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# Construction of multi-layer geosynthetic containment systems to mitigate groundwater contamination

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**Abstract.** This paper presents the construction of multi-layer geosynthetic containment systems as part of improvements to a stormwater management system to mitigate groundwater contamination at a coal combustion residual landfill in southeastern USA. The improvements consisted of lining the perimeter ditch and sedimentation pond to contain ash sediments and minimize infiltration into the groundwater. A composite liner comprised of HydroTurf synthetic turf system (i.e., a 1.5-mm thick high-density polyethylene (HDPE) textured geomembrane overlain by a synthetic turf that is covered with an infill/ballast material) underlain by a geosynthetic clay liner (GCL) was selected for the perimeter ditch. For the sedimentation pond, a 150-mm thick reinforced concrete layer underlain by a 1.5-mm thick HDPE textured geomembrane-GCL composite liner was selected to facilitate cleaning of the pond. The selection, construction, and lessons learned of the multi-layer geosynthetic containment systems are discussed.

## 1. INTRODUCTION

This paper presents the construction of multi-layer geosynthetic containment systems as part of improvements to a stormwater management system to mitigate groundwater contamination at a coal combustion residuals (CCR) landfill in southeastern USA. The CCR landfill was used for the disposal of CCR from electrical power generation operations of coal-fired steam units at the facility since 1982. As shown in Figure 1, the CCR landfill is bounded to the west, south, east, and north by unlined stormwater ditches and to the southwest by unlined sedimentation and drainage ponds connected to the stormwater ditches. Stormwater runoff management for the CCR landfill consists of procedures for sloping the ash as material is transferred and compacted, applying temporary and permanent cover as necessary, implementing erosion and sedimentation controls in the landfill interior, and the use of a stormwater retention and conveyance system to manage stormwater runoff from the CCR landfill. The existing West Ditch, which is one of the perimeter ditches, and Sedimentation Pond receive contact stormwater from the active face of the CCR landfill; this runoff is conveyed via culverts that connect to the existing Drainage Pond and ultimately to the other perimeter ditches (i.e., South, East, and North Ditches).

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Remediation of the perimeter stormwater management system was proposed as a means of source control for the CCR landfill. The proposed remediation included: (i) removal of ash sediments from the ditches and ponds; (ii) regrading and lining of the West Ditch and Sedimentation Pond; and (iii) regrading to permitted design grades and placement of vegetative cover to restore the South, East, and North Ditches and Drainage Pond to the minimum capacity of the permitted system. The selection and construction of the lining systems for the West Ditch and Sedimentation Pond are the focus of this paper.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

**Fig.** 1. Existing CCR landfill stormwater management system.

## 2. LINING OPTIONS EVALUATION

The authors evaluated four conceptual improvement alternatives to the West Ditch and Sedimentation Pond to help reduce infiltration into the groundwater. Conceptual cross-sections for each alternative are provided in Figure 2. A geosynthetic clay liner (GCL) is placed below each liner concept to comply with internal guidance requirements for the facility. With the GCL underneath the geomembrane, all four alternatives function as composite liners with leakage rates due to advection significantly less than the leakage rates through single liners such as geomembrane liners alone or GCLs alone [1]. Due to the high groundwater table at the site, a geomembrane-backed GCL (i.e., a GCL with bentonite bonded to a geomembrane) was selected with the geomembrane side installed downwards in order to prevent premature hydration of the GCL from upward groundwater migration. Also, available laboratory data indicate that GCL is self-healing when wetted, dried, and rewetted [2, 3].

### 2.1 Summary of Lining Options Evaluation

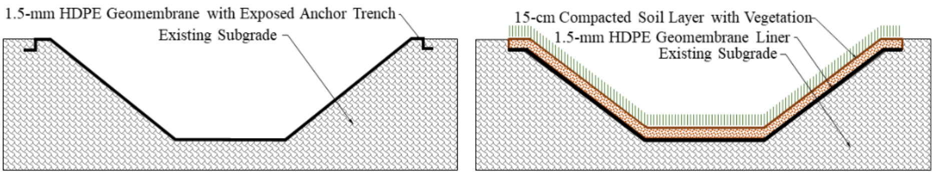
The following four lining system improvement alternatives were evaluated to reduce infiltration into the groundwater table and meet the hydraulic capacity requirements of the stormwater management system.

***Alternative 1*** – geomembrane-GCL composite liner with the 1.5-mm thick high-density polyethylene (HDPE) geomembrane exposed. This alternative was the least labor intensive but would require frequent inspections for holes and other defects to assess the liner integrity especially following periodic cleaning/maintenance.

***Alternative 2*** – geomembrane-GCL composite liner overlain by 0.3-m thick compacted soil layer with vegetation. This alternative would require semi-annual vegetation management (e.g., mowing) as well as inspection and occasional replacement of the soil layer and/or vegetation.

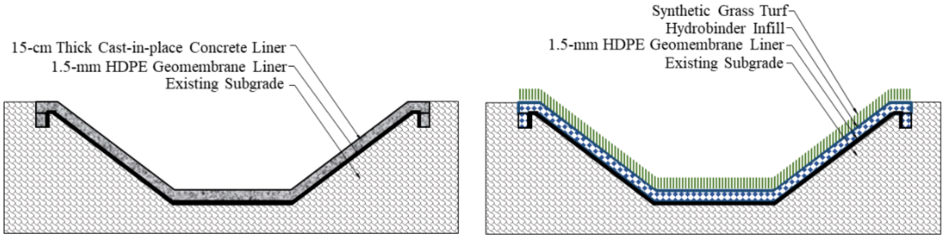
***Alternative 3*** – geomembrane-GCL composite liner overlain by a 0.15-m thick cast-in-place concrete layer with reinforcement. This alternative would require visual inspection as well as occasional replacement of the concrete sections.

***Alternative 4*** – A HydoTurf-GCL composite liner with hydrobinder infill as a ballast. The HydroTurf system is comprised of a layer of a 1.5-mm thick HDPE textured geomembrane overlain by a synthetic turf that is covered with an infill/ballast material [4]. The infill for the HydroTurf system is a cementitious infill that gets hydrated after installation to create a layer that behaves like concrete. After hydration, the system exhibits strength behavior like concrete with hydraulic properties of a grassed channel. This concept would require visual inspection as well as occasional replacement of the HydroTurf sections.



Alternative 1: Exposed Geomembrane

Alternative 2: Geomembrane + Compacted Soil Layer



Alternative 3: Geomembrane + Cast-in-place Concrete

Alternative 4: Hydroturf With Hydrobinder Infill

**Fig. 2.** Lining System Alternatives

The above four design alternatives were evaluated against one another to provide a metric for comparison. The alternatives were evaluated for: (i) lining system functionality; (ii) if the lining system meets the State regulatory requirements; (iii) the overall effectiveness of the liner to prevent infiltration; (iv) the long-term performance of the stormwater management system as compared to the existing system; (v) the initial construction cost; (vi) maintenance requirements and expectations for long-term maintenance to maintain lining system effectiveness; and (vii) the estimated annual maintenance costs evaluated over an assumed lifetime of 30 years. An HDPE geomembrane has the appropriate physical, chemical, and mechanical properties [5, 6] to meet most of the above evaluation criteria. Each criterion was scored from one to four (1-4), with one being the least effective and four being the most effective against the existing conditions.

Based on the evaluation, lining the West Ditch with the HydroTurf-GCL composite liner and the Sedimentation Pond with concrete underlain by the geomembrane-GCL composite liner would provide the improvements to the stormwater management system as part of the corrective measures. For the Sedimentation Pond, a minimum 339 g/m$^2$ nonwoven geotextile was placed between the geomembrane and concrete layers to serve as a cushion and protection layer during pouring of the concrete.

