

Comprehensive Approach for Managing Risk from CCP Storage Facilities

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KEYWORDS: CCP impoundment, condition assessment, risk evaluation, hazard potential classification, emergency action plan, geotechnical investigation

INTRODUCTION

The storage of Coal Combustion Products (CCP) has come under greater regulatory scrutiny in recent years. The owner of the storage facility is responsible for operating and maintaining the facility in a safe manner. The maintenance of the storage facility includes many activities, processes, and procedures. A risk assessment of a CCP storage facility would recognize the dam/embankment as the primary risk factor. Although a dam/embankment can be designed and constructed to be a safe structure, lack of routine maintenance and repair, or changing conditions, can eventually cause the dam to become unsafe. To avoid problems down the road and to manage the risks associated with a CCP storage facility, an owner should have a risk-management program in place. A good dam/embankment risk-management program is comprised of several components that include both long-term and short-term actions and activities.

CONDITION ASSESSMENT

Periodic condition assessments of the dam/embankments are vital to managing risks associated with a CCP storage facility. The condition assessment focuses on many aspects of the dam/embankment including the original design assumptions, construction records' maintenance, and modifications made to the structure. The condition assessment establishes the condition of the dam at a point in time and provides information necessary for determining specific actions to be taken regarding repairs, operations, and monitoring. The process is cyclical, recognizing the need for continued vigilance.

Document Review

The initial step of the condition assessment involves a document review. This step includes a review of all relevant documents, studies, plans, hazard potential classifications, photographs, and any other information related to the dam/embankment. To make this step more manageable, a review of design documents provides a basis for

all remaining work. Reviewing the design documents will provide key information necessary to understanding the past and current behavior of the structure.

Original geotechnical data, analyses, and design assumptions obtained from project records should be assessed to determine their continued applicability in evaluating the safety of the dam/embankment. If modifications have been made to the structure subsequent to the original construction, the criteria used for design should be consistent and/or compatible with the original criteria. If inconsistencies are found, further investigations are warranted.

Hydrologic/hydraulic design assumptions should likewise be reviewed. If water control constraints exist in the field, such as blocked entrances, restrictions on operation of outlet gates or spillways, or if there has been a reduction in impoundment capacity, review of the original design can help assess the criticality of the condition.

Project design drawings and specifications should also be included in the design records review. A drawing review provides information regarding the original topography; the embankment plan layout, height, and cross-section; and location of above-ground and below-ground structures that may or may not have been removed. The specifications define the materials intended for the construction of the embankment, the quality control requirements, and the installation process. Knowing the design assumptions and the material specifications, a review of the construction records will be meaningful, especially if the materials approved for use on the project differ from the specified item. Review of the design documents will provide the qualified reviewer insight into the intent of the original engineer and allow for an evaluation of subsequent modifications to the structure.

If a thorough condition assessment has not been previously performed on a storage facility, retrieval of original design records will be critical. Typically, the operations and/or engineering department will have project files dating back to the original design and construction of the dam/embankment. Also, if the dam/embankment was modified or repaired at some point in the past, documents are likely available. When there is a lack of documentation relative to the design of a facility and critical studies or investigations (stability, hydrologic, hydraulic, seismic) have not been performed (or documented) to confirm that potential safety deficiencies do not exist, studies should be performed to confirm the condition and performance of the impoundments. While the investigations and studies are in progress, the continued CCP storage facility operation may be justified based on the prior satisfactory performance of the embankments under prior maximum loading conditions. To mitigate the risk potential, instrument and monitoring data, periodic inspection reports and the findings of the on-going condition assessment should be reviewed and evaluated. If unsatisfactory or marginal conditions are found to exist, then pond operations should be suspended immediately, and consideration should be given to initiating emergency action procedures.

Construction Data Review

Construction reports, correspondence, material test reports, and photographic documentation of the construction process may contain valuable information that will help in the condition assessment of CCP storage facility dam/embankments. In addition construction sequencing, construction problems, field alterations or modifications, and weather conditions may provide valuable insight into current-day performance problems. Construction records should be used judiciously, however, realizing the restricted applicability of such data as material strengths and permeability's, geological factors, and construction descriptions. Post-construction changes that might influence embankment stability or any other aspect of impoundment safety should be considered in the condition assessment. One example of such a change might a change in the use/occupancy or the regrading of adjacent properties that affects stormwater runoff.

Previous Inspection Reports

A condition assessment should also include review of previous inspection reports, analysis of instrumentation data, and an understanding of current and historic operation and maintenance procedures. If prior inspection reports included recommendations for remediation of a condition or installation of additional instrumentation/monitoring devices, the inspection team should make note of the recommendations and the justification for the recommendations. If data are available from new instrumentation, it should be reviewed and analyzed in an effort to corroborate the initial reasoning and justification for the instrumentation. If a concern is validated by the data from new instrumentation, the findings should be noted in the assessment report. A recommendation for further study or remedial action should accompany the statement of finding to allow the risk to be effectively monitored or mitigated.

