high-density polyethylene (HDPE), the geomembrane must be a minimum of 60-mils in thickness.

Thus, the composite liner in the Coffeen GMF Pond was designed and constructed with components exceeding the minimum required in 40 CFR 257.71(a)(1)(ii).

The major components of the construction and Construction Quality Assurance (CQA) of the GMF Pond liner are discussed in the sections below.

2. Foundation Preparation

Foundation preparation consisted of removing the soil to foundation grade in the bottom of the GMF Pond, construction of the perimeter berm containing the GMF Pond, and surveying and certifying the foundation surface.

The construction contractor initially stripped topsoil below the root zone within the GMF Pond and its perimeter berm location.

The bottom of the GMF Pond was excavated to and into the Vandalia Till. The excavated till was used to raise portions of the GMF Pond bottom to foundation grade sloping from the northwest corner to the south and east. The foundation surface was proof rolled and visually observed. Soils in undercut areas were removed and then backfilled with excavated till from the GMF Pond.

Nuclear moisture/density gauge testing was performed during foundation backfill placement at a minimum rate of one test per 10,000 yd^3 (and a minimum one test per compacted lift). The material was placed in approximately 8-inch lifts and compacted with a Cat 815 sheepsfoot compactor and/or a smooth drum roller to at least 95% Standard Proctor maximum dry density with moisture contents of -2% to +2% of optimum. Areas that showed deficiencies in compaction or moisture content were reworked or removed, and then compacted with a Cat 815 sheepsfoot compactor and/or a smooth drum roller and tested for moisture/density. Nuclear moisture/density and Standard Proctor test results are included in Appendix D in the Coffeen GMF Pond Liner Documentation Report located in the operating record.

Finished foundation grades were verified by survey and certified (Appendices I and J in the Coffeen GMF Pond Liner Documentation Report located in the operating record), and CQA certifications of completion were provided by the CQA Officer.

3. Berm Construction

The perimeter berm was constructed with structural fill excavated and hauled directly from the GMF Pond and other borrow areas within the facility. Nuclear moisture/density gauge testing was performed during berm construction at a minimum rate of one test per 10,000 yd^3 (and a minimum one test per compacted lift). Fill was placed in approximately 8-inch lifts and compacted with a Cat 815 or 825 sheepsfoot compactor to at least 95% Standard Proctor maximum dry density with moisture contents of -2% to +2% of optimum. Areas that showed deficiencies in compaction or moisture content were reworked or removed, and then compacted with a Cat 815 or 825 sheepsfoot compactor and tested for moisture/density. Nuclear moisture/density and Standard Proctor test results are included in Appendix D in the Coffeen GMF Pond Liner Documentation Report located in the operating record.

Four (4) Shelby tube samples (ST-040 through ST-043) were collected from the perimeter berm, and were delivered to Hanson's Geotechnical Laboratory in Springfield, Illinois. A soil sample from each tube was tested to determine in-place hydraulic conductivity (permeability). Table 3.1 summarizes the hydraulic conductivity test results.

Table 3.1 Laboratory Permeability Test Results of Perimeter Berm

Sample No.	Location	Hydraulic Conductivity, (k_V)
ST-040	East Berm	1.5×10^{-9} cm/sec
ST-041	North Berm	1.9×10^{-9} cm/sec
ST-042	West Berm	5.4×10^{-9} cm/sec
ST-043	South Berm	4.7×10^{-9} cm/sec

4. Test Soil Liner

Prior to construction of the full scale soil liner, one test soil liner was constructed to the west of Landfill Cell L1 using one borrow source. Landfill Cell L1 is located directly west of the GMF Pond. The purpose of the test soil liner was to verify that the material and methods of construction proposed for the full scale soil liner would provide the appropriate permeability performance criteria required by 35 IAC 811.306(d).

The borrow material for the test soil liner was obtained from clay material excavated from the footprint of Landfill Cell L1 that was stockpiled to the west of Cell L1 ("West Landfill Liner Stockpile"). The clay material from the West Landfill Liner Stockpile was determined to be the same material that was to be used to construct the full scale soil liner in the GMF Pond. Therefore, the single test liner was utilized for both Landfill Cell L1 and the GMF Pond. In accordance with 35 IAC 811.306(d)(2), the material selected had sufficient fines to achieve an in-place hydraulic conductivity of 1.0×10^{-7} cm/sec or less.

4.1 Prequalification of Borrow Material

While no prequalification testing is required by the regulations, a program of laboratory testing was carried out on typical samples of the material used for the construction of the test soil liner and the GMF Pond's full scale soil liner. Tables 4.1 and 4.2 summarize the borrow material properties determined from testing (Appendix E.1 in the Coffeen GMF Pond Liner Documentation Report located in the operating record contains laboratory test reports).

Table 4.1 Properties of Borrow Material

Sample No.	Percent of Fines	Liquid Limit	Plasticity Index	Maximum Dry Density (MDD)	Optimum Moisture Content (OMC)
West Landfill Liner Stockpile					
1 L1 Liner	71.0%	36%	22%	110.5 pcf	16.1%
GMF Pond Liner Stockpile					
SP-002-001	76.7%	40%	25%	110.8 pcf	15.9%
GMF Pond Test Pits (combined samples)					
DP-13 2'-6'	96.9%	54%	35%	98.3 pcf	22.1%
DP-13 4'-8'	85.5%	41%	25%	106.5 pcf	17.4%
DP-21 2'-6'	93.6%	48%	30%	100.0 pcf	19.7%
DP-21 4'-8'	86.2%	41%	25%	105.4 pcf	17.9%
West Borrow Pit	90.1%	41%	23%	103.4 pcf	16.5%

Table 4.2 Constant Head Permeability Test Results of Borrow Material

Sample No.	Dry Density	Moisture Content	Permeability Result
West Landfill Liner Stockpile 1 L1 Liner	95% of MDD	1.5% West of OMC	5.0 x 10^{-9} cm/sec
GMF Pond Test Pits (combined samples)			
DP-13 2'-6'	95% of MDD	2.0% Wet of OMC	1.1 x 10^{-8} cm/sec
DP-13 4'-8'	95% of MDD	0.5% Wet of OMC	4.1 x 10^{-8} cm/sec
DP-21 2'-6'	95% of MDD	1.5% Wet of OMC	9.1 x 10^{-9} cm/sec
DP-21 4'-8'	95% of MDD	1.5% Wet of OMC	8.8 x 10^{-9} cm/sec
West Borrow Pit	95% of MDD	1.0% Wet of OMC	7.9 x 10^{-8} cm/sec

Based on the test results summarized in Tables 4.1 and 4.2, the field compaction criteria for the soil liner were set as follows to assure that a field permeability value of 1.0 x 10^{-7} cm/sec or less could be achieved:

Dry Density $\geq$ 95% MDD
Moisture Content = 0% to 5% Wet of OMC

4.2 Test Soil Liner Construction

The construction of the test soil liner was initiated on May 20, 2009. The foundation was proof rolled and visually observed for soft areas or unsuitable soils. No material removal or backfilling was required.

The test soil liner was constructed west of Landfill Cell L1 with material from the West Landfill Liner Stockpile. The material was keyed into the foundation material and compacted with a Cat 815 sheepsfoot compactor in approximately 8-inch lifts. Nuclear moisture/density gauge testing was performed at a minimum rate of one test per acre per lift or one test per 1,000 yd^3 to 95% Standard Proctor MDD with moisture contents of optimum to +5% (as determined in Section 4.1 above). Areas that showed deficiencies in compaction or moisture content were reworked or removed, and then compacted with a Cat 815 sheepsfoot compactor and tested for moisture/density. Nuclear moisture/density test results and a drawing showing the testing locations are included in Appendix E.3 in the Coffeen GMF Pond Liner Documentation Report located in the operating record. The Standard Proctor test report is included in Appendix E.4 in the Coffeen GMF Pond Liner Documentation Report located in the operating record.

On May 22, 2009, the test soil liner was completed after it was smooth drum rolled and then covered with a clear plastic covering to prevent moisture loss.

