# Liner Evaluation Report
# Duck Creek GMF Pond

Illinois Power Resources
Generating, LLC
Duck Creek Power Station
Fulton County, Illinois

*October 2016*

HANSON
Engineering | Planning | Allied Services

**DUCK CREEK GMF POND**
**ILLINOIS POWER RESOURCES GENERATING, LLC**
**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 Duck Creek GMF Pond Liner Evaluation Report and the Duck Creek 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 Duck Creek GMF Pond Liner Evaluation Report and the Duck Creek GMF Pond Liner Documentation Report in the operating record are accurate, and the **Duck Creek GMF Pond** meets the requirements set forth in 40 CFR 257.71(a)(iii) as published on April 17, 2015. As required by 40 CFR 257.70(c)(2), the **Duck Creek GMF Pond** meets the requirements in 40 CFR 257.70(c)(2).

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## 1. Summary

The Duck Creek GMF Pond (GMF Pond) was constructed to retain wet-sluiced gypsum produced in the flue-gas scrubber at the Duck Creek Power Station. Construction of the GMF Pond began in 2007 with excavation of the site. Construction of the liner components began in April 2008 and was completed in February 2009. The GMF Pond encompasses about 30.0 acres within Section 18, Township 6 North, Range 5 East of the Fourth Principal Meridian, just north of the Duck Creek Power Station.

The composite liner system in the GMF Pond was designed to exceed compliance with Illinois Environmental Protection Agency rules for solid waste landfills by having a double HDPE geomembrane. Basic 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), the GMF Pond was designed and constructed with an alternate liner system composed of the following, from lowest elevation to highest elevation:

- Three (3) feet of compacted clay with a hydraulic conductivity less than $9.8x10^{-7}$ cm/sec (from actual field testing);
- A geosynthetic clay liner (Bentomat SDN); and
- A 60-mil HDPE geomembrane.

In addition to the Part 811 requirements, the Duck Creek GMF Pond has a second 60-mil HDPE geomembrane with an active leachate collection system in the interstitial space between the two geomembranes. From the lowest geomembrane going upward, the additional components are listed below:

- One-foot of drainage sand for the leachate collection system;
- One-foot of cushion soil; and
- A second 60-mil HDPE geomembrane.

The dual liner with interstitial leachate collection system was designed to limit leachate head on the bottom geomembrane to 12 inches or less.

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 contained 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 $1 \times 10^{-7}$ 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) and (iii), 40 CFR 257.70(b) and (c) -- Design criteria for new CCR landfills and any lateral expansion of a CCR landfill -- provide:

*(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 $1 \times 10^{-7}$ 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.*

*(c) If the owner or operator elects to install an alternative composite liner, all of the following requirements must be met:*

*(1) An alternative composite liner must consist of two components; the upper component consisting of, at a minimum, a 30-mil GM, and a lower component, that is not a geomembrane, with a liquid flow rate no greater than the liquid flow rate of two feet of compacted soil with a hydraulic conductivity of no more than $1 \times 10^{-7}$ cm/sec. GM components consisting of high density polyethylene (HDPE) must be at least 60-mil thick. If the lower component of the alternative liner is compacted soil, the GM must be installed in direct and uniform contact with the compacted soil.*

*(2) The owner or operator must obtain certification from a qualified professional engineer that the liquid flow rate through the lower component of the alternative composite liner is no greater than the liquid flow rate through two feet of compacted soil with a hydraulic conductivity of $1\times10^{-7}$ cm/sec. The hydraulic conductivity for the two feet of compacted soil used in the comparison shall be no greater than $1\times10^{-7}$ cm/sec. The hydraulic conductivity of any alternative to the two feet of compacted soil must be determined using recognized and generally accepted methods. The liquid flow rate comparison must be made using Equation 1 of this section, which is derived from Darcy's Law for gravity flow through porous media.*

$$\text{(Eq. 1)} \qquad \frac{Q}{A} = q = k\left(\frac{h}{t} + 1\right)$$

*Where,*
*Q = flow rate (cubic centimeters/second);*
*A = surface area of the liner (squared centimeters);*
*q = flow rate per unit area (cubic centimeters/second/squared centimeter);*
*k = hydraulic conductivity of the liner (centimeters/second);*
*h = hydraulic head above the liner (centimeters); and t = thickness of the liner (centimeters).*

(3) *The alternative composite liner must meet the requirements specified in paragraphs (b)(1) through (4) of this section.*

In accordance with 40 CFR 257.70(b)(1) above, the composite liner in the Duck Creek 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 Duck Creek 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 Duck Creek 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 Duck Creek 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 Duck Creek 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 Duck Creek 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 Duck Creek 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) Duck Creek Power Station, Canton, Fulton County, Illinois. Feezor Engineering, Inc. (March 2009, Revised July 2009)" in the Duck Creek 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 Duck Creek GMF Pond meets the minimum requirements of 40 CFR 257.71(a)(1)(iii), i.e., an alternative composite liner that meets the requirements of § 257.70(c).