## 3. ASH SEDIMENTS DELINEATION FIELD INVESTIGATION

Following selection of the remedial options (i.e., lining the West Ditch and Sedimentation Pond to minimize infiltration), the authors conducted an ash sediments field investigation program to delineate the vertical and horizontal extents of ash sediments in the perimeter ditches and sedimentation ponds/basins located in the vicinity of the CCR landfill. Ash thickness was measured at the sampling points presented in Figure 3. The total ash thickness was measured to the nearest centimeter (cm).

Measurement of ash/sediment thickness at dry locations were performed using a steel hand-auger. A 10-cm diameter hole was excavated at each sampling point and samples were retrieved for visual analysis throughout its depth. The criteria for termination depth were either: (i) at bedrock; or (ii) when a change of color and texture was detected in the samples, which indicate the ash/native soil interface. Specifically, ash sediments were identified by its grayish color while native soils were characterized by the presence of organics (i.e., topsoil) or exhibited a white to light yellow color (sands and fragments of limestone). Some portions of the former coal pile runoff ditch (FCPRD) in Figure 3 showed thick deposits of coal (with an average thickness of 1.2 m).

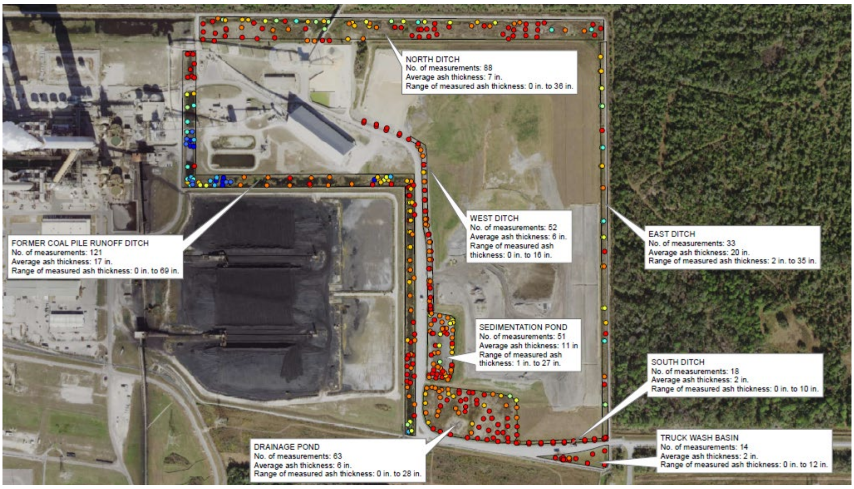


**Fig. 3.** Ash thickness measurement locations

A vibratory, hand-held sediment sampler equipment was used to measure the ash/sediment thickness where water was encountered (i.e., most of the FCPRD, Sedimentation Pond, North Ditch, and East Ditch). The sampler was equipped with a transparent graded plastic tube wherein the color of the sample was inspected, and the depth of penetration was recorded. The criterion for termination depth was when the sampler could not proceed deeper upon prolonged vibration. In some instances, the sampler could not reach the bedrock or the sand layer, indicating that the deposits of ash sediments could be thicker. This occurred in few localized spots along the northern edge of the North Ditch and the East Ditch; however, site conditions did not allow safe access to sample further.

In summary, ash thickness measurements were taken at a total of 440 sampling points. Data obtained from the ash field investigation were used to produce contour maps of ash thickness and to estimate the volume of ash at each location. Ash thickness ranged from 0 to 175 cm with an average of 14 and 27 cm in the West Ditch and Sedimentation Pond, respectively. Approximately 16,360 cubic meters ($m^3$) of ash sediments was estimated to be removed as of the dates of the field investigation.

# 4. CONSTRUCTION

Construction of the stormwater improvements project for the CCR landfill was undertaken during the period of 10 December 2020 to 5 June 2021. Construction quality assurance (CQA) engineering and field monitoring services were provided in support of the following stormwater improvements: (i) ash removal from the North and East Ditches and Drainage Pond; (ii) West Ditch liner installation to convey contact stormwater runoff from the CCR landfill; (iii) Sedimentation Pond liner installation to receive contact stormwater runoff from the CCR landfill; and (iv) construction of ancillary structures (i.e., culverts, headwalls, spillway, outlet structure, access walkway, and erosion controls). Services included review and approval of contractor's submittals, geotechnical and geosynthetic laboratory conformance testing, field CQA monitoring, testing, and documentation services, and preparation of certification of construction completion report for submittal to the regulatory agency. The following sections presents a summary of the CQA services for the geosynthetics components of the lining systems for the West Ditch and Sedimentation Pond.