4.2.1 Sampling and Testing Programs for Test Soil Liner

Pursuant to the CQA Plan, the test soil liner was sampled and tested for physical properties utilizing both laboratory and field testing. Required were at least five (5) two-stage field tests to determine the hydraulic conductivity (both vertical and horizontal hydraulic conductivity were calculated), and at least two (2) undisturbed Shelby tube samples tested in the laboratory for vertical hydraulic conductivity to determine a statistical correlation with the field tests.

4.2.1.1 Laboratory Testing

Two (2) Shelby tube samples were collected from the test soil liner on May 22, 2009. ST-01 and ST-02 were delivered to Hanson's Geotechnical Laboratory for laboratory permeability testing. A sample from each tube was tested for particle size analysis, Atterberg limits, and hydraulic conductivity. Table 4.3 summarizes the test results (Appendix E.5 in the Coffeen GMF Pond Liner Documentation Report located in the operating record contains laboratory test reports and Shelby tube sample locations).

Table 4.3 Results of Laboratory Testing Program for Test Soil Liner

Sample No.	Percent of Fines	Liquid Limit	Plasticity Index	Hydraulic Conductivity, k_v	Pass / Fail	Lift
ST-01	75.1%	39.2%	25.2%	2.0×10^{-9} cm/sec	Pass	5
ST-02	76.0%	40.8%	26.9%	1.8×10^{-9} cm/sec	Pass	5

4.2.1.2 Field Testing

Six (6) two-stage (Boutwell) field permeability tests were conducted on the test soil liner. The tests were carried out to measure the limiting values of field saturated hydraulic conductivity. The first stage of the test measured the vertical component of hydraulic conductivity (k_v) while the second stage measured the horizontal component (k_h). Table 4.4 summarizes the Boutwell test results (Appendix E.6 in the Coffeen GMF Pond Liner Documentation Report located in the operating record contains Boutwell testing locations and the report of the field testing results).

Table 4.4 Results of Field Testing Program for Test Soil Liner

Boutwell Test No.	Stage 1 Hydraulic Conductivity, k_v	Stage 2 Hydraulic Conductivity, k_h
1	1.31×10^{-8} cm/sec	6.33×10^{-9} cm/sec
2	5.55×10^{-8} cm/sec	6.18×10^{-8} cm/sec
3	1.09×10^{-8} cm/sec	5.74×10^{-9} cm/sec
4	9.13×10^{-8} cm/sec	1.94×10^{-8} cm/sec
5	1.02×10^{-8} cm/sec	3.34×10^{-9} cm/sec
6	1.19×10^{-8} cm/sec	7.37×10^{-9} cm/sec

4.2.1.3 CQA Certification of Test Soil Liner

Based on the laboratory and field test results, the CQA Officer certified the construction of the test soil liner and that construction of the full scale soil liner could begin using the same soils and procedures used to construct the test liner.

5. Full Scale Soil Liner Construction

Construction of the full scale soil liner began on April 14, 2010 in the northwestern section of the GMF Pond and continued to the south and east. The soil material from the GMF Pond Liner Stockpile and the West Borrow Pit were used to construct the 3-ft thick soil liner within the GMF Pond. Like the test soil liner, the soil was placed in approximately 8-inch thick lifts and compacted with a Cat 815 sheepsfoot compactor. Nuclear moisture/density gauge testing was performed at a minimum rate of one test per acre per lift or one test per 1,000 yd^3 to 95% Standard Proctor MDD with moisture contents of optimum to +5%. Areas that showed deficiencies in compaction or moisture content were reworked or removed, and then compacted with a Cat 815 sheepsfoot compactor and tested for moisture/density. Nuclear moisture/density and Standard Proctor test results are included in Appendix F in the Coffeen GMF Pond Liner Documentation Report located in the operating record.

Twenty-one (21) Shelby tube samples were collected at various stages of the liner construction. The hydraulic conductivity of the compacted soil liner was sampled and laboratory tested in accordance with ASTM D5084. The samples were delivered to Hanson's Geotechnical Laboratory for permeability testing. A sample from each tube was tested to determine hydraulic conductivity. The sample intervals included at least one permeability test from each of the five liner construction lifts. Table 5.1 summarizes the hydraulic conductivity test results, which are all less than the 1.0 x 10^{-7} cm/sec performance criterion. Permeability test results and a drawing showing Shelby tube sample locations are included in Appendix F.3 in the Coffeen GMF Pond Liner Documentation Report located in the operating record.