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 $1 x 10^{-7}$ cm/sec, overlain by a geomembrane of no less than 60-mils in thickness.

In addition, the Duck Creek GMF Pond has a second 60-mil HDPE geomembrane overlying an interstitial leachate collection system.

40 CFR 257.71(a)(1)(iii) requires that an alternative composite liner meet the requirements of 40 CFR 257.70(c), which requires (A) a lower component, that is not a geomembrane, with a liquid flow rate no greater than the liquid flow rate of two feet of compacted soil with a hydraulic conductivity of no more than $1 x 10^{-7}$ cm/sec; and (B) an upper component consisting of, at a minimum, a 30-mil geomembrane. If the geomembrane is composed of high-density polyethylene (HDPE), the geomembrane must be a minimum of 60-mils in thickness.

The soil liner comparison in 40 CFR 257.70(c)(2) is based on an assumed water driving head. In the ideal case, there should be no driving head as the overlying geomembrane would prevent downward migration of water. However, for practical purposes, the driving head is the water head on the overlying geomembrane. For the GMF Pond as-built case, the driving head is limited to 12-inches by the interstitial leachate collection system. For the comparison case, the double geomembrane liner would not exist, and the maximum driving head would be approximately 33.7 feet (the elevation difference between the lowest portion of the clay liner and the overlying pond surface).

The 40 CFR 257.70(c)(2) demonstration calculations comparing these two scenarios are contained in the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

In summary, the lower component of the minimum alternative composite liner required by 40 CFR 257.70(c) has a flow rate per unit area of $1.785 \times 10^{-6}$ cm/sec. The geosynthetic clay liner (GCL) in the GMF Pond has a flow rate per unit area of $4.9 \times 10^{-8}$ cm/sec, and the as-built clay liner for the GMF Pond has a flow rate per unit area of $1.307 \times 10^{-6}$ cm/sec. Consequently, each of the two components of the as-built liner of the GMF Pond exceeds the performance standard set by 40 CFR 257.70(c)(2) for the lower component of an alternative composite liner.

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.

Foundation preparation in 2008 consisted of removing excess soil above foundation grade, construction of the perimeter berm containing the GMF Pond, and surveying and certifying the subgrade surface prior to construction of the test soil liner and the full scale soil liner.

The construction contractor began removing soil material to foundation grade and stockpiling the cut material for later reuse as liner material. Unsuitable sand material was removed from several locations and these areas were backfilled with suitable foundation soils. The foundation surface was proof rolled and visually observed and any unsuitable soils were reworked or removed and replaced.

Foundation backfill lifts were compacted with a Cat 815 sheepsfoot compactor and tested for compaction using a Troxler nuclear moisture/density gauge at a minimum rate of one test per 10,000 $yd^3$ (minimum one test per compacted lift). Fill was placed in approximately 8-inch lifts and compacted to at least 95% Standard Proctor maximum dry density with moisture contents of -2% to +2% of optimum. Nuclear moisture/density and Standard Proctor test results are included in Appendix E in the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

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

## 3. Berm Construction

The perimeter berm was constructed with structural fill excavated and hauled directly from within 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 E of the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

After berm construction was completed, eight Shelby tube samples were collected from the berm, and a soil sample from each tube was tested to determine in-place hydraulic conductivity (or permeability). In-place berm hydraulic conductivities ranged from $2.2 \times 10^{-8}$ cm/sec to $1.0 \times 10^{-7}$ cm/sec. Permeability test results and a drawing showing Shelby tube sample locations are included in Appendix E-3 of the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

## 4. Test Soil Liner

Prior to construction of the full scale soil liner, two test soil liners were constructed using two different borrow sources. Test Soil Liner No. 1 was constructed in the southeast corner of the GMF Pond footprint. Test Soil Liner No. 2 was constructed to the northeast of the GMF Pond at a location outside the footprint, on higher ground, to avoid flooding from heavy rainfalls being experienced at the project site. The purpose of the test soil liners was to verify that the material and methods of construction proposed for the full scale soil liner would provide the quality of construction required by the design.

The borrow materials for Test Soil Liner No. 1 were the natural glacial till materials taken from the lower ±5 feet of GMF Pond excavation footprint. The borrow materials for Test Soil Liner No. 2 were obtained from the natural glacial till materials taken from the upper excavation levels in the GMF Pond footprint.

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

### *4.1 Test Soil Liner No. 1*

#### 4.1.1 Prequalification of Borrow Materials

While no prequalification testing was required by the regulations, a program of laboratory testing was carried out on typical samples of the glacial till materials used for the construction of Test Soil Liner No. 1. Tables 4.1 and 4.2 summarize the primary borrow material properties determined from the testing (Appendix F-1 of the Duck Creek GMF Pond Liner Documentation Report located in the operating record).

**Table 4.1 Properties of Borrow Materials for Test Soil Liner No. 1**

| Sample Location | Percent of Fines | Liquid Limit | Plasticity Index | Maximum Dry Density (MDD) | Optimum Moisture Content (OMC) |
|---|---|---|---|---|---|
| GMF Pond Southeast Floor | 70.9% | 22% | 5% | 122.4 pcf | 11.0% |
| GMF Pond Northwest Floor | 68.4% | 23% | 7% | 122.9 pcf | 11.6% |

**Table 4.2 Results of Constant Head Permeability Tests on Borrow Materials**

| Sample Location | Dry Density | Moisture Content | Permeability Result |
|---|---|---|---|
| GMF Pond Southeast Floor | 95% of MDD | OMC | $2.1 \times 10^{-6}$ cm/sec |
| | 95% of MDD | 3% Wet of OMC | $9.6 \times 10^{-8}$ cm/sec |
| GMF Pond Northwest Floor | 95% of MDD | OMC | $9.1 \times 10^{-7}$ cm/sec |
| | 95% of MDD | 3% Wet of OMC | $3.8 \times 10^{-8}$ cm/sec |

The measured percentages of fines and permeability values confirmed that the material was suitable to achieve the required design hydraulic conductivity. Based on these results, the field compaction criteria for the soil liner were set as follows:

Dry Density ≥ 95% MDD
Moisture Content = 0% to 5% Wet of OMC

4.1.2 Construction

The construction of Test Soil Liner No. 1 was initiated on May 1, 2008. The test soil liner was built in five lifts of approximately 8-inches 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%. Nuclear moisture/density test results and a drawing showing the testing locations are included in Appendix F-3 of the Duck Creek GMF Pond Liner Documentation Report located in the operating record. The Standard Proctor test reports are included in Appendix F-4 of the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

On June 17, 2008, Test Soil Liner No. 1 was completed after it was smooth drum rolled and then covered with plastic sheeting to prevent moisture loss.

#### 4.1.3 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.

##### 4.1.3.1 Laboratory Testing

Three (3) Shelby tube samples (ST-01 thru ST-03) were collected from the original Test Soil Liner No. 1 on May 28, 2008. On June 18, 2008, three (3) additional Shelby tube samples (ST-04 thru ST-06) were collected from the test soil liner following repairs from flooding. A sample from each tube was tested for particle size analysis, Atterberg limits, and/or hydraulic conductivity. Table 4.3 summarizes the results of the testing (Appendix F-5 of the Duck Creek GMF Pond Liner Documentation Report located in the operating record contains laboratory test reports and Shelby tube sampling locations).

**Table 4.3 Results of Laboratory Testing Program for Test Soil Liner No. 1**

| Sample No. | Percent of Fines | Liquid Limit | Plasticity Index | Hydraulic Conductivity, $k_v$ | Lift |
|---|---|---|---|---|---|
| ST-01-5 | 67.7% | 22% | 7% | $2.5 \times 10^{-7}$ cm/sec | 2 |
| ST-02-2 | 71.8% | 23% | 7% | $1.7 \times 10^{-7}$ cm/sec | 4/5 |
| ST-03-3 | 65.0% | 21% | 5% | $8.7 \times 10^{-8}$ cm/sec | 3/4 |
| ST-04-5 | | | | $3.0 \times 10^{-7}$ cm/sec | 2 |
| ST-05-3 | | | | $1.7 \times 10^{-7}$ cm/sec | 4 |
| ST-06-2 | | | | $2.1 \times 10^{-7}$ cm/sec | 4/5 |

##### 4.1.3.2 Field Testing

Six (6) two-stage (Boutwell) field permeability tests were conducted on Test Soil Liner No. 1. The tests were carried out to measure the limiting values of field saturated hydraulic conductivity. The first stage of the test measures the maximum possible value for the vertical component of permeability ($k_v$) and the second stage measures the maximum possible value for the horizontal component of permeability ($k_h$). One test installation malfunctioned during testing and was abandoned. Table 4.4 summarizes the results of the testing.

