FOUR CORNERS POWER PLANT
CCR LANDFILL LINER DOCUMENTATION § 257.70
DRY FLY ASH DISPOSAL AREA (DFADA) CELL 4

Liner Design Criteria	Liner Design Documentation
§ 257.70 Design criteria for new CCR landfills and any lateral expansion of a CCR landfill. ***§ 257.70 (a) (1) 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.***	The Cell 4 lateral expansion of the Dry Fly Ash Disposal Area (DFADA) at Arizona Public Service's (APS's) Four Corners Power Plant is designed with an alternative composite liner that meets the requirements of § 257.70 (c). Please note that Cell 4 is referred to in design documentation as "Site 4".
§ 257.70 *(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 $1x10^{-7}$ 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.*	The following documentation of compliance with the requirements of 257.70 (b)(1) through (4) is provided in accordance with the requirement of 257.70 (c) (3). To comply with Subpart 257.70 (b), the upper component of the alternative composite liner is a 60-mil HDPE geomembrane. The lower component is a Cetco Resistex 200 FLW9 geosynthetic clay liner (GCL). The alternative composite liner is constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients, physical contact with CCR or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation. The configuration and application of geosynthetic materials in Cell 4 are well-demonstrated and conventional. When exposed to a composite leachate prepared from Four Corners CCR including Flue Gas Desulfurization (FGD) solids, the Cetco Resistex 200 FLW9 GCL component exhibited a long-term (more than 9,000 hours) hydraulic conductivity (k, measured by ASTM D5887) of 7.6×10^{-10} cm/sec as compared to the manufacturer's published ("Technical Reference") value of 3.0×10^{-9} cm/sec, indicating no loss of performance when exposed to CCR/FGD leachate. In daily operation, the alternative composite liner system will be subjected only to stresses from initial installation of the overlying bottom ash bottom drainage layer and subsequent static overburden loading of stockpiled ash and blended ash/FGD solids. The alternative composite liner is constructed of materials that provide appropriate shear resistance between the upper and lower components to prevent sliding on slopes. The HDPE is textured to increase friction between the geomembrane and the GCL. Based on limit-equilibrium slope stability analyses, the composite liner material interfaces have sufficient shear resistance to prevent sliding on the sides and base and the landfill cell. The alternate composite liner is constructed on a minimum 1-foot thick soil layer that has been recompacted to at least 95% of maximum dry density (ASTM D698). The native formation below the compacted soil is native weathered and unweathered shale. The shale is assessed to be competent and capable of supporting the loads and stresses of landfill construction and operation, as

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	shown by the successful construction and operation of the adjacent DFADA Cells 1 through 3 on the same foundation. The alternative composite liner covers the entire base footprint of Cell 4, extends beyond the limits of the landfilled ash, and is sloped inward to ensure leachate is directed into the leachate collection and removal system (LCRS). Along the northern edge of Cell 4, the composite liner system has been connected to the Cell 1 and 2 liner systems to provide a continuous liner system beneath the three adjacent landfill sites (Cells 1, 2, and 4).
§ 257.70 (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 $1x10^{-7}$ 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 $1x10^{-7}$ cm/sec. The hydraulic conductivity for the two feet of compacted soil used in the comparison shall be no greater than $1x10^{-7}$ 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.* (Equation 1 not reproduced) *(3) The alternative composite liner must meet the requirements specified in paragraphs (b)(1) through (4) of this section.*	To comply with Subpart 257.70 (c) (1), the upper component of the alternative composite liner is a 60 mil HDPE geomembrane. The lower component is a Cetco Resistex 200 FLW9 geosynthetic clay liner (GCL), which is a dry-blended, polymer-treated GCL with a manufacturer specification maximum hydraulic conductivity (k) of 3 x 10^{-9} cm/sec and a reported thickness (t) of 0.7 cm. To comply with Subpart 257.70 (c) (2), using Equation 1 in § 257.70 (c) (2), the unit liquid flow rate (q) was calculated as q = 5.32 cm^3/sec/acre for the GCL compared to a calculated q = 6.04 cm^3/sec/acre for two feet of 1 x 10^{-7} cm/sec compacted soil. For both calculations, the hydraulic head (h) above the liner was 30 cm, which is the maximum head to be allowed by the overlying LCRS; for the GCL calculation, the hydraulic conductivity (k) was 3 x 10^{-9} cm/sec from the manufacturer specifications and the liner thickness was 0.7 cm from direct communication with the manufacturer; for the compacted soil calculation, the hydraulic conductivity (k) was 1 x 10^{-7} cm/sec and the liner thickness was 60.96 cm (2 feet). To comply with Subpart 257.70 (c) (3), documentation is provided in the section of this document that corresponds to Subpart 257.70 (b)(1) through (4).

