Enhancing Coal Ash Impoundment Closure Using Value Engineering

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Abstract
Great Lakes Environmental & Infrastructure (Great Lakes E&I) was selected to perform the closure of two historic CCR impoundments at a coal fired power plant undergoing decommissioning. Significant value engineering was provided by Great Lakes E&I during the project which allowed for the completion of several additional scopes of work and modifying original scope workplans to match significant changes in conditions without significant increases to cost or schedule. This was achieved with extensive collaboration between the Client, Engineer, and Great Lakes E&I including: daily interaction, thorough site inspections, the support of UAS imaging and survey, and CAD services provided by Great Lakes E&I. By the completion of the project, Great Lakes E&I had removed a combined volume of waste of approximately 81,000 CY which was placed in an onsite CCR landfill, placed approximately 20,000 CY of intermediate and final cover soil, and constructed approximately 56,000 SF of riprap armored embankment. Significant changes to the workplan and design were developed by Great Lakes E&I during the project with the agreement of the Client and Engineer that resulted in considerable schedule and cost savings. This paper will discuss the execution sequence of the project, and present the technologies and value engineering used to provide this to the Client.

Introduction
In January 2018, Great Lakes E&I was awarded a Coal Ash Impoundment Closure project as part of the decommissioning of a coal-fired power plant. The plant had been operating over a long period of time in the area before the coal fueled boilers were shut down in favor of other gas-fired units. Due to the long operating history of the site, an extensive 80 Acre CCR landfill exists onsite, which has one remaining open placement area for final waste consolidation. The two impoundments, A and B, to be removed as part of plant decommissioning were centrally located between three water storage reservoirs which were used to supply cooling water to the plant’s boilers and cool the Circulating Water from the Plant’s Steam Turbines. The two impoundments were sheetpile reinforced surface impoundments constructed as an extension to a central island between the reservoirs. The removal and closure of these ash impoundments
represented the final stage in the decommissioning of the plant ash system, and final closure of the onsite CCR landfill.

Although the sequencing and scheduling of the project was impacted by differing site conditions, the work activities performed generally remained the same as the base scope. During execution of the base scope of work, several other unexpected challenges were encountered. Great Lakes E&I was able to provide invaluable value engineering support to minimize additional schedule delays and increased cost. With the value engineering that Great Lakes E&I provided to the Client and Engineer, the project team was able to complete all of the base scope of work, as well as several additional scopes, without a significant increase in cost and with an impeccable safety record.

Project Overview
The removal of the ash impoundments was originally planned as a two phase approach. Great Lakes E&I was to arrive onsite and perform the pre-ash removal work with a smaller internal crew and a large subcontract portion as phase one of the construction. This was to minimize risks, both safety and production, associated with having multiple crews performing different tasks in the same area. The first phase of the originally scoped work was as follows:

- Remove the impoundment perimeter asphalt
- Remove the impoundment containing sheetpile reinforcement with a 100 ton crane
- Construction of a dewatering discharge line for the reservoir that the impoundments were immediately adjacent to.

The second phase of construction involved Great Lakes E&I mobilizing a larger crew, and starting the bulk of the remediation process. The work associated with the second phase included:

- Dewatering of the remaining standing water in the impoundments and the adjacent reservoir
- Removal and stockpiling of existing slope protection riprap
- Excavation and segregation of embankment fill soils
- Excavation of the impoundment ash
- Placement of ash in the onsite landfill
- Construction of a temporary cap over the landfill placement area
- Construction of a new soil embankment and riprap protection in the former impoundment area

Actual construction followed a different approach however, due to site constraints discovered after mobilization. After performing a geotechnical analysis on the confining embankment, it was discovered that removal of the sheetpile by crane was not feasible. This caused Great Lakes E&I to mobilize their crew sooner in order to self-perform the sheetpile removal with an excavator mounted hydraulic shear. Due to the resequencing
of the sheetpile removal, the project was executed in a single mobilization phase, as follows:

