Challenges and Successes of Operating an Innovative Coal Combustion Product Containment Facility

Craig C. Schuettpelz¹, Todd J. Stong¹, Jennifer Charles²

¹Golder Associates Inc., 44 Union Blvd., Suite 300, Denver CO 80228
²Great River Energy, 2875 Third Street SW, Underwood, ND 58576

CONFERENCE: 2015 World of Coal Ash – (www.worldofcoalash.org)

KEYWORDS: Coal Combustion Products, Operations, Impoundment, Landfill, Instrumentation, Seepage, Stability

ABSTRACT

Coal combustion residual (CCR) management is an integral part of energy generation facility operations. The efficient use of existing composite-lined areas not only reduces costs of disposal, it helps to minimize the environmental footprint over which CCRs are placed. This paper discusses the challenges and successes of operating an innovative “upstream raise” facility at a coal-fired generation facility. An “upstream raise” concept takes advantage of the physical properties of both sluiced and hauled CCPs, including flue gas desulfurization (FGD) material, bottom ash, and fly ash to contain CCRs in a vertically expanding facility. However, although vertically expanding facilities are an efficient use of space, they require attention from engineers and operators above and beyond the standard of care for a traditional impoundment or landfill. Discussion in this paper will focus on facility operations and the importance of engineers working together with plant personnel, especially day-to-day operators, to ensure safe facility operations. A range of topics will be discussed, including working within existing site constraints such as in-place liner systems, installing and monitoring instrumentation, evaluating the interior and exterior slopes, and working with CCP properties and quantities that change with time as plant operations continually evolve.

INTRODUCTION

Since construction and operation of the first coal-fired power generation facility, engineers and operators have been tasked with containing materials produced as a result of the steam generation process. The goal of these containment systems has historically been two-fold: maximize efficiency and minimize costs. Efforts to contain these materials do not provide revenue to the producer, so historical practices may have been geared toward “easy” methods of handling and containment.
As with most things in life, change is inevitable and the “easy” way out might not always be the most appropriate solution in the long run. Engineers, managers, and operators continually work to provide greater efficiencies, greater cost-saving solutions, and improve environmental stewardship. Rules and regulations are updated and changed to protect environmental resources and align the expectations of containment facilities with the opinions of the general public at that time. In addition, indirect changes within the generation facility such as advanced air quality control measures or changes to coal resources produce varying quantities of byproducts of the combustion process and even new materials that may not have existed when the facility was sited and designed.

EVALUATING CHANGE

Prior to implementing new or altered CCR handling and deposition practices, power generation facility personnel should perform a comprehensive and site-specific evaluation of the materials requiring containment, existing infrastructure, proposed/potential infrastructure, and both the annual capital costs and operational costs associated with existing and new facilities. The goals of such an evaluation are to come away with a site-wide material “flow” model and an economic impact model. The combination of these models will help facility personnel to determine the most appropriate methods of reducing disposal/storage costs, minimizing environmental risks, maximizing CCR marketability, and evaluating the likely effects of technological advances. Evaluation of these changes is discussed in more detail in previous papers presented at the 2007 World of Coal Ash and the 2003 International Ash Utilization Symposium.

The remainder of this paper will focus on the experiences of site engineers, consulting engineers, and operational personnel during the design and construction of an innovative CCR containment facility after completion of the site-wide CCR evaluation.

THE UPSTREAM RAISE DESIGN CONCEPT

The main goals of the CCR containment facility described below are the same as those listed in the introduction to this paper: maximize efficiency and minimize costs. To accomplish these goals, the engineers worked together with the site operational personnel to develop a vertically expanding “upstream raise” design over an existing composite-lined footprint that was originally meant to exist only as an impoundment. A vertically expanding facility limits capital costs associated with permitting, construction, and closure and reduces environmental liability by exposing less ground area to CCRs and accompanying contact water.

An upstream raise design relies on the zonal deposition of CCR materials based on the specific engineering properties of the materials (Figure 1). The design takes into account the production rates of CCRs to be contained in the facility, maximizing the capacity of the facility to accept materials produced in the greatest quantities (FGD
sludge and bottom ash) while minimizing the use of materials with less availability (fly ash that is typically sold for beneficial reuse at this site).

![Figure 1: Upstream Raise Typical Zonal Deposition Section](image)

A fly ash shell on the exterior of the facility was designed wide enough to be a working surface, specifically to support truck traffic and to provide a surface less susceptible to erosion and damage prior to reclamation (final cover placement). The bottom ash drain relies on a high permeability material to draw the internal water table of the facility (caused by sluiced FGD material) as far from the perimeter of the facility as practical. FGD material is deposited hydraulically on the interior of the facility and is generally characterized as having low strength and low hydraulic conductivity. Challenges faced during the design and operation of this facility are discussed in greater detail below.