Table 5.1 Laboratory Permeability Test Results of Soil Liner

Sample No.	Hydraulic Conductivity, (k_V)	Pass / Fail	Lift
ST-019	2.1 x 10^{-9} cm/sec	Pass	2
ST-020	4.3 x 10^{-9} cm/sec	Pass	1
ST-021	3.8 x 10^{-9} cm/sec	Pass	4
ST-022	1.8 x 10^{-9} cm/sec	Pass	4
ST-023	3.8 x 10^{-9} cm/sec	Pass	5
ST-024	4.0 x 10^{-9} cm/sec	Pass	1
ST-025	2.7 x 10^{-9} cm/sec	Pass	3
ST-026	9.6 x 10^{-9} cm/sec	Pass	3
ST-027	7.4 x 10^{-10} cm/sec	Pass	4
ST-028	2.7 x 10^{-9} cm/sec	Pass	2
ST-029	2.7 x 10^{-9} cm/sec	Pass	5
ST-030	6.0 x 10^{-9} cm/sec	Pass	3
ST-031	6.7 x 10^{-9} cm/sec	Pass	2
ST-032	4.2 x 10^{-9} cm/sec	Pass	5
ST-033	2.4 x 10^{-8} cm/sec	Pass	4
ST-034	4.5 x 10^{-9} cm/sec	Pass	4
ST-035	5.3 x 10^{-9} cm/sec	Pass	5
ST-036	1.1 x 10^{-8} cm/sec	Pass	3
ST-037	3.0 x 10^{-9} cm/sec	Pass	1
ST-038	3.8 x 10^{-9} cm/sec	Pass	1
ST-039	2.7 x 10^{-9} cm/sec	Pass	2

Base grades and completed liner elevations were surveyed to ensure construction to the design grades and to verify minimum soil liner thickness. Record drawings and certified survey data are included in Appendices I and J, respectively, in the Coffeen GMF Pond Liner Documentation Report located in the operating record. After the soil liner was smooth drum rolled, CQA certifications of its construction and grades were provided by the CQA Officer prior to installation of the 60 mil HDPE geomembrane liner.

6. HDPE Geomembrane Liner Installation

Prior to installation of the 60-mil textured HDPE geomembrane liner on the floor and side slopes of the GMF Pond, the surface of the full scale soil liner was accepted by the geomembrane installer. Installation of the geomembrane liner began on July 24, 2010, and placement continued through September 17, 2010, with liner installation testing and repairs completed by September 22, 2010. Textured geomembrane liner was used on the GMF Pond floor and side slopes.

On the side slopes, the HDPE geomembrane was laid parallel to the slope and the tie-in weld with the bottom geomembrane was welded a minimum of 5 feet past the toe of the slope. Adjacent panels were overlapped approximately 4-6 inches and were shingled in the direction of the drainage.

Production seaming of the geomembrane panels was made using a dual hot wedge fusion welder. This device creates an air channel between two fused seams that can later be tested with pressurized air to assure there is no leakage. Destruct sample sites and repairs were welded with extrusion welds which were checked for leaks with a vacuum box. All seams were sampled at a rate of one destruct sample for every 500 feet of seam and tested for strength parameters in the laboratory.

A third party engineering firm monitored the installation of all geosynthetic materials and assembled the manufacturing quality control (MQC) data, manufacturing quality assurance (MQA) testing data, installer subgrade acceptance, panel placement information, laboratory CQA test data from destruct samples, and field CQA test data for seam welding integrity. All of this data is included in the "Geosynthetics Quality Assurance Report, Gypsum Stack, AERG (Ameren) Coffeen Power Station, Coffeen, Montgomery County, Illinois. Feezor Engineering, Inc." in the Coffeen GMF Pond Liner Documentation Report located in the operating record.