Instrumentation Data Collection and Analysis

An instrumentation program should involve instruments and evaluation methods that are as simple and straightforward as possible. Instrumentation data collection and data evaluation can be an effective tool in monitoring the on-going performance of the dam/embankment and the effort to manage CCP storage facility risks. Instrumentation provides measurements of key parameters that can be used to monitor the ongoing performance of the dam/embankment. Parameters may include seepage flow, ground water levels, deformations, or other physical measurements on the embankments. Instrumentation may also supply background information such as impoundment levels and daily precipitation totals.

Experience shows that the ongoing evaluation component of instrumentation data programs is often overlooked. Therefore, the condition assessment includes a review and evaluation of the instrumentation data generated since the completion of the last condition assessment. This data evaluation and the presentation of the results are essential for comparison and trending with historical data. If data has not been evaluated on a regular, routine basis throughout the year, the evaluation performed

during the condition assessment can identify possible areas of concern on the dam/embankment. The visual inspection can then focus on these areas of possible concern.

Operation and Maintenance Procedures

Operation and maintenance (O & M) procedures document the routine activities and systematic inspection processes, and define project maintenance requirements. Proper documentation of the dam/embankment's current condition and past performance is necessary to assess the adequacy of operation, maintenance, surveillance, and proposed corrective actions. A good set of O & M procedures will also specify documentation requirements for the CCP storage facility. The O & M procedure should also define a periodic inspection program that verifies throughout the operating life of the storage facility the structural integrity of the dam/embankment, assuring protection of human life and property.

The condition assessment includes the review of maintenance and inspection records and reports. This review can bring to light conditions which might otherwise go unnoticed. These conditions might be minor in nature, or they may disrupt operation or threaten dam/embankment safety. If such conditions are encountered, it is necessary to determine the adequacy of structures and facilities to continue serving the purposes for which they were designed and to identify the extent of deterioration as a basis for planning maintenance, repair, or rehabilitation.

Field Inspection of Structures

Visual inspections, performed as a part of the Condition Assessment, are one of the most economical means an Owner can use to mitigate risks associated with the operation of a CCP storage facility. The visual inspection is a straight forward process that requires relatively inexpensive equipment and can usually be completed in one to two days. Equipment typically includes:

- Hard hat
- Safety shoes and glasses
- Notebook and pencil
- Camera and GPS device
- Hand level
- Two-meter ruler and tape measure
- Volume container and timer (to measure rate of leakage/flow rates)
- Flashlight and/or mirror (to inspect an outlet pipe, etc.)

Prior to starting the field inspection of a facility, the inspection team should have completed a recent review of the design records, construction records, and previous inspection reports as described above. The visual inspection should be organized and

systematic, inspectors should have appropriate tools and equipment, and observations should be recorded and documented with photographs. An accurate and detailed description of the conditions observed enables meaningful comparison with past and future observations. The ability to state that an observed condition, say an area of seepage, is effectively the same today as it was one, two, or three years ago is of vital importance when assessing the risks associated with that condition.

Likewise, from a risk management stand point, it is important to be able to clearly demonstrate that the area of observed seepage at a CCP storage facility embankment has expanded from approximately 10 square meters to 40 square meters or that the observed flow has increased from 5 liters per minute to 30 liters per minute. Therefore, recording quantities, dimensions, specific locations of observations, and documentation with photographs is among the most important component of a CCP storage facility risk management plan.

Assessment Report

If a condition assessment is to be an effective tool in the management of risks associated with the operation of CCP storage facility, the findings of the assessment must be documented. Typically, an assessment report is prepared at the conclusion of the assessment. The report should include the following sections:

- Description of facility including location, storage capacity, and operating procedures
- Engineering data
- Visual Inspection design criteria
- Evaluation of stability, hydraulics, and hydrology
- Recommendations for maintenance and remedial repairs; operational restrictions or modifications; or further analysis and studies to identify solutions.

The report should be distributed and reviewed with company management. Upon acceptance of the report appropriate levels of funding should be allocated by management to implement the recommendations.

EVALUATION OF HAZARD POTENTIAL

An evaluation of the hazard potential is an important part of risk management for CCP impoundments. The Federal Emergency Management Agency (FEMA) defines hazard potential for dams as follows: “The possible adverse incremental consequences that result from the release of water or stored contents due to failure of the dam or misoperation of the dam or appurtenances.”¹ Hazard potential is typically classified as low, significant, or high. It should be noted that the hazard potential classification does not indicate the relative probability or potential for a failure. It indicates the level of consequences if the dam were to fail.

