Dewatering CCR- The Current State of Practice

Paul Schmall, Ph.D., P.E.\textsuperscript{1}, and Greg Landry, P.E.\textsuperscript{1}

\textsuperscript{1} Moretrench, 100 Stickle Ave., Rockaway, NJ 07866

KEYWORDS: fly ash, dewatering, wellpoints, wells, sumps, rim ditches, horizontal drains

ABSTRACT

The past several years have seen numerous applications of dewatering techniques in CCR. Those techniques include rim ditching and sumping, wellpoints and deep wells, as well as horizontally installed drainage methods. Access to the surface of any ash pond still remains the initial challenge. Deeper ponds lend themselves to the use of widely spaced wells for dewatering. Unfortunately, wells are typically installed with sizable drill rigs. Access had been facilitated with floating roads or a shallow crust provided with wellpoint dewatering. Wellpoints are now commonly installed by hand from very wet and unstable pond surfaces using temporarily stabilized working platforms. Based on preliminary CPT data, the target depth of penetration of the dewatering system is anticipated. CPT data will provide some indication of the ponds hydrogeological behavior. Early field testing is typically performed to verify the hydrogeological behavior and depth of penetration of the dewatering devices. Pilot tests have been performed with shallow wellpoints and wells up to 150 ft (46 m) in depth. Advancements in dewatering techniques in CCR include high capacity well / wellpoint screen that is compatible with the difficult behavior of ash, the use of variable frequency driven pumps that are effective in very low yielding conditions, and where the ash water chemistry is prone to well fouling. This paper will highlight recent applications of the common dewatering techniques, as well as benefits and complexities more recently understood associated with dewatering and ash stabilization.

INTRODUCTION

The publication of the EPA’s CCR Rule has spurred an unprecedented amount of construction activity on CCR impoundments across the country. These construction tasks include both activity intended to achieve closure of the impoundments and “pre-closure” activity such as the removal of surface and interstitial water. Various dewatering techniques have been deployed depending on the project conditions and desired outcome. The theory and practice of dewatering or removing pore water from CCR impoundments has, of necessity, advanced significantly in recent years.
Safe access to the CCR surface is the initial challenge when beginning work on a saturated impoundment. Local and shallow stabilization with rim ditches and sumps may be appropriate for some applications, wellpoints may be more appropriate where a deeper crust is warranted, while mass area dewatering with widely spaced, high capacity wells may be best where deeper and widespread drainage is necessary.

The amount and quality of geotechnical information available to designers and contractors has also greatly improved in recent years. Previously, limited historical information was all that was available. However, it is now common for CCR closure projects to include standard penetration test (SPT) borings, cone penetration test (CPT) borings, geotechnical laboratory data and, where applicable, pumping test data.

One difficulty that has arisen in dewatering CCR impoundments is the fouling of dewatering devices. Fouling may occur via physical, chemical or biological means. Various fixes for this problem have been used including treating the wells after fouling has occurred and designing the pumping system to mitigate the fouling before it forms.

Finally, much of the water pumped from CCR impoundments must be treated prior to discharge to the environment. Actual treatment methods and requirements will vary from site to site. However, solids loading in the form of total suspended solids (TSS) or turbidity is one parameter that nearly always needs to be monitored and reduced. Metals may also be associated with this phase.

**DEWATERING TECHNIQUES**

Historically, when it has been necessary to dewater CCR, most operators have chosen to dig a network of ditches leading to a sump or sumps. This technique is suited to long-term pond maintenance activity or to closure projects with very long schedules where the speed of drainage is not critical. Most closure contractors experienced in ash will have the ability to implement this solution without the use of a specialty contractor.

The speed of drainage will depend on the size of the hydraulic gradient between the ash and the ditch. In most cases, it will not be possible to dig the ditch more than a few inches below the top of the saturated ash (i.e. below the phreatic surface) before the ditch fills in with ash. Therefore, the gradient will be low, leading to slow drainage. Furthermore, depending on the stability of the pond, this method may only be applicable to areas of the pond that are reachable from the edge, from a stabilized road, or if using amphibious equipment. Placing land-based equipment on a saturated ash surface in order to dig a drainage ditch presents a significant safety hazard, certainly with operators unfamiliar with ash. A typical trench drainage operation is shown in Figure 1.
A description of the details of how a wellpoint system functions was given in a previous paper by the authors (Landry and Schmall, 2017).

The main advantage of a wellpoint system is that it is a relatively economical system for finer ash where many low yield devices on close centers are necessary. The wellpoint system with closely spaced devices is also advantageous where it is necessary to lower the phreatic surface as closely as possible to the bottom of a pond with an underlying impermeable layer (either an artificial liner or naturally occurring barrier such as clay or rock).

The main disadvantage of wellpoints is that they work on vacuum and are therefore limited in how high they can lift water. Typical drawdowns that are observed in fly ash would be approximately 15 to 18 ft (4.6 to 5.5 m). However, actual results will depend on the specifics of the situation. Wellpoints installed from the surface of an ash pond are shown in Figure 2.

One difficulty in implementing a dewatering system in order to stabilize CCR is that access to the unstable pond surface is needed in order to install dewatering devices. In response to this difficulty, a method of installing wellpoints by hand from a temporarily stabilized platform of geogrid and plywood has been developed. This technique has been used safely on many saturated ash surfaces. Figure 3 shows wellpoints being installed from geogrid and plywood.
Figure 2. A typical grid of wellpoints on a CCR impoundment.

Figure 3. Wellpoint installation from geogrid and plywood.
One benefit of the ash being so loose when saturated is that the wellpoints may be jetted in by hand without the need for heavy equipment on the pond. Once a certain percentage of wellpoint system has been installed using this method, the installer may decide to stabilize an area by activating it, thus allowing the use of equipment for further installation once a dry crust has been established on that area.

Wellpoints are ideal for dewatering shallow ponds and for creating a near-surface dewatered zone that can support heavy equipment. In the case of ponds that need more drawdown than wellpoints are able to provide, it may be necessary to install an initial system of wellpoints at the surface, excavate a lift of ash, reinstall a new system of wellpoints at the lower ash surface, and continue in that fashion until the phreatic surface is low enough to complete the project. This technique is shown in Figure 4 below.

Figure 4. A surface system of wellpoints allows ash to be excavated in lifts.

Alternatively, the practitioner may elect to use a system of deep wells, if appropriate. As above, the details of deep wells are described in a previous paper by the authors (Landry and Schmall, 2017).

The main advantage of deep wells is that for practical purposes they are not limited in drawdown. Therefore, they lend themselves to deeper impoundments where a deep dewatering device will have more contact area with saturated ash, increasing the capacity of each device to pump water. Deep wells are also advantageous where coarser, more transmissive ash may exist at greater depths. A series of widely spaced wells in this condition may be able to produce significant pore water lowering with minimal equipment on the surface that may interfere with closure operations. Test wells installed in impoundments over 100 ft (30 m) deep in favorable conditions have
produced effective drawdown areas extending to hundreds of feet away from the pumping well.

Deep wells are typically the least expensive dewatering solution *where favorable conditions exist*. They also present fewer piping obstructions to the earthwork contractor than wellpoints. The main disadvantage of deep wells is that they are generally not economical to install on close centers because each well is equipped with a submersible pump, making the unit cost relatively high. Therefore, their success is dependent on the favorable conditions described above—a deep pond that allows continuous contact between the well and the saturated ash, even when the pore water is drawn down to the required level. Furthermore, deep wells require safe access to the pond surface for large drilling equipment. This type of equipment requires a stable platform. Typically, this platform is created with wellpoints as described above or by pushing material onto the pond to create a floating road. Figure 5 shows well drilling on a pond surface previously stabilized with wellpoints.

![Figure 5. Large drill rig on a pond stabilized with a surface layer of wellpoints.](image)

Several deep well systems to date have been installed from the open pond water from floating barges and flexi-floats. These installations can be activated while the pond is still flooded. This type of an installation totally circumvents the typical working platform safety concerns of working on unimproved ash. Figure 6 is one such installation set-up used for installing wells to 60 ft (18 m) depth.
Figure 6. A floating working platform used for over-water deep well installation.

One new development in CCR dewatering techniques that has generated some recent interest is the use of horizontally drilled or trenched drainage pipes. If successfully implemented, this technique would have the advantage of a long drain line, submerged in the ash, with continuous contact between the drain and the saturated ash.

Although there have been reports of successfully implementing this technique, in the authors’ experience, it has generally yielded poor results. Several reasons for this stand out:

1) Horizontal directional drilling techniques used from the pond edge may be able to successfully install a drain pipe (of questionable efficiency). However, trenching techniques, more commonly used in standard construction dewatering, rely on very large and heavy machines that are not safe to operate on saturated CCR.

2) The authors are not aware of a satisfactory method for installing a granular filter pack in a horizontally directionally drilled well without significant borehole smear effects. Further, as mentioned above, trenching techniques which can install a filter pack simultaneously with the drain cannot be safely used on saturated CCR without significant effort to improve the ash surface. A filter pack is readily installed in vertical wellpoints and wells by pouring the filter down the annular space between the wellpoint or well and the borehole wall. The importance of a filter pack is discussed below. In brief, the filter pack is critical to the proper functioning of the dewatering system, increasing its capacity and preventing the pumping of ash in the dewatering discharge.

3) Most CCR impoundments were created by hydraulically sluicing ash. This creates a stratigraphy within the impoundment consisting of very distinct horizontal layers with significant differences in hydraulic conductivity between
layers. If the horizontal drain is installed such that it misses the more permeable layers its effectiveness will be greatly reduced

4) A horizontally installed drain, if constructed without a proper filter pack, must be installed in very coarse ash or bottom ash to effectively generate water through the drain without plugging.

Figure 7 shows a horizontal drain installed in an ash pond and pumped by vacuum methods.

![Figure 7. Pumping a horizontal drain in a CCR impoundment.](image)

**MONITORING OF DEWATERED ASH**

Concurrent with construction activities, the practice of real-time pore pressure monitoring for working platform safety is increasing. This has been done extensively on several projects where dewatering installation, earth retention installation, and earthwork operations have involved sizable equipment. This practice has permitted safer site work than previously.

Monitoring is also necessary for built work in place. Most pond closures are what are referred to as hybrid closures or consolidations. These projects all require ash excavation from outlying areas, stacking of the ash in the consolidation area, and either construction of a slope of drained ash or a retaining structure for containment of the stacked material. These projects require the drained shear strength to be maintained
for relatively long-term slope stability. On one project in particular, the dewatered slope height was in excess of 100 ft (30 m). Ash is particularly vulnerable to changing characteristics either due to precipitation, changes in surface and process water handling, or changes induced by construction vibrations. As the designs of these closures have advanced, so has the need for instrumentation to verify consistency of the ash characteristics. Pore pressure is probably the most significant geotechnical condition to monitor. Ground movements may be the next most significant. Dewatering system design must include some built-in redundancy to accommodate some variability in conditions and system performance.

**GEOTECHNICAL INFORMATION FOR DEWATERING DESIGN**

As discussed above, the amount of geotechnical information available to closure designers and contractors has increased in both quantity and quality in the last two to four years. Geotechnical information useful for dewatering design includes traditional SPT boring logs with soil/ash descriptions and stratigraphy, CPT logs, grain size analysis, and pump test data.