A TEAM APPROACH

An upstream raise facility requires care above and beyond that which is typical of a traditional impoundment or landfill since it requires placing a wet (sluiced) material above the original surrounding containment berms as well as stacking materials to vertical heights of greater than 100 feet (30 meters). Seepage and stability are critical components of the design and the placement and control of CCRs and liquids becomes essential for the facility to function as designed and operate as intended.

Consulting engineers designed the upstream raise facility in close cooperation with site engineers and operational personnel. The resulting team was strong in both technical aspects of the proposed facility design (structural stability and seepage) as well as practical aspects of implementing the design (placement quantities and rates, maintenance of equipment and infrastructure). The team approach was implemented from the permitting stages of this facility through the initial construction and operations stages and continues today.

PERMITTING

Site personnel worked closely with a consulting engineer between 2000 and 2003 to perform a site-wide evaluation of CCR containment practices and how these practices could be improved. Discussions between the site engineers and consulting engineers
led to the idea of an upstream raise design, similar to mine tailings facility designs implemented by mining engineers.

Permitting the facility with the state regulatory agency was the first hurdle with implementing such a design. An extensive engineering effort was performed to evaluate whether the facility would be feasible based on the quantities and properties of materials produced at the site at that time. Originally this effort was somewhat disconnected from the site operations; however, engineers would realize over time that the “operability” of the facility, that is the ability of site operations personnel to understand and efficiently construct the facility, would be the most important piece of the puzzle in the coming years.

Throughout the permitting effort, site and consulting engineers worked together to use existing in place systems and infrastructure to their advantage. An important example is the use of an existing composite liner system that was installed in the late 1980s. Composite liner systems were not common until later into the 1990s, especially for CCR containment; however, site engineers decided that composite liner systems represented sound engineering and environmental practice. The existing liner system did not have all the desired components for an upstream raise design, but engineers realized that the upstream raise design could be modified to allow use of the existing environmentally protective liner system to save capital costs and accomplish the proposed design with minimal sacrifice to structural performance. Hence the first major epiphany from collaboration between site engineers and consulting engineers:

**Use appropriately designed existing facilities to maximize available site footprints and reduce capital costs**

The upfront capital costs (composite liner construction) associated with new CCR containment facilities are often the most difficult expenses to take on for a utility. Using available footprints had immediate and substantial cost advantages; however, the largest advantage was that the state regulatory agency was very much in favor of keeping a maximum volume of CCRs over the same footprint without siting an entire new area. Challenges exist when working with an outside agency, but those challenges are essential to efficient designs and offer the “checks and balances” required to align industry’s goals with those of the general public. A second understanding among site engineers and consulting engineers:

**Let the State regulatory agency know what is coming and both why and how it addresses the utility's goals and the State's goals**

Since the State regulatory agency knew what was coming and the goals of the project via the permit document as well as face-to-face meetings, the design concepts were met with favor in negotiating facility approval.
INITIAL DESIGN

Once permitted, the design progressed to construction. This original construction phase is where engineers realized they required an intimate knowledge of how the operational personnel worked, why they worked as they do, and what they were concerned about. Therefore, the third collaborative realization:

**Operational equipment and site operational personnel may not be particularly conducive to change, so keeping at least some familiarity with past operations will enhance the chance of success**

This realization is not meant to be read that new technologies should be avoided; rather, site engineers and consulting engineers should look to take advantage of existing systems and operational practices. Many existing systems and operational practices can be altered or used in different ways to accomplish the goals of a future CCR containment plan.

As an example, FGD material and ash that were historically more haphazardly sluiced into large impoundments were re-evaluated. FGD material would be consciously sluiced directly into the upstream raise facility (single handling). The deposition point would be routinely moved by operations personnel to maximize the distribution of coarse and fine particles around the facility, limiting the accumulation of lower-strength, fine particles in one region of the facility. Similarly, bottom ash would be sluiced to a specific area of one of the historic impoundments to be dewatered. The dewatered material could then be loaded and hauled for immediate placement in the upstream raise “bottom ash drain” zone where the physical properties are relied upon to make the facility function. So, in essence, the FGD material and bottom ash would be handled as they were historically handled. Minor changes to pumps, pipeline alignments, and deposition locations would require only slight modifications to fit the design of the upstream raise facility. By keeping similar methods of operation, the operations personnel easily caught on to how things would operate and how to troubleshoot problems.

Efficient and safe operation of the upstream raise facility depends on the operations personnel. They are the individuals taking the daily pulse of facility and can understand when changes are happening and how rapidly those changes occur. After this realization, almost every meeting during the initial design and in the decade since the upstream raise was put into operations involves a combination of site engineers, site operational personnel, and the consulting design engineer.

The initial design concept was not changed substantially from the permit application. However, collaboration with operational personnel helped to decide, at least the initial, practical items having to do with the operational constraints of such a design:

- Working widths of bottom ash and fly ash,
- Frequency with which to construct lifts,
• Lift thicknesses,
• Regularity of moving deposition location of sluiced materials (e.g. FGD material),
• Widths and turning radii of roads,
• Cold-weather implications to workability, and
• Availability of certain CCRs throughout the year.

The list of operational constraints to the initial design could be extended depending on who is consulted, but the point of the list is to enforce the realization that operational personnel should be consulted early and often to come up with the “best” possible design for all involved parties.

ONGOING OPERATIONS

The upstream raise has been under construction since 2002 and has presented continued challenges for both engineers and operators. The following paragraphs will provide some examples of the complexities of operating the upstream raise facility.

Initial facility design involved extensive seepage and stability analyses; however, instrumentation was not extensively discussed amongst engineers or the State agency. Therefore, nearly all instrumentation installed in the facility was installed after construction commenced. Typical dam and slope monitoring equipment was installed (piezometers, tell-tale drains, inclinometers); but engineers were constrained to the location and position of some of this instrumentation based on the available working surfaces in the facility (i.e. it is not feasible to work on the sluiced FGD material surface). Additionally, some of the piezometers and the inclinometers ended up interfering with access and roads as the facility increased in height. These difficulties could be managed, but were not favorable for the operational personnel. A fourth realization during construction of the upstream raise:

**Make a plan and install instrumentation at the start of facility modifications...**

...and try to keep things out of the way of operations

The purpose of instrumentation is to confirm (to the best of our abilities) that the facility is being operated and constructed as designed for the safety of site personnel and the environment as well as for risk management of the utility company. Seepage and stability were of particular interest during construction of the upstream raise facility and were used as methods of evaluating safety and risk. As the facility continues to progress upward, things are changing: FGD material consolidates, ash settles, and materials are continually being added to slopes. Therefore, the facility needs regular attention to determine if the design is being followed in operational practice.

Slope stability and seepage analyses should be updated regularly and should be based on the instrumentation readings, geometry constructed and actual materials placed, which may, temporarily, not correspond to the design geometry. The design engineers must recognize that CCRs are a manufactured material and are temporally variable. Additionally, it should be the responsibility of the design engineer to talk with the
operations personnel about the material properties. If CCRs change, the operations personnel are the first to know and collaboration allows the operations personnel to discuss these field observations directly with engineers. The team can then consider whether additional safety and/or risk evaluations should be performed in a timely manner. A fifth realization during construction and operations:

**Evaluate the safety and risk posed by the facility continually during construction.**

---

Allow for design/construction changes based on field observations (facility geometry, material properties, equipment changes) provided by operations personnel

---

So far, this paper has discussed five key realizations that have come about since working on a site-wide CCR evaluation at a particular power generation facility. Challenges during design and construction led to the development of a team to successfully maintain safe, efficient, and cost-effective operations. The last realization is likely the most important that has occurred over the past decade of construction of the upstream raise CCR facility:

**Continued involvement of operations personnel drives ownership of the facility and ultimately leads to a final product that the site engineers, operations personnel, and consulting engineers were looking for**

---

Through the design and construction process and many operational decisions along the way, stressing the importance of collaboration between the engineers and the operations personnel has proven to drive the success of the upstream raise design. Rather than handing off a design to the operations personnel to construct, those operations personnel are involved from the start and in decisions along the way. This attitude of involvement tends to instill a sense of ownership by those involved in the design and construction of the project. Before long, the relationship had developed enough to where operations personnel and the engineers were relying on each other’s input to improve designs and make construction of the upstream raise facility (Figure 2) more efficient.
CONCLUSIONS

Construction of the upstream raise over the last decade has proven to be a complex, but worthwhile endeavor. The utility experienced significant cost savings from both a capital cost perspective and an operational cost perspective. The “team approach” allowed design and construction challenges to be overcome more quickly and with better results than if either the engineers or operations personnel were operating independently without the other. Six major realizations during permitting, design, and construction that led to the success of the upstream raise CCR containment facility are:

- Use appropriately designed existing facilities to maximize available site footprints and reduce capital costs
- Involve the State regulatory agency early and often
- Keep some familiarity with past operations and take advantage of in-place designs and infrastructure
- Make a plan and install instrumentation at the start of facility modifications
- Evaluate the safety and risk posed by the facility continuously during construction and allow for design/construction changes based on field observations
• Continued involvement of operations personnel drives ownership of the facility and ultimately leads to a final product envisioned during design.

Ultimately, the team approach has improved every individual’s ownership in the site and the upstream raise CCR facility and has reinforced the original goals of the facility: maximizing efficient operations and reducing CCR containment costs while at the same time fulfilling environmental goals by minimizing the CCR facility footprint. The facility has turned into a source of pride for those participating in the design and the construction of the facility that shows at each independent review of the facility’s performance.

REFERENCES