Federal agencies and state dam safety agencies each has a hazard potential classification system, which are similar but have slight variations. In the FEMA document, the following descriptions of low, significant, and high hazard potential are given. The U. S. Environmental Protection Agency (USEPA) has adopted the same descriptions for their assessments of CCP impoundments.

- Low Hazard Potential – Dams assigned the low hazard potential classification are those where failure or misoperation results in no probable loss of human life and low economic and/or environmental losses. Losses are primarily limited to the owner's property.
- Significant Hazard Potential – Dams assigned the significant hazard potential classification are those dams where failure or misoperation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.
- High Hazard Potential – Dams assigned the high hazard classification are those where failure or misoperation will probably cause loss of human life.

The determination of hazard potential classification for facilities is based on visual observations, engineering judgment, and/or dam-break analyses. The first step in the process is to collect all available information on topography, land use, population centers, roadways and bridges, critical environmental areas, and other key factors. In some cases, evaluation of existing data and engineering judgment may be sufficient for determining the hazard potential classifications.

In many cases, dam-break analyses and flood inundation mapping are required to determine the classification. Dam-break analyses consist of modeling a breach in an embankment and analyzing the downstream flood wave caused by the breach. There are several computer programs that can be used for the modeling, including HEC-RAS, FLDWAV, FLO-2D, and others. Some of the programs can only model water, but some can model viscous or semi-solid material such as CCP material.

Analyses are performed for two conditions – a “sunny-day” failure and for failure during a design storm event, such as the 100-year storm event. CCP impoundments and embankments are different from typical dams across a valley because a failure could potentially occur in different impoundments and in many different directions. Multiple analyses are typically required. The breach locations should be based on review of topography and an initial evaluation of potential consequences due to a breach.

Based on the results of the downstream routing, flood inundation maps are prepared to illustrate the extent of flooding as result of the dam breach. The maps also include depth and velocity of flow and arrival time at critical areas. The potential for loss of life and economic and environmental damage can be evaluated based on these parameters. The flood inundation mapping is critical part of the emergency action plan described in the next section.

RISK MANAGEMENT

Based on the results of the condition assessment and hazard potential evaluation, the level of risk to the owner can be evaluated. This section describes some short-term and long-term ways to mitigate those risks.

Emergency Action Plan

An emergency action plan (EAP) should be prepared for the CCP impoundments. An EAP is a formal document that identifies potential emergency conditions and specifies pre-planned actions to be followed to reduce the potential for loss of life and property or environmental damage. The purpose of the plan is to provide a framework for thorough and proactive emergency action planning to help save lives and reduce damage in areas that would be inundated as a result of a breach. The EAP should be compatible with the overall emergency response plan for the facility.

The EAP typically includes the following sections.

- Emergency notification
- Notification procedures/notification flowchart
- Statement of purpose and scope of the EAP
- Site description
- Emergency detection, evaluation and classification
- Preparedness
- Inundation maps
- Appendices:
 - Training, exercises, updating
 - Definitions
 - Approval and distribution

The EAP contains procedures and information to assist the Owner in issuing early warning and notification messages of the emergency situation to responsible downstream emergency management authorities. It also contains the inundation maps to show the emergency management authorities the critical areas for action in case of an emergency. A narrative description of the areas affected is included to clarify unusual conditions.

Appendices include a training plan that provides for technically qualified personnel to be trained in monitoring the impoundments and embankments, problem detection and evaluation, appropriate remedial measures, and communication provisions within the EAP. The appendices also include a section devoted to preparedness exercises. Preparedness exercises are provided for the preparation of practice scenarios for the various conditions, including Advisory, Warning, and Emergency Condition Levels, and

the testing of the state of training and readiness of key personnel responsible for actions during an emergency.

Additional Investigations and Engineering Analyses

The condition assessment described above may indicate potential dam safety deficiencies such as:

- Uncontrolled seepage on the exterior slope, at the embankment toe, or along pipe penetrations
- Signs of potential slope instability such as cracks on the crest or slope, scarps near crest or bulging near the exterior toe, or surficial slides
- Settlement of the crest
- Potential for overtopping the embankments during the design storm event

In addition, the condition assessment may indicate that visually the embankments appear to be in good condition, but there are inadequate or missing engineering data to document the condition. According to the USEPA guidelines for their assessments, inadequate or missing documentation would lead to a poor rating for the embankments even if no deficiencies are observed.

Additional investigation and analyses may be warranted to evaluate the observed potential safety deficiencies and/or to provide adequate documentation of the existing condition. A geotechnical investigation consisting of test borings, soil and rock sampling, observation wells, test pits, and laboratory testing would be performed to evaluate the properties of the embankments and the underlying soil and rock foundation strata. The data from the investigation would be used for performing seepage, slope stability, and settlement analyses. In addition, hydrologic/hydraulic analyses would be performed to evaluate the potential for overtopping during the design storm event.

Based on the results of the investigations and analyses, the need for remedial measures can be determined. Potential remