



Stantec Consulting Services Inc.
3052 Beaumont Centre Circle, Lexington KY 40513

September 17, 2018
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Revision 1

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

**RE: Liner and Leachate Collection and Removal System Design Demonstration
New CCR Landfill
TVA Shawnee Fossil Plant
Paducah, McCracken County, Kentucky**

1.0 PURPOSE

As described in 40 CFR § 257.70, an owner or operator of a new CCR landfill is required to demonstrate that the design of the liner and the leachate collection and removal system meets certain requirements. This letter documents Stantec's certification that the liner and leachate collection and removal system design for the TVA Shawnee Fossil Plant's (SHF) new CCR landfill complies with requirements in the EPA Final CCR Rule 40 CFR § 257.70.

2.0 SUMMARY OF FINDINGS

The attached demonstration documents that the liner and leachate collection and removal system for the New CCR Landfill meets the requirements set forth in 40 CFR § 257.70.

3.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Michael J. Steele, being a Professional Engineer in good standing in the Commonwealth of Kentucky, do hereby certify, to the best of my knowledge, information, and belief:

1. that the information contained in this certification is prepared in accordance with the accepted practice of engineering;
2. that the information contained herein is accurate as of the date of my signature below; and
3. that the liner and leachate collection and removal system for the TVA SHF New CCR Landfill meets the requirements specified in 40 CFR § 257.70.



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**RE: Liner and Leachate Collection and Removal System Design Demonstration
New CCR Landfill
TVA Shawnee Fossil Plant
Paducah, McCracken County, Kentucky**

SIGNATURE _____

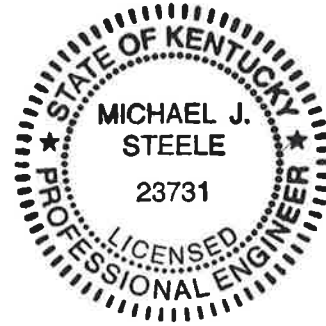
DATE _____

9/17/2018

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ATTACHMENTS: Liner and Leachate Collection and
Removal System Design Demonstration



**Liner and Leachate Collection
and Removal System Design
Demonstration
TVA Shawnee New CCR
Landfill**

New CCR Landfill
TVA Shawnee Fossil Plant
Paducah, McCracken County,
Kentucky



Prepared for:
Tennessee Valley Authority
Chattanooga Tennessee

Prepared by:
Stantec Consulting Services Inc.
Lexington, Kentucky

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**LINER AND LEACHATE COLLECTION AND REMOVAL SYSTEM DESIGN DEMONSTRATION
TVA SHAWNEE NEW CCR LANDFILL**

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1.0 INTRODUCTION

On April 17, 2015, the EPA published the "Disposal of Coal Combustion Residuals (CCR) from Electric Utilities" final rule (EPA Final CCR Rule) in the Federal Register. The Tennessee Valley Authority (TVA) contracted with Stantec Consulting Services Inc. (Stantec) to evaluate the new coal combustion residuals (CCR) landfill unit at the Shawnee Fossil Plant (SHF) for compliance with the liner and leachate collection and removal system requirements of the EPA Final CCR Rule.

1.1 OBJECTIVE

As required by § 257.70 of the EPA Final CCR Rule, an owner or operator of a new CCR landfills is required to demonstrate that the design of the liner and the leachate collection and removal system meets certain requirements. The objective of this report is to document that the new CCR landfill complies with liner and leachate collection and removal system design requirements.

1.2 UNIT DESCRIPTION

SHF is a coal-fired, electric-generating plant. The plant is located in McCracken County, Kentucky, along the south shore of the Ohio River near river mile 946, just east of the confluence of Little Bayou Creek with the Ohio River.

The new CCR landfill will be located on the Shawnee East Site, which consists of about 205 acres that TVA acquired in 2016 next to the eastern boundary of the SHF reservation. The CCR landfill will be constructed in three stages over a total footprint of 88 acres. The embankment will be about 115 feet tall with maximum 4H:1V slopes and will accommodate about 8 million cubic yards of CCR material (fly ash, bottom ash, and gypsum) across an estimated 25-year operational life.

2.0 CRITERIA

The EPA Final CCR Rule § 257.70 requirements for liner and leachate collection and removal system design are:

40 CFR § 257.70. *New CCR landfills and any lateral expansion of a CCR landfill must be designed, constructed, operated, and maintained with either a composite liner that meets the requirements of paragraph (b) of this section or an alternative composite liner that meets the requirements in paragraph (c) of this section, and a leachate collection and removal system that meets the requirements of paragraph (d) of this section.*

2.1 LINER SYSTEM

The EPA Final CCR Rule § 257.70 requirements for the liner system are:

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40 CFR § 257.70(b)(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;*

40 CFR § 257.70(b)(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;*

40 CFR § 257.70(b)(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;*

40 CFR § 257.70(b)(4). *Installed to cover all surrounding earth likely to be in contact with the CCR or leachate.*

40 CFR § 257.70(c)(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 1×10^{-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.*

40 CFR § 257.70(c)(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 1×10^{-7} cm/sec.*

2.2 LEACHATE COLLECTION AND REMOVAL SYSTEM

The EPA Final CCR Rule § 257.70 requirements for the leachate collection and removal system are:

40 CFR § 257.70(d). *The leachate collection and removal system design must be designed, constructed, operated, and maintained to collect and remove leachate from the landfill during the active life and post closure care period. The leachate collection and removal system must be:*

(1) *Designed and operated to maintain less than a 30-centimeter depth of leachate over the composite liner or alternative composite liner;*

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(2) Constructed of materials that are chemically resistant to the CCR and any non-CCR waste managed in the CCR unit and the leachate expected to be generated, and of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying waste, waste cover materials, and equipment used at the CCR unit;

(3) Designed and operated to minimize clogging during the active life and post-closure care period.

3.0 DEMONSTRATION

The new CCR landfill at SHF was evaluated with respect to the requirements outlined in Section 2.0. A summary of the relevant engineering analyses and results are provided in this section.

3.1 SUBSURFACE PROFILE (LANDFILL, FOUNDATION SOILS, AND PHREATIC SURFACE)

A vertical profile (stratigraphic column) through the new landfill and subsurface soils down to bedrock can be divided into three primary groups:

- Landfill Materials consisting of the bottom liner, stored CCR, and the final cover (cap). Planned CCR that will be stored in the landfill includes fly ash, bottom ash, and rejected gypsum (Flue Gas Desulfurization or FGD product).
- Foundation Soils extend down to approximately 60 feet (average) below the current ground surface. For the engineering analyses, the Foundation Soils were subdivided into four alternating layers of clay and silts/sands. Data on these materials were obtained from site explorations.
- Deep Soils are much older depositions below the Foundation Soils. Less data are available for these materials, which were characterized using published information from geology maps and historical, deep borings at the SHF site. The deep soil materials consist of dense gravels, sands, silts, and clays that are assumed to be about 285 feet thick beneath the site.

Published information (Harris et al. 1994) from deep boreholes in the vicinity indicates that the top of bedrock is at approximately elevation +20 feet, which is (on average) 345 feet below the current ground surface.

During the site explorations, multiple instruments (standpipe piezometers) were installed to monitor phreatic conditions. The resulting data were used to define a design piezometric surface for computing static porewater pressures in the subsurface soils.

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3.2 LINER

The liner system falls under an Alternative Composite Liner, as described in the CCR Rule. The design configuration consists of the following materials and thicknesses, as listed in order of construction (bottom to top):

- Compacted subgrade;
- Reinforced polymerized Geosynthetic Clay Liner (GCL);
- 60-mil thick Linear Low Density Polyethylene (LLDPE) flexible geomembrane;
- Geocomposite drainage layer or 12-inch granular drainage layer; and
- Sufficient cover material to provide three feet of total liner cover.

3.2.1 Chemical Resistance

Literature indicates that LLDPE exhibits satisfactory resistance to chemical attack from compounds associated with CCRs. The GCL will incorporate polymer to provide further resistance to chemical attack.

3.2.2 Liner Integrity

The liner will be constructed across a suitable subgrade to promote a uniform bearing condition. Material selection and installation procedures are intended to reduce the potential for damage during construction and operations, and protect the liner from climactic conditions.

The liner subgrade was designed to achieve a minimum five-foot separation above the hydrostatic impact from the design phreatic condition. This reduces the potential for damage to the liner due to uplift forces.

As part of subgrade preparation, surfaces will be proofrolled using heavy equipment. Subgrade embankment will be compacted to design requirements. Resulting settlements from embankment loading are predicted to result in negligible liner strain.

The liner will be covered by a minimum of three feet of protective cover (buffer between heavy equipment and geosynthetics) prior to operations.

3.2.3 Shear Resistance

The design includes a 60-mil thick textured LLDPE liner and reinforced GCL. The layers of the composite liner system were evaluated and determined to meet shear resistance objectives.

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The design provides for conformance testing of materials used to construct the bottom liner to meet required shear resistance. Based on available manufacturer's data (Koerner, Narejo, 2005), the required interface strength between various layers is attainable.

3.2.4 Liner Extents

The design limits of liner extend past the edge of placed CCR within the landfill. Stormwater and leachate collection ponds will be lined similar to the landfill.

3.2.5 Alternative Liner Permeability Comparison

The upper component of the design liner system is a 60-mil thick textured LLDPE. The lower component is GCL. The GCL permeability is specified at 5×10^{-9} cm/sec or lower with a thickness of 3 to 8 mm (EPA 2001). The CCR Rule (§257.70(c)(2)) requires the use of the modified Darcy's Law equation:

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

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).

Modeling of the landfill bottom liner system was performed using the EPA HELP model. Results of this model indicate that there is 0.051 centimeters of head on the liner system at project initiation and 0.0255 centimeters later in operations. At project initiation the GCL is 8 mm thick and is compressed by anticipated loading to 3 mm later in operation.