## 4.1 CQA of Geosynthetics

### *4.1.1 Geosynthetic Materials*

A 1-mm thick GCL, manufactured by Solmax Geosynthetics LLC. was used in the construction of the lining system for the Sedimentation Pond and West Ditch. A 1.5-mm thick textured HDPE geomembrane used for the Sedimentation Pond was manufactured by Agru America, Inc. For the West Ditch, a 1.25-mm thick textured HDPE geomembrane manufactured by Agru was used. A synthetic turf system with cementitious infill was installed over the 1.25-mm thick geomembrane in the West Ditch to provide erosion protection. The synthetic turf was supplied by Watershed Geosynthetics, LLC (Watershed Geo). The cementitious infill material was also supplied by Watershed Geo. A 339-$g/mm^2$ needle-punched nonwoven geotextile, manufactured by SKAPS Industries, was used as cushion layer to protect the geomembrane from the overlying reinforced concrete in the Sedimentation Pond.

### 4.1.2 Testing and Documentation

The manufacturer quality control (MQC) certificates and test results for the rolls of these geosynthetics were reviewed by CQA personnel and found to be in compliance with the CQA Documents. Conformance sampling and testing was performed on the rolls of geosynthetics delivered to the project site. The CQA conformance test results were reviewed by CQA personnel and were found to be in compliance with the CQA Documents. No conformance testing was performed on the GCL because: (i) it was generally considered not a design or regulatory requirement; and (ii) the specified hydraulic conductivity test per ASTM D6766 [7] was considered to be a leachate compatibility test and therefore not applicable to this project.

### *4.1.3 Field Monitoring Activities*

GCL: The GCL rolls were lifted using cargo straps attached to a skid steer with a forklift attachment or straps attached to an excavator bucket. The rolls were deployed by inserting a spreader bar attached to a low-ground pressure (LGP), track-mounted skid steer vehicle and unrolled with the geomembrane side downwards (i.e., in contact with the subgrade). CQA personnel monitored the deployment of the GCL rolls. During deployment, the CQA personnel checked for the following: (i) manufacturing defects; (ii) damage that may have occurred during shipment, storage, and handling; (iii) damage resulting from installation activities; (iv) GCL was unrolled and placed in a manner that kept the GCL in sufficient tension to avoid excessive wrinkling and was securely anchored in the anchor trench; and (v) measures were taken to keep the GCL free of contamination and protected from premature hydration. Figure 4 shows a photographic documentation of the GCL installation in the West Ditch.

**Fig. 4.** View of the 1-mm thick GCL installed on the northern end of the West Ditch.

Geomembrane: Installation of the 1.5-mm thick and 1.25-mm thick geomembranes included panel deployment, trial seams, production seaming, nondestructive seam testing, destructive seam sampling and testing of seams, and geomembrane repairs. These were monitored by CQA personnel to confirm compliance with the CQA Documents. Figures 5 and 6 show photos of the geomembrane installation in the West Ditch and Sedimentation Pond, respectively.

**Fig. 5.** Installation of the 1.25-mm thick geomembrane in the West Ditch.

**Fig. 6.** Installation of the 1.5-mm thick geomembrane in the Sedimentation Pond.

The results of the destructive sampling and testing are summarized and discussed below.

- *West Ditch*: For the 1.25-mm thick geomembrane installed in the West Ditch, two (2) fusion destructive seam samples were tested for a total seam length of approximately 275 linear m (lm).
- *Sedimentation Pond*: For the 1.5-mm thick geomembrane installed in the Sedimentation Pond, nine (9) fusion destructive seam samples were tested for a total seam length of

approximately 1,355 lm.

Synthetic Turf System: CQA personnel monitored the installation of the synthetic turf and placement of cementitious infill and found them to be in compliance with the CQA Documents. Figure 7 shows photos of the installation of the synthetic turf and cementitious infill in the West Ditch. The infill was placed/spread using a top-dresser attached to a LGP equipment with dust control stationed on the outside of the West Ditch. During installation, water was applied with sprinklers to ensure appropriate hydration and curing of the cementitious infill. Thickness measurements were made to ensure that a 22-mm minimum dry thickness and a 19-mm minimum finished thickness after hydration were achieved, in accordance with the CQA Documents.

**Fig. 7.** Installation of synthetic turf and cementitious infill in the West Ditch.

Geotextile: CQA personnel monitored the deployment of the nonwoven geotextile rolls for manufacturing defects; damage that may have occurred during shipment, storage, and handling; and damage resulting from installation activities. There was no damage observed during the handling and deployment of the geotextile over the geomembrane prior to placement of the reinforced concrete liner in the Sedimentation Pond. After deployment of the geotextile, CQA personnel observed that the geosynthetic installer overlapped geotextile panels end-to-end a minimum of 60 cm and continuously sewed the 15-cm overlap.

### 4.2 CQA of Concrete Liner

The construction of the concrete liner on the Sedimentation Pond was monitored by CQA personnel. CQA personnel reviewed concrete mix design submittal provided by the concrete supplier prior to concrete production and delivery to the project site. 3-day, 7-day, and 28-day compressive strength tests per ASTM C39 [8] were performed to confirm a minimum 28-day concrete compressive strength of 27.6 MPa was achieved. The test results were found to be in compliance with the CQA Documents.

## 5. CONSTRUCTION CHALLENGES AND LESSONS LEARNED

Preparation of the subgrade for installation of the geosynthetics in the Sedimentation Pond which happened to be the lowest point of the landfill with a shallow groundwater elevation presented a significant challenge and therefore a high-risk task during construction. This affected construction cost and schedule of completion. The contractor however overcame this challenge by implementing a rigorous dewatering operation consisting of utilizing a well-point pumping system to reduce groundwater intrusion to achieve a relatively dry subgrade for installation of the geosynthetics and overlying concrete. Groundwater inflow points were identified from visual observations during subgrade excavation into bedrock to allow the contractor to control inflows by pumping out groundwater from those points.

The primary lessons learned from the project was properly estimating the seasonal groundwater levels to facilitate construction. The subgrade elevations were adjusted a couple of times to finally install the geosynthetics lining systems especially for the Sedimentation Pond in addition to the continuous pumping to lower the groundwater table.

Also, the use of a geomembrane-backed GCL with the geomembrane component installed downwards helped to prevent premature hydration of the GCL during construction.

## 6. CONCLUSIONS

The selection and construction of multi-layer geosynthetic containment systems as part of improvements to a stormwater management system to mitigate groundwater contamination at a CCR landfill in Florida are discussed. The following section presents a summary of findings from this study:

- Four lining system alternatives were evaluated to provide containment for the perimeter stormwater management system that collect and store ash sediments.
- The containment systems included: (i) a HydoTurf-GCL composite liner for the West Ditch; (ii) a 150-mm thick reinforced concrete layer underlain by a 1.5-mm thick HDPE textured geomembrane-GCL composite liner for the Sedimentation Pond; (iii) a geomembrane-backed GCL with the geomembrane component installed downwards was selected in order to prevent premature hydration of the GCL during construction; and (iv) also, a minimum 339-g/m$^2$ nonwoven geotextile was placed between the geomembrane and concrete layers to serve as a cushion and protection layer during pouring of the concrete
- The average thickness of ash sediments in the perimeter drainage ditches and ponds varied from 3 to 49 cm with a volume of approximately 16,340 m$^3$ estimated for removal prior to improvements to the stormwater management system.
- During construction, a rigorous dewatering operation was implemented to reduce groundwater intrusion to achieve a relatively dry subgrade for installation of the geosynthetics and overlying concrete liner.

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