**Table 4.4 Results of Field Testing Program for Test Soil Liner No. 1**

| Date of Installation | Test No. | Stage 1 Permeability, $k_v$ | Stage 2 Permeability, $k_h$ |
|---|---|---|---|
| July 18 and 19, 2008 | 1 | $9.77 \times 10^{-8}$ cm/sec | $6.23 \times 10^{-8}$ cm/sec |
| July 18 and 19, 2008 | 2 | $2.20 \times 10^{-7}$ cm/sec | $1.54 \times 10^{-7}$ cm/sec |
| July 18 and 19, 2008 | 3 | $3.17 \times 10^{-6}$ cm/sec | $9.53 \times 10^{-7}$ cm/sec |
| July 18 and 19, 2008 | 4 | Abandoned | Abandoned |
| July 18 and 19, 2008 | 5 | $1.84 \times 10^{-7}$ cm/sec | $5.17 \times 10^{-7}$ cm/sec |
| July 18 and 19, 2008 | 6 | $9.71 \times 10^{-8}$ cm/sec | $1.30 \times 10^{-7}$ cm/sec |

### *4.2 Test Soil Liner No. 2*

#### 4.2.1 Prequalification of Borrow Materials

Prequalification testing of the borrow materials for the gypsum stack soil liner was not a requirement of the CQA Plan. However, Shelby tube samples collected from the test soil liner were tested for particle size analysis, Atterberg limits, and hydraulic conductivity.

#### 4.2.2 Construction

The construction of Test Soil Liner No. 2 was initiated on July 28, 2008. The test soil liner was built in five approximately 8-inch lifts and compacted with a Cat 815 sheepsfoot compactor.

Nuclear moisture/density gauge testing was performed at a minimum rate of one per acre per lift or one per 1,000 $yd^3$ to 95% Standard Proctor MDD with moisture contents of optimum to +5%. Nuclear moisture/density test results and a drawing showing the testing locations are included in Appendix F-3 of the Duck Creek GMF Pond Liner Documentation Report located in the operating record. The Standard Proctor test reports are included in Appendix F-4 of the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

On August 1, 2008, Test Soil Liner No. 2 was completed after it was smooth drum rolled and then covered with plastic sheeting.

#### 4.2.3 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.

##### 4.2.3.1 Laboratory Testing

Three (3) Shelby tube samples were collected from the test liner. A sample from each tube was tested for particle size analysis, Atterberg limits, and hydraulic conductivity. Table 4.5 summarizes the results of the testing (Appendix F-5 of the Duck Creek GMF Pond Liner Documentation Report located in the operating record contains laboratory test reports and Shelby tube sampling locations).

**Table 4.5 Results of Laboratory Testing Program for Test Soil Liner No. 2**

| Sample No. | Percent of Fines | Liquid Limit | Plasticity Index | Hydraulic Conductivity, $k_v$ | Lift |
|---|---|---|---|---|---|
| ST-08-1 | 95.7% | 34% | 14% | 1.1 x $10^{-7}$ cm/sec | 3/4 |
| ST-09-2 | 97.5% | 38% | 18% | 1.3 x $10^{-8}$ cm/sec | 4 |
| ST-10-3 | 95.0% | 36% | 17% | 1.3 x $10^{-8}$ cm/sec | 3 |

4.2.3.2 Field Testing

Five (5) two-stage (Boutwell) field permeability tests were conducted on Test Soil Liner No. 2. The tests were carried out to measure the limiting values of field saturated hydraulic conductivity. The first stage of the test measures the maximum possible value for the vertical component of permeability ($k_v$) and the second stage measures the maximum possible value for the horizontal component of permeability ($k_h$). A complete report of the field testing and data is included in the "Geosynthetics Quality Assurance Report, Gypsum Stack, AERG (Ameren) Duck Creek Power Station, Canton, Fulton County, Illinois. Feezor Engineering, Inc. (March 2009, Revised July 2009)" included in the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

Table 4.6 summarizes the results of the testing.

**Table 4.6 Results of Field Testing Program for Test Soil Liner No. 2**

| Date of Installation | Test No. | Stage 1 Permeability, $k_v$ | Stage 2 Permeability, $k_h$ |
|---|---|---|---|
| August 4 and 5, 2008 | 1 | $5.87 \times 10^{-8}$ cm/sec | $2.79 \times 10^{-6}$ cm/sec |
| August 4 and 5, 2008 | 2 | $3.92 \times 10^{-8}$ cm/sec | $9.79 \times 10^{-9}$ cm/sec |
| August 4 and 5, 2008 | 3 | $1.44 \times 10^{-7}$ cm/sec | $3.09 \times 10^{-8}$ cm/sec |
| August 4 and 5, 2008 | 4 | $5.53 \times 10^{-7}$ cm/sec | $5.28 \times 10^{-7}$ cm/sec |
| August 4 and 5, 2008 | 5 | $3.59 \times 10^{-6}$ cm/sec | $4.29 \times 10^{-7}$ cm/sec |

### *4.3 CQA Certification of Test Soil Liners*

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

## 5. Full Scale Soil Liner Construction

Soil materials excavated from the GMF Pond and from the north clay liner soil stockpile were used to construct the 3-ft thick soil liner within the GMF Pond. The soil was placed in approximately 8-inch lifts and compacted with a Cat 815 sheepsfoot compactor. Material placement commenced at the north end of the GMF Pond and proceeded to the south. Nuclear moisture/density gauge testing was performed at a minimum rate of one test per acre per lift or one test per 1,000 $yd^3$. As-placed densities met at least 95% Standard Proctor MDD with moisture contents of optimum to +5%. Nuclear moisture/density and Standard Proctor test results are included in Appendix G in the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

Eighteen (18) Shelby tube samples were collected from the soil liner at various stages of construction. The hydraulic conductivity of the compacted soil liner was sampled and laboratory tested in accordance with ASTM D5084. 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. The hydraulic conductivity results ranged from $8.6 \times 10^{-9}$ cm/sec to $9.8 \times 10^{-7}$ cm/sec. Permeability test results and a drawing showing Shelby tube sample locations are included in Appendix G-3 in the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

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 K and L, respectively, in the Duck Creek 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 GCL and 60-mil HDPE geomembrane liner.

## 6. GCL Installation

The GCL panels were placed on the rolled surface of the compacted soil liner. Panels were placed on the slopes with the long edge of the panel parallel to the direction of drainage. Panels on the floor were oriented in a manner to make installation as efficient as possible. GCL seams were constructed by overlapping their adjacent edges, generally 6 to 12 inches. The GCL panels included a proprietary groove along the longitudinal seams to ensure a proper seal. Seams at the end of panels were shingled in the direction of the grade and granular bentonite was applied to seams at end-of-rolls and at repairs at a rate of ¼ pound per lineal foot.

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) Duck Creek Power Station, Canton, Fulton County, Illinois. Feezor Engineering, Inc. (March 2009, Revised July 2009)” in the Duck Creek GMF Pond Liner Documentation Report located in the operating record.

## 7. Lower HDPE Geomembrane Liner Installation

Prior to installation of the lower 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. In addition, the installation of the GCL was accepted by the geomembrane installer. Installation of the lower geomembrane liner began on September 27, 2008, and placement continued through November 5, 2008. Textured geomembrane liner was used on the GMF Pond floor and side slopes.

The lower HDPE geomembrane was placed immediately over the GCL. 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.

## 8. Upper HDPE Geomembrane Liner Installation

Following installation of the lower 60-mil textured HDPE geomembrane liner, a 10-oz. non-woven geotextile was placed on top of the geomembrane. Twelve inches of drainage media was then installed on the 10-oz. geotextile. Leachate collection pipes and appropriate leachate collection sumps were installed within this drainage layer. The drainage layer was then covered with a 4-oz. non-woven geotextile, one-foot of cushion soil, and a second 60-mil HDPE geomembrane. The second geomembrane was installed utilizing the same practices as the lower geomembrane.

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) Duck Creek Power Station, Canton, Fulton County, Illinois. Feezor Engineering, Inc. (March 2009, Revised July 2009)" in the Duck Creek GMF Pond Liner Documentation Report located in the operating record.