For two feet of compacted clay, the flow rate per unit area (q) is defined by the CCR Rule to be 1×10^{-7} cubic centimeters/second/squared centimeter. Considering GCL with the initial modelled condition, "q" is calculated to be 5×10^{-9} cubic centimeters/second/squared centimeter and later in operations the q for compressed GCL is still 5×10^{-9} cubic centimeters/second/squared centimeter. The GCL will contain polymers to resist chemical attack and maintain a hydraulic conductivity of 1×10^{-9} cm/sec or lower, which results in q lower than the CCR Rule prescriptive clay liner. Therefore, the GCL has a lower liquid flow rate than the prescriptive clay liner and is an acceptable design alternative.

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3.2.6 Upper Component Liner Thickness

The upper component of the liner is a 60-mil thick LLDPE liner, which is greater than the 30-mil thickness required by the CCR Rule.

3.3 LEACHATE COLLECTION AND REMOVAL SYSTEM

The design leachate collection and removal system consists of either geocomposite or 12 inches of granular drainage media on top of the liner system. If geocomposite is used, then the design requires three feet of protective cover. If granular drainage media is used, then the design requires two feet of protective cover to be placed on top of the granular drainage media.

The collector lines are constructed of fusion welded HDPE pipe and drain to manholes from which leachate either gravity flows or is pumped. The system drains to another manhole where it is collected and then pumped to the lined leachate pond. From there, the leachate is pumped via force main, evaluated, treated if needed, and then discharged at a Kentucky Pollutant Discharge Elimination System (KPDES) compliance point to the Ohio River.

3.3.1 Leachate Depth and Conveyance

The landfill was assessed in the open and closed conditions under a variety of scenarios to determine leachate production. The critical period was found to be the open condition with 10 feet or less of CCR placed. The peak infiltration rates under this condition resulted in 0.02 inches (0.051 cm) of head on the liner system. The pipe system was hydraulically sized to accommodate predicted flows from the HELP model.

The subgrade for the liner/leachate collection and removal system was designed to achieve positive drainage after settlement.

Geocomposite and granular drainage media transmissivities were analyzed at the design grades with suitable reduction factors. The conveyance system was analyzed to determine leachate collector pipe spacings.

3.3.2 Chemical Resistance and Structural Strength

The materials used in the leachate collection and removal system are HDPE pipes, HDPE drainage netting, geotextiles, non-calcareous washed river gravels and granular drainage media. HDPE has satisfactory chemical resistance properties (Ineos, 2012) to chemical attack from compounds associated with CCRs. Granular drainage media and river gravels are generally inert.

The HDPE pipe system was determined to meet criteria for crushing, deflection, ring bending, etc. Designed protective cover thickness over the liner and leachate components is in accordance with manufacturer recommendations.

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3.3.3 Design Mitigative Measures Against Clogging

The leachate system is designed with access through manholes for cleanout of the system. Geotextile material surrounds the gravel envelope around the collection pipes to reduce sediment infiltration.

Pumped segments will generate sufficient velocity to prevent clogging of the force main with fines. Sediment conveyed through the system will settle in the lined leachate collection pond which has been designed to allow cleanout without damage to the liner system.

4.0 CONCLUSION

Based on this assessment, the liner and leachate collection and removal system design for the TVA SHF New CCR Landfill meets the requirements of § 257.70 of the EPA Final CCR Rule.

5.0 REFERENCES

- "Assessment of Maximum Allowable Strains in Polyethylene and Polypropylene Geomembranes". Ian D. Peggs, Bruce Schmucker and Peter Cary, Geofrontiers Congress, 2005
- "Design Considerations for Geosynthetic Clay Liners (GCLs) in Various Applications", GR-GCL-5 Geosynthetic Institute 475 Kedron Avenue Folsom, PA 19033-1208 USA, Revision 1 (Editorial): January 9, 2013
- Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces by George R. Koerner, Ph.D., P.E. Geosynthetic Research Institute Folsom, PA 19033-1208 Dhani Narejo, Ph.D. GSE Lining Technology, Inc. Houston, TX 77073, GRI Report #30, June 14, 2005
- Geosynthetic Clay Liners Used in Municipal Solid Waste Landfills, EPA530-F-97-002 Revised December 2001, United States Environmental Protection Agency (5306W) Washington, DC 20460
- GRI-GCL3, Geosynthetic Research Institute
- GRI-GM13, GM-17, Geosynthetic Research Institute
- Harris, J. B., Street, R. L., Kiefer, J. D., Allen, D. L., Wang, Z. M. (1994). "Modeling Site Response in the Paducah, Kentucky Area". Earthquake Spectra. Vol 10, No. 3.

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TVA SHAWNEE NEW CCR LANDFILL**

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Ineos Chemical Resistance Guide, INEOS Olefins and Polymers, USA February 2012,
<https://www.ineos.com/globalassets/ineos-group/businesses/ineos-olefins-and-polymers-usa/products/technical-information--patents/ineos-hdpe-chemical-resistance-guide.pdf>

LLDPE Chemical Resistance, <http://www.vita.com.cy/index.php/chemical-resistance-of-lldpe>