In particular, the authors have observed that although most CCR materials are of low permeability, thin but highly permeable zones may exist at various depths in the ash column. These transmissive zones are generally only a small portion of the overall ash thickness but represent most of the ash’s ability to transmit water. These zones may be identified by taking advantage of the near continuous data sampling ability of the CPT. In general, high transmissivity is identified on a CPT log by comparing the measured pore pressure response \( (u) \) to the expected hydrostatic pressure. As the CPT probe is advanced, it creates a pressure wave in front it. In low permeability zones, the measured pressure will be higher than hydrostatic pressure because the pressure induced with the driving of the probe dissipates slowly. In more permeable zones, no pressure builds up with the driving of the cone and the measured pressure will tend to match the expected hydrostatic line. These pore pressure response zones also tend to correlate to zones of relatively high tip resistance \( (q_t) \) which would be expected from coarser, more granular material. This is to be expected since most saturated ash columns will be very soft, while thin layers of coarser material will tend to be more pronounced to the cone. Figure 8 is a CPT log showing zones of high permeability.

While it is possible to estimate the dewatering effort required based on SPT, CPT, and laboratory data, the best way to design a dewatering system is using real field data obtained from a dewatering pilot or pump test (Figure 9). This test usually consists of either a pumped deep well or series of wellpoints and measurement of the resulting drawdown in strategically placed instruments. Data obtainable from such tests include traditional aquifer parameters such as transmissivity and storage coefficient. Equally important, the test provides an opportunity to measure the yield of a representative dewatering device or a device constructed and installed the way the wells or wellpoints will be be constructed and installed during production dewatering.
Figure 8. Log of CPT with zones of high permeability.

Figure 9. Typical wellpoint pilot test configuration.
It may also be advantageous to perform a proof-rolling test in the dewatered area while the pilot test is taking place. This may involve several passes near the pumping system with the types of equipment to be used during closure. This would typically be done near the end of the test after significant drawdown has occurred and would involve visual observations of ash condition after proof-rolling, feedback from the equipment operator about the performance of the equipment, and observations of pore pressure increases with appropriately installed instruments.

In general, with respect to dewatering design, in addition to site history the geotechnical investigation information available should ideally be able to answer the following questions:

1) What is the thickness and quality of the CCR? i.e. Is it all fly ash, all bottom ash, or a mixture?
2) How much flue gas desulfurization (FGD) material is present in the impoundment and where is it?
3) What is the water level in the CCR?
4) What is the nature of the surrounding native soil and will it act as a barrier to groundwater inflow into the pond or will it cause the pond to be recharged with natural groundwater as the pond is dewatered?
5) What is the groundwater level outside of the pond and is it influenced by nearby water bodies?
6) What are the pumping characteristics of the CCR? i.e. transmissivity and storage coefficient?
7) How much water can be expected from a representative dewatering device?

DEWATERING SYSTEM FOULING

Fouling has been observed in several CCR dewatering systems. Although this problem does occur in traditional construction dewatering systems installed in soil, the unique chemistry of the ash and its porewater make this a particular problem in CCR. Fouling occurs when physical, chemical, or biological processes cause excessive buildup of ash, chemical precipitates or bacteria around the well screen, and pump intake. Fouling reduces the effectiveness of the dewatering system, limiting the flow into each device.

Physical fouling is generally due to the excessive migration of ash through the dewatering device’s screen. Some of the ash may remain lodged at the edge of the device and impede flow. The remainder of the ash will travel as TSS in the water stream and add to the treatment load as discussed below. This type of fouling can be virtually eliminated by selecting a properly designed and field tested filter pack and well screen that are compatible with the site’s CCR material. The method for selecting the filter pack is generally based on Terzaghi’s filter pack criteria for dams and is discussed in detail in other publications such as Powers et al. 2007. Special adjustments must be made for the unique characteristics of ash and the design MUST be field tested.
Chemical fouling generally happens when the conditions in the pore water change, causing previously dissolved constituents to drop out of solution (e.g. metals and metal salts) and form precipitates which clog the dewatering system. The phenomenon usually happens near the turbulent intake zone of a pump where the water mixes with oxygen in the air, changing the redox state of the dissolved constituents. It can be mitigated by designing the dewatering system such that the pump intake is never exposed to air. This may increase system cost by requiring wells to be drilled deeper in order to keep water above the pump intake while also meeting drawdown requirements. If chemical fouling has already occurred, it is possible to treat it by recirculating a mild acid in the well and then mechanically agitating the water column to loosen the precipitates. It may also be possible to operate the system while adding a sequestering agent to keep constituents in solution. Products to perform these functions are available commercially. Wellpoint systems operate under vacuum and are therefore less prone to this type of fouling. Good results have also been reported using pneumatically driven pumps rather than submersible electric turbines. However, these types of pumps are only appropriate for low yielding wells as their capacities are generally limited to approximately 15 gallons per minute or less. Figure 10 depicts chemical building up on a pump removed from a fouled well.

![Figure 10. The results of fouling due to iron-reducing bacteria.](image)

Biological fouling occurs when conditions in the well/pump intake area favor the growth of certain species of bacteria. The bacteria will both reproduce and change the chemistry in the environment, potentially causing additional precipitation and impeding water flow. One example of this is iron reducing bacteria. Iron in the Fe$^{3+}$ state is readily dissolved in water under most environmental conditions. However, iron reducing bacteria use Fe$^{3+}$ as a catalyst to create energy. In the process, the iron is reduced from the soluble Fe$^{3+}$ to the insoluble Fe$^{2+}$ state. Similar to chemical fouling above, this problem is typically dealt with by recirculating a mild acid to neutralize the bacteria colony and dislodge the precipitate.
PROPERLY INSTALLED DEWATERING SYSTEMS AS PRE-TREATMENT

As discussed above, the use of a granular filter medium to surround the well screen is critical to preventing physical fouling (plugging with ash). However, this filter pack can serve a greater benefit by excluding suspended ash particles from the pumped water stream. On some projects, the ability to handle and treat water has proven to be the rate-determining factor in the progression of a project. Therefore, the efficient and continuous treatment of water is critical to a successful project.

Metals and TSS are two constituents commonly monitored to comply with discharge permits. TSS is generally removed by settling, mechanical filtration, or coagulation and flocculation. Metals may be dissolved in the water or sorbed to the solid particles. The distribution between the dissolved and sorbed phases will depend on the type of metal and the chemistry of the pore water. Bulk laboratory analysis of the water may show a relatively high metals concentration. However, it is necessary to compare the results for filtered and unfiltered samples to determine how much of the metals loading is associated with the solid phase. Therefore, using an engineered filter pack at each dewatering device to exclude solid particles reduces TSS loading on the system, reduces associated consumables such as bag filters, and will remove a portion of the metals without the need for expensive pH adjustment schemes or ion exchange resins. Reducing consumables will significantly reduce the overall treatment system cost over the life of the project. Figure 11 shows the granular filter pack left in place in an excavated ash face where the wellpoint has been removed.

Figure 11. Granular filter pack in a partially excavated jetted wellpoint hole.
The typical measures taken to minimize aeration of the water as it passes through a dewatering system are also very effective for mitigating problematic changes to water chemistry prior to treatment. It is widely known that the effluent from a CCR dewatering system is more amenable to treatment than water from the highly aerated water from a rim ditch; some metals, once oxygenated, are more difficult to extract from the treatment stream. The water stream from a dewatering system is also more chemically consistent for the treatment process.

CONCLUSIONS

The past several years of closure activities on ash ponds have allowed the industry to mature and discover best practices. Although every pond has its own unique hydrogeological behavior, there are several engineering practices that have been consistently applied with success on numerous ponds. Those engineering practices include interpreting CPTs and pilot tests that have permitted successful use of wellpoint and deep well dewatering in ash. Safe access has been practiced for “hand” system installations, and included the use of real time monitoring where heavy equipment is used. We continue to see the complexities of water and ash chemistry in these closure projects and the complexities of system fouling and the influence of the dewatering technique on the water treatment process.

REFERENCES