- Removal and Disposal of perimeter asphalt and concrete structures
- Dewatering of all standing water in the impoundments
- Lowering the reservoirs adjacent to the impoundments
- Degrading and stockpiling of clean embankment soils
- Removal of the first ~10 feet of sheetpile by hydraulic shear
- Excavation and placement of the ash from the impoundments in the onsite landfill
- Final scraping and confirmation samples of the impoundments to meet State and Federal requirements
- Added Scope – Removal of ash from the areas surrounding the impoundments
- Added Scope – Removal of ash from a historic ash staging and loadout area
- Added Scope – Removal of the residual coal from the coal unloading yard
- Degrading and stockpiling of the remaining embankment soils
- Removal of the final ~15 feet of sheetpile by hydraulic shear
- Construction of a new soil embankment and riprap protection at the impoundment area
- Construction of a temporary cap over the landfill placement area

Additional detail on the process and specifics associated with the work scopes, as well as the ancillary tasks which were performed to provide additional value to the Client and Engineer, are discussed in the sections below.

Preconstruction Activities
After receiving a notice to proceed from the Client, Great Lakes E&I began the preparation of the preconstruction documents and services which comprise our standard preconstruction package. Included in the documents we prepare for both internal and client usage are the following:

- Project Specific Health and Safety Plan, including relevant Activity Hazard Analyses (AHA’s) and Job Hazard Analyses (JHA’s) outlines from previous projects
- Construction schedule generated using the Primavera P6 software, and following the industry standard best practices, as outlined by AACEI, DCMA, USACE, and the PMI
- Detailed project execution plans as necessary, demonstrating that Great Lakes E&I has a thorough understanding of the project as outlined by the client

During this time, Great Lakes E&I also performed the necessary site preconstruction activities, including general mobilization activities, locating existing site survey control and setting up internal survey equipment, and performing both conventional preconstruction surveys and UAS based preconstruction surveys. Two of the additional preconstruction activities which were performed on this particular site were a
geotechnical investigation of the impoundment confining embankments, and a bridge structural analysis.

Structural and Stability Analysis
Great Lakes E&I was asked to include the cost and effort for performing a geotechnical analysis on the road/embankment adjacent to the impoundments, which was to support the sheetpile removal crane. A separate structural analysis for the three critical site access bridges was performed by the Client prior to mobilization. Both of these analyses were performed by subcontractors to the Client and Great Lakes E&I, and were critical in the development of the final work plan to avoid potential incidents from ground failure.

The structural analysis which was performed on the site bridges was used to determine the allowable bearing loads to ensure the safety of the site crews, and that no equipment was used which would cause damage to, or destroy, the bridges. The subcontractor performed an in-depth inspection of the three bridges, as well as a review of the historic design drawings to perform their analysis. After making some assumptions about the bridge footings, which were not shown on the drawings or visible beneath the accumulated sediment, the subcontractor informed Great Lakes E&I that the two bridges used to access the impoundment area from shore were sufficiently constructed to support the load of the heaviest piece of equipment, the 100 ton crane; and that the one bridge along the haul route to the onsite landfill, was insufficiently constructed to support the load of our dozer and continual ash hauling trucks. After reviewing the results of the analysis with the Client and Engineer, it was determined that while the bridge deck was not strong enough to support the equipment, the bridge abutments and piers were sufficient. Great Lakes E&I installed hardwood crane mats over the bridge, to distribute the load more evenly across the width of the deck, and to the bridge abutments on either end.

After determining that site bridges would support the weight of passing equipment, Great Lakes E&I started the geotechnical investigation. The engineer providing the investigation brought a truck-mounted drill rig onsite to perform characterizing boreholes through the embankment soils. Samples of each distinct layer of soil encountered were collected for soil parameter analysis, including Unit Weight, Friction Angle, and Short Term Cohesion. A safety factor of 1.4 was determined for the in place, unloaded, conditions. After loading the embankment soils with the live weight of the crane and vibratory driving head however, stability modeling showed that the embankment would fail after the removal of the sheetpiles. Because of this analysis, Great Lakes E&I adjusted the work plan to perform sheetpile removal in a sequential fashion. This allowed greater flexibility in the execution of the sheetpile removal utilizing standard excavating equipment and a hydraulic shear. Upon reviewing the embankment fill material as it was excavated, it was discovered that the material that the embankment was constructed of was actually a mix of several onsite materials, including lenses of low strength organic material from the surrounding reservoirs. Great Lakes E&I also
discovered that the strength of the sheetpile tiebacks had been significantly reduced by corrosion over the years since they had been installed. The combination of the corroded sheetpiles and inconsistent embankment soils could have meant that slope failures likely would have happened, even if the geotechnical analysis had stated otherwise. Leaving the sheetpiles in place contributed to other benefits to the project, as explained below.