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§ 257.70 (d) The leachate collection and removal system 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: *§ 257.70 (d (1) Designed and operated to maintain less than a 30-centimeter depth of leachate over the composite liner or alternative composite liner;*	To comply with Subpart 257.70 (d) (1), the DFADA Cell 4 will have a leachate collection and removal system (LCRS) that has been designed to be capable of being constructed, operated, and maintained to collect and remove leachate from the landfill during the active life and post-closure care period. The DFADA Cell 4 design includes an LCRS that consists of the following components: • Sloping bottom configuration designed to maintain less than a 30-centimeter (cm) head of leachate over the HDPE liner • Bottom ash bottom drainage layer • Perforated HDPE LCRS collection pipes that are bedded in gravel that is wrapped with geotextile • Solid wall HDPE conveyance pipe • Leachate collection pond The base of the DFADA Cell 4 will be graded by cut and structural fill to provide a "ridge and valley" surface that will direct and collect incident flows to a central channel that will discharge to a lined leachate collection pond at the west edge of the landfill cell. The design is based on the site topography, balanced cut and fill quantities, and the results of infiltration/leachate discharge modeling. The performance criteria of the final design are: • a minimum base slope of 4.5 percent for the bottom (ground); • a minimum valley bottom slope of 1.0 percent for the perforated LCRS collection pipes; and • a 200-foot spacing between perforated pipes. The HELP model (Berger, K., Schroeder, P.R., 2013: The Hydrologic Evaluation of Landfill Performance (HELP) Model. Version HELP 3.95 D. Institute of Soil Science, University of Hamburg, Germany) was used to evaluate the relative leachate discharge performance for the range of possible design variables. The model results were used to estimate leachate flow depths and peak daily leachate flow rates entering the LCRS collection pipes. The selected bottom configuration was demonstrated to be sufficiently steep to maintain less than a 30-cm head of leachate over the HDPE liner, aligned with the cut and fill constructed topography at the site, and allowed reasonable balance of grading cut and fill quantities.
§ 257.70 (d) (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; and	To comply with Subpart 257.70 (d) (2), the LCRS will be 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. The components of the LCRS were sized conservatively to pass the calculated peak daily discharges of leachate associated with the early-stage, worst-case scenario of a 5-foot thick CCR waste layer: • The LCRS bottom drainage layer will be constructed with Plant bottom ash, which is known to have good permeability and structural properties that make it a suitable drainage material. APS has stockpiled bottom ash within the DFADA for the bottom drainage layer of Cell 4. The hydraulic conductivity of bottom ash was assigned as 5×10^{-3} centimeters per second (cm/s), the value used for the design and permitting of the Lined Ash Impoundment (LAI). The value used for the LAI was

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	based on laboratory testing performed by APS in 2002, supported by a comparison to values published by USACE and FHWA. The bottom drainage layer will be approximately three-feet thick to provide for safe placement, to protect the buried LCRS collection pipes from landfill equipment loads, and to protect the underlying geosynthetic materials. The bottom ash drainage material is a CCR material and is chemically resistant to the leachate from CCR materials to be placed in the landfill. • Perforated HDPE LCRS collection pipes will be installed in the bottoms of the valleys to collect and convey leachate to a common solid HDPE conveyance pipe that discharges to the Cell 4 leachate collection pond. The LCRS collection pipes will be bedded and covered in gravel that is wrapped with geotextile. The LCRS collection pipe diameter was designed assuming the LCRS collection pipes were flowing at 50 percent of capacity to account for unanticipated sediment accumulation and biological and chemical clogging. The design demonstrated that the selected 3- and 6-inch diameter HDPE SDR 11 pipes, with the selected installation method, would not experience significant structural deflection under the 150-foot maximum anticipated thickness of overburden (landfilled ash and soil cap). HDPE is demonstrated to be chemically resistant to the leachate from CCR materials.
§ 257.70 (d (3) Designed and operated to minimize clogging during the active life and post-closure care period.	To comply with Subpart 257.70 (d) (3), the LCRS is designed to minimize opportunity for clogging during the active life and post-closure care period. The primary means by which clogging is prevented is by successively filtering leachate flow from each LCRS material to the next, thereby minimizing piping of finer materials. The LCRS designed for DFADA Cell 4 is demonstrated in effectiveness by the performance of the essentially similar DFADA Cell 3 LCRS configuration, which has operated for over 3 years with steady leachate flow and no identified performance degradation. The LCRS filter/drainage interfaces are as follow: • FGD/Fly Ash to Bottom Ash Drain - Laboratory tests demonstrate that the blended FGD and fly ash undergo a pozzolanic reaction that yields a solid material with a strength similar to a hard clay. Based on particle gradations for the FGD solids and fly ash solids, they are individually filtered by the bottom ash of the bottom drainage layer, suggesting that fines from the blend will not migrate into or clog the bottom drainage layer. • Bottom Ash Drain to Geotextile - The bottom ash bottom drainage layer flows to the gravel drain surrounding the perforated LCRS collection pipes. The drain is wrapped by a 10-oz. nonwoven geotextile. The bottom ash is demonstrated to be filtered effectively by the geotextile, meaning that bottom ash fines will not clog the geotextile interface or flow into the gravel drain. • Gravel Drain to Perforated LCRS Collection Pipe - The gravel drain flows into perforated LCRS collection pipes that drain to a solid HDPE collection header and eventually from the landfill into the leachate collection pond. The pipe perforations are matched to the gradation of the gravel drain to ensure that gravel does not pipe into or clog the LCRS collection pipes.

Certification Statement 40 CFR § 257.70(a)(1) – Design criteria for new CCR landfills and any lateral expansion of a CCR landfill.

CCR Unit: Arizona Public Service; Four Corners Power Plant; Dry Fly Ash Disposal Area (DFADA) Cell 4

I, Alexander W. Gourlay, being a Registered Professional Engineer in good standing in the State of New Mexico, do hereby certify, to the best of my knowledge, information, and belief, that the information contained in this certification has been prepared in accordance with the accepted practice of engineering. I certify, for the above-referenced CCR Unit, that the documentation as to whether the design of the CCR Unit meets the requirements of 40 CFR § 257.70(a) is accurate.

Alexander W. Gourlay, P.E.
Printed Name

August 6, 2019
Date