**Construction Activities**

**Asphalt Removal**

Once the preconstruction work had been completed, and a work plan was finalized with the Client and Engineer, construction of the base work scope began. The first activity undertaken was the removal of the asphalt and concrete outfall structures surrounding the impoundments. The asphalt was easily removed using standard size hydraulic excavators, and was directly loaded into tandem trucks for offsite recycling. Concrete removed from the ash disposal pipe trench and decant water overflow trenches was sized by the excavators, and was hauled offsite for disposal.

**First Phase Embankment Degrading**

After the overlying asphalt was removed from around the impoundments, the decommissioning of the ponds was able to begin. Since Great Lakes E&I had modified the work plan to perform removal of the sheetpile with conventional equipment and in phases, the tasks of sheetpile removal and embankment degrading were able to occur concurrently. The embankment protective riprap was relocated further downslope, to recover during later stages of construction as onsite stockpiling area(s) were extremely limited. Removal of the first ~10 feet of embankment soil then began, with two excavators working in tandem down the sides of each impoundment. The excavated soil was hauled to the onsite landfill for use as the temporary cover at the end of the project, and to the adjacent fuel storage area for stockpiling as future embankment fill soil. As the crews progressed, they uncovered the deadmen and tiebacks supporting the sheetpile within the embankment fill. Upon inspection, it was discovered that the sheetpile supports were mostly slackened or had rusted out of their walers. Once a sufficient length of the embankment had been removed, sheetpile removal with the hydraulic shear began. The sheetpile was incrementally removed by making a series of vertical cuts approximately every five sheetpile lengths, and then cutting the vertical strips off at ground level. The Client was able to contract with a local metal recycler to salvage the removed sheetpiles as scrap metal, reducing the overall cost of this activity. This embankment degrading and sheetpile removal allowed for ease of access to the impoundments for excavation with standard boom and stick excavators, and maintained the hydraulic isolation of the impoundments from the surrounding reservoirs. Continually throughout the embankment degrading and sheetpile removal process, dewatering of the impoundments and the surrounding reservoirs was able to take place. The standing water in the impoundments was discharged through the permitted internal outfalls into the adjacent reservoir, after being tested to ensure that all permit requirements were met. The three connected reservoirs were lowered by releasing water through the
permanent permitted outfall structure, consisting of two 36 inch valves and a flow measurement flume. The flow rates and water quality were monitored and managed by the Client to ensure compliance with permit requirements.

Impoundment Ash Removal
Following the first phase of sheetpile removal around Impoundment A and completion of the impoundment dewatering, excavation of ash from that area began. The ash was removed by CAT 349 sized excavators, working from one end of the impoundment to the other. By handling the ash in this sequence, Great Lakes E&I was able to pull the ash from the center of the pond up to the remaining sheetpile, allowing for static dewatering of the ash. Water that was drained from the ash was transferred initially to Impoundment B for temporary storage. The transfer of water between the impoundments continued through the duration of construction as an ongoing activity. The method of stacking and decanting water provided valuable drainage that mitigated the effects of the 15+ inches of rain the project received, reducing the delays associated with this weather.

All ash which was excavated from Impoundment A was hauled by tandem truck to the onsite landfill for final placement. The ash that was excavated and exported from the impoundment areas met paint filter test requirements prior to final placement. Various samples of the ash were taken for the development of moisture-density proctor curves, including mixes at various percentages of ash and native soil. This allowed Great Lakes E&I to monitor compaction in the landfill with the varying mixtures of soil, ash, and coal which were disposed in the landfill.

Once the ash was removed from Impoundment A down to the top of native soil, a temporary sediment pond was constructed. This pond was constructed using soils and claystone bedrock scraped from the bottom of the impoundment, and was used as temporary water storage for the contact water which remained in Impoundment A, and for dewatering the standing contact water from Impoundment B. The use of Impoundment A for temporary storage of contact water was implemented before the final scraping and confirmation sampling of the Impoundment bottom. This method eliminated the need for a large number of mobile water storage tanks, allowed for settling of some of the suspended ash, and allowed for the evaporation of standing water which reduced the total volume of filtering performed later in the project. This was another piece of value engineering which Great Lakes E&I was able to provide to the Client that reduced total project cost, and even though it delayed the confirmation sampling and closure of this impoundment, it did not extend the project duration.

As the dewatering of Impoundment B was nearing completion, the ash in the impoundment was pulled from the center and stacked along the interior of the sheetpile. This was done similarly to the way Impoundment A was performed. All captured decanting water generated from the ash stacking was pumped to the constructed sediment pond in Impoundment A for eventual filtering and discharge through the permitted internal outfall. After the ash had decanted enough to be loaded into the site
haul trucks, excavation and disposal of the ash began. The impoundment was excavated from the perimeter access roads from both sides of the impoundment using two CAT 349 size excavators. The ash which was encountered in this impoundment was similar to the ash in Impoundment A, but seemed to have a larger volume of coal distributed in lenses through the waste. All waste material excavated from Impoundment B was also dry enough to pass the paint filter test.

The waste export from the impoundment areas to the landfill in whole, went according to plan. Great Lakes E&I encountered several small difficulties during the excavation, including the failure of sections of sheetpile when the supporting ash was removed, significant rainfall, and equipment issues, but all of these challenges were easily managed by the onsite team without significant impact to cost or schedule.

Impoundment Closure
With the bulk volume of ash removed from the impoundments, final cleanup of the areas and treatment of the stored water began. Testing of the water performed by the Client and Engineer indicated that although the water stored in the temporary sedimentation pond appeared clear, it was above the maximum TSS limit for release to the onsite reservoirs through the permitted internal outfall. Great Lakes E&I first attempted to use a simple, economic method for filtering out ash particles by pumping, but found that filtering the pump discharges with an ACF Dirtbag was not practical. This method was ineffective as the fabric appeared to blind over quicker than expected. While this method may work in some situations, the application that was needed was a 'set and forget' solution, which the Dirtbag did not provide. Great Lakes E&I mobilized a small modular filtering system from a local dewatering vendor, which was equipped with a dual stage filtration process, filtering from 10 microns in the first stage down to 1 micron in the second stage. The system was able to filter all the water in the pond to acceptable levels, without issue.

Concurrently with the discharge of the sediment pond water, numerous test pits were dug around the perimeter of the ponds and in the pond bottoms. The purpose of these pits was to confirm that there were no areas with interbedded embankment fills and ash or coal. Test pitting was performed under the direction of the Engineer, was observed by all parties, and was documented by the Engineer. All test pits confirmed to the satisfaction of the Engineer that there was no residual bottom ash in the impoundments. However, several of the test pits showed localized areas where solidified fly ash had been beneficially used at the time of original construction as a substitute for concrete to provide structural stability for the sheetpiles. This beneficially reused fly ash had hardened to a consistency of a low strength concrete. All fly ash material was removed except that which had been beneficially used as an integral component of remaining infrastructure. After it was determined that all impacted material was removed to the bottom of the impoundments, final scraping of the impoundments was performed. The scraping was performed by a CAT 320 Long reach excavator, which was placed on the interior of the impoundment and worked from one end to the other. Scraped material
was placed along the edge of the remaining sheetpile, and was excavated and hauled by the CAT 349 excavator and tandem trucks.

As the scraping of the impoundments was performed, confirmation samples were taken of the cleaned subgrade. A total of 11 samples were collected between both impoundments to meet state and federal regulatory closure requirements. Samples were collected by the Engineer, with assistance and observation provided by the project team. A sequential approach to sample collection and processing was chosen due to the three week turnaround time for the sample processing. The sequential process of sampling allowed the project team to be flexible in excavation and hauling plans, where if contaminants were detected above the acceptable limits, resources could be relocated to perform additional excavation. This would have allowed for a reduction in the critical path impact from a failing sample, but all samples taken from the impoundments were tested at acceptable closure levels. Following receipt that the impoundments were free of remaining waste, construction of the new embankment could take place.

Internal Outfall Ash Removal
As reservoir levels were lowered, ash was identified outside of the impoundments at the internal outfalls into the adjacent reservoir. In this limited area, ash appeared to have migrated through the internal outfalls during impoundment operations as ‘carryover’ of suspended fine particles. Great Lakes E&I was able to perform investigations on the extent of the ash carryover into this area using our UAS system. With this tool, Great Lakes E&I developed figures as the water level was lowered to help define the limits and estimate the volume of material which required removal. The UAS system was also used for generating figures to depict the sequencing of excavation and inspection to assist the Engineer in preparing the closure report. The UAS inspections performed allowed Great Lakes E&I to perform strategic planning with the Client and Engineer on the path forward for the excavations. A significant level of effort was put into the lowering of the reservoir. Earthen cofferdams were constructed at the two canals which connected the three reservoirs, as well as the reservoir inlet to isolate the body of water. A system consisting of three six inch self-priming pumps was used to remove approximately 225 Million gallons of water out of the reservoir immediately adjacent to the impoundments, and into the other two reservoirs. This process involved constructing temporary pump pads, relocating the pumps multiple times to maintain the intakes under water, and further UAS investigation to locate areas with more water depth.

After determining the extent of the ash at the internal outfall area, excavation of the material began. The material was excavated by a CAT 320 Long Reach excavator, removing the material and placing in tandems for transport to the landfill. As this material was only recently dewatered and exposed to air, it was of a much wetter consistency than the impoundment ash. Great Lakes E&I was able to manage this excess moisture prior to disposal at the onsite landfill, as discussed below. The excavation of ash in the outfall area was a phased process. The excavation began as a
straightforward ash removal, excavating and removing surficial ash down to a weathered claystone subgrade, but become more difficult as the excavation progressed. The material further away from the rocky shore soils became a combination of viscous, gelatinous organic muck, containing pockets of ash. The identification of ash in this material was further complicated by localized pockets of gray weathered claystone. The claystone had a color very similar to bottom ash, but with a smooth and highly plastic nature, compared to the ash which is a non-cohesive material. This difference in material properties enabled the Engineer to differentiate the ash material from the claystone. This combined muck material dried readily in the direct sunlight, exhibiting a loss in volume and a color change from dark black to grey-white in a matter of several days. Great Lakes E&I managed this combined material similarly to wet ash by spreading, mixing, and drying to achieve paint filter test requirements prior to placement in the landfill.

In order to confirm that all ash was removed from the internal outfall areas, excavation face inspections and potholing were performed under the observation of the Client and Engineer. Progressive inspections were performed on an as needed basis, to ensure that the ash had been removed completely. Potholes were performed to confirm that no underlying layers of ash were present around the interior of the excavation. Potholes were also taken around the perimeter of the excavation area to remove any additional pockets of ash which were not contiguous with the main area. Potholes were taken along the perimeter of the excavation at the internal outfall area on approximate 10 foot spacing, providing confidence to the Engineer that removal was complete.

Coal Yard Residual Coal Removal

Another added scope which Great Lakes E&I was able to perform for the Client was the removal of the residual coal remaining in their coal unloading yard. This work was added to Great Lakes E&I’s scope as a way to increase the volume of waste hauled to the landfill under the contract to help achieve acceptable drainage grades. The coal yard area consisted of two long strips of coal storage, bounded on either side by rail lines, and bisected by the coal unloading embankment and structures. As Great Lakes E&I would find during the excavation, there were numerous buried utility lines running through the coal yard subgrade, between the coal and the subgrade, and through the coal. Several utility locates were performed in this area prior to construction, as prescribed by the site safety plan, and all located lines were deenergized before removal. Several unknown concrete structures were found in the excavation, but those were left undamaged.

Initial estimates of the volume of waste in the coal yard by the Engineer were around 100,000 CY. This was calculated based on thickness potholes which were performed through the coal yard, and assuming worst case thickness scenarios. After excavation began, it was seen that the majority of the coal was much thinner than initially estimated. Great Lakes E&I performed subsequent volume estimates using the previously collected pothole data, UAS imaging, and CAD to develop an estimate of the
final volume of coal which could be removed without impact to the rail infrastructure. The final calculated estimate of coal to be removed was approximately 24,000 CY.

Excavation of the residual coal was performed by the same excavators used to remove ash from the impoundments, and the same tandem haul trucks. The coal removed varied in gradation and moisture significantly through the excavation, being more finely grained and tightly compacted around the plant feed conveyors, and similar to a wet sludge in the lower areas where puddles of stormwater could collect. Great Lakes E&I maintained offsets from all critical infrastructure in the areas, leaving utility lines in place where possible, avoiding damage to buried and exposed concrete structures, and without impact to the rail embankments. All coal material was hauled to the same onsite CCR landfill for placement concurrently with the ash removed from the internal outfall area mentioned above. The final volume of coal removed was approximately 20,000 CY. The final volume varied from the Great Lakes E&I estimated volume due to highly variable subgrade elevations throughout the entire yard. Actual coal thickness was found to vary between ~0.5 ft and ~8 ft, with insignificant variance in pre-excavation surface elevations.

Ash Temporary Storage Area Ash Removal
As a way to manage the import of ash material into the onsite landfill during inclement weather, the Client had constructed an ash temporary storage area internal to the landfill. This area was a soil-bottomed area with ecology block retaining walls, and an interior ramp to assist the loading of trucks. Great Lakes E&I was tasked to remove the retaining wall, remove the residual ash in the area, and fill the area to achieve positive drainage. The ecology blocks were removed by an all-terrain forklift, power washed with a hot water power washer by the onsite labor crew, and were stored for future use by the Client. Any loose surficial ash was removed and placed in the onsite landfill, exposing the subgrade soils. Great Lakes E&I was able to cross-utilize the excavator and trucks from the coal yard removal activity, and place the coal as a fill material in this area. Performing the filling of this area with the excavated coal provided a beneficial reuse of the material, as it conserved onsite clean soil reserves, and allowed the area to be closed/capped into the landfill. Great Lakes E&I provided the site survey, UAS imaging, and CAD design work necessary to facilitate the waste and cover placement. Great Lakes E&I worked with the Engineer to design the area with appropriate cover thicknesses and to meet site drainage requirements.

Landfill Operations
Great Lakes E&I performed its own waste management and placement at the onsite CCR Landfill. The landfill consisted of a large triangular cell, with a large square depression in the center. The landfill cell was the most recent placement area for the ash generated during plant operation, and as such the area Great Lakes E&I was placing on had an extensive subgrade of previously placed ash. There is a large onsite clean soil stockpile adjacent to the placement and final landfill footprint, which was available for Great Lakes E&I to use. A portion of the clean embankment fill soil was
also hauled to the landfill for stockpiling. This soil was to be used as the interim cover on the active placement areas, and as final cover for the former Ash Temporary Storage Area. This soil was stockpiled adjacent to the central depression area.

Great Lakes E&I was held to a compaction specification for the landfill of 90% maximum dry density with +/- 2% optimal moisture as tested by nuclear density gauge or other approved testing method. To facilitate the placement and testing of the ash material, Great Lakes E&I took various representative samples of the ash, including various percentages of native soil and coal to generate moisture-density curves. A subcontractor was utilized to take all proctor samples, perform laboratory analysis, and perform onsite density testing. Placement and compaction was originally planned to be performed by a Cat 815 Sheepsfoot compactor, but upon comparative testing with the planned grading equipment, a CAT D6 dozer, it was found that the dozer provided adequate compaction to meet the specification. This allowed Great Lakes E&I to reduce the project cost for the client, while maintaining the quality of the final product. Great Lakes E&I encountered a challenge onsite while performing compaction testing on the excavated coal material. During compaction testing by nuclear density gauge, compaction and moisture values did not match visual conditions, showing moisture percentages of 40-70%, which was inconsistent with the visually much drier material. Consultation with the testing subcontractor and research showed that because the gauges measured moisture content by hydrogen concentration, a hydrocarbon fuel such as coal would provide abnormally high moisture readings. Compaction was subsequently performed by wheel rolling with fully loaded tandem trucks, or by sand cone density tests.

The condition of the ash transported from the impoundments, internal outfall area, temporary storage area, and coal from the coal yard all varied between each other. The ash from the impoundments came to the landfill in a condition which was significantly above optimal moisture. The initial plan to dry the waste as it was placed in the central depression area proved not practical, as there was not enough surface area to promote drying while receiving the significant precipitation received in spring and early summer. Drying pads were subsequently constructed on either end of the triangular placement area, which proved sufficient for achieving optimal moisture for placement. The ash and organic muck that was excavated from the internal outfall area and transported to the landfill proved too wet to dewater in a timely manner on the drying pads, so the material was blended with dry ash and coal as it was placed in the landfill to achieve a stable lift. Ash from the temporary storage area was dry and powdery, and required hydrating prior to placement. After the onsite waste was consolidated in the landfill area, the ash which was placed on the drying pads was placed and compacted in the depression footprint to bring it up to grade. This material had dried past the optimal moisture content of the material, so required thorough moisture conditioning prior to placement.

Once consolidation and relocation of ash was completed in the landfill, interim cover placement was performed. A one foot lift of clean cover soil was chosen by the Client to
provide erosional protection and meet regulatory requirements between project closeout and final landfill closure when the permanent cap will be installed. Great Lakes E&I was able to provide more value engineering on the interim grades. Great Lakes E&I performed several design iterations for the Client and Engineer on the final grades in the landfill based on the anticipated final waste volume which was to be placed. Great Lakes E&I modified the grades as necessary to promote drainage to the existing drainage features. Performing this service for the Client and Engineer provided great value, as the excavation and placement of waste was able to continue in the landfill area throughout the extensive revision process, avoiding any delays associated with stopping work due to lack of final design grades. The final interim design met all slope drainage requirements, consisted of a perimeter ditch to transfer stormwater off of the active placement area, and had a minimum of one foot of cover soil.

Embankment Construction
After the removal of the ash and confirmation sampling in the impoundment area, a new soil embankment was constructed to replace the one that was removed. The embankment was constructed similarly to the embankment already present, as a compacted soil slope with riprap slope protection, and a geotextile filter fabric underlay. In the design package, the embankment was provided mostly as a conceptual outline of what was required, showing required top and toe elevations, riprap size, and riprap thickness. When Great Lakes E&I mobilized to the field and began construction however, it was determined that this conceptual design was more than the Client actually needed to meet the design intent. Great Lakes E&I was able to refine the embankment slope design, providing additional value engineering to the Client. After reviewing the design intent with the Engineer and the Client’s water resources representatives, Great Lakes E&I was able to raise the elevation of the toe of the slope to reach the lowest possible water elevation in the reservoir, minus two feet for wave protection, and to more closely match the elevations of the existing embankment. This saved additional schedule and cost to the Client, as it lowered the volume of imported riprap which was required for construction, and reduced the time and effort associated with the task.

The first phase in performing the final construction of the embankment was to remove the remaining sheetpile and interior embankments. During inspection of the work area, it was observed by Great Lakes E&I that the sheetpile remaining along the slopes bordering the two non-adjacent reservoirs was preventing groundwater from seeping into the former impoundment area. After consultation with the Client, it was decided that the sheetpile which existed along the border of the other two reservoirs was to remain, as structural reinforcement, and as a means of mitigating groundwater in the fill placement area. This prevented significant additional effort involved with managing groundwater on the site, as the other alternatives, draining all the reservoirs below working elevation, or conventional groundwater dewatering systems, would have been excessively expensive and caused significant delays.
The embankment construction itself was performed with the same excavators and dozer used for the removal and placement of the ash, after decontamination. Embankment fill soil was taken from the soil stockpiles generated previously onsite, and was hauled into place and compacted to meet project specifications. Great Lakes E&I generated a compaction testing map and grid to manage the testing requirements of the embankment in an efficient manner. This figure allowed the testing subcontractor to easily exchange testing technicians to the site without a learning curve or resulting in missing data. Compaction was achieved in this area by several methods, including track walking with the CAT D6 dozer, track walking with the CAT 349 Excavator, and by pinwheel attachment for the excavator.

Final construction along the slopes was also achieved with a CAT 349 excavator, performing both geotextile and riprap placement. Geotextile panels were laid out on the slopes with the assistance of a spreader bar, and labor crews tacking the geotextile in place with 60d nails. Riprap was then placed along the slope, starting at the toe trench and working up the slope to minimize slipping of the geotextile. The completion of this scope marked the substantial completion of the project.

**Post-construction Activities**

After receipt of substantial completion of the project from the Client, the close-out of miscellaneous punch list items could be completed. On this project, these tasks included final cleanup of the roads and site facilities, final erosion control measures, final site survey and UAS imaging, and any additional scopes required to meet the Client’s needs. Following completion of the punch list items, site demobilization occurred.

Once demobilization was complete, review and compilation of final project data was performed. Great Lakes E&I generated all of the site as-builds for the project, including compiling survey data into an easily interpreted format, production of final thickness verification figures, generation of final quantities, and recording of the control points installed by Great Lakes E&I. Project data was compiled from the entire duration of the project, categorized as necessary, and uploaded to the Client’s file management website. Data reserved this way included all of the project daily reports, weekly meeting agendas, UAS orthographic data, project photos, and project survey data. The completion of the data transfer and final project billing marked the completion of the project.

**Lessons Learned**

There were two main lessons learned by the Great Lakes E&I team during the execution of the project. The first lesson learned was seizing the opportunity for using machine grade control. Great Lakes E&I was working on a separate project concurrently with this one where a GPS controlled dozer was being used. As that project completed and the machine was available for transfer to this project, the project team decided that the use of the GPS control was not needed. Even though the grading and cover
placement was relatively simple, the application of a GPS controlled dozer would have reduced the amount of time the Great Lakes E&I project team needed to be in the field to support the field crew by staking. It also would have made the placement of cover soil easier and faster, yielding an overall cost savings for the duration of its use.

The second lesson learned for Great Lakes E&I on the project was the applicability of UAS services to the construction industry. The system that Great Lakes E&I utilized on this project provided great value to all parties involved with the project. The images and survey data that was gathered allowed for much more efficient discussions involving design changes and clarifications, allowed for collection of a much larger amount of data than would be conventionally gatherable, and allowed for inspections and investigations that would have been otherwise unattainable. The Great Lakes E&I UAS program was in a developmental stage during the period this project was executed, but since Great Lakes E&I has distributed drones to several of our other projects, and is providing UAS services to many of our other clients.

Conclusion
Great Lakes E&I successfully completed a CCR impoundment closure during which a significant amount of changed scope and added scope occurred and was managed. Due to careful project management and value engineering, this added scope did not extend the schedule or increase the project cost by a significant amount. Workplans were dynamically changed with collaboration between the Client and Engineer to adjust to project conditions and significant changing conditions. Great Lakes E&I integrated the input from the Client and Engineer in the design progression of the critical areas on the project to develop the optimal solution. The integration and extensive use of UAS imaging and survey techniques provided significant value to all parties involved, and is a technology which is providing more value across all projects executed across the company. The ability of Great Lakes E&I to provide rapid surveying, CAD analysis, and UAS imaging proved to be invaluable on this project, and many similar projects that Great Lakes E&I has executed. The collaboration between all parties and the value engineering services provided by Great Lakes E&I are a valuable addition to any project team with appropriate support, and can provide a cost and schedule savings for all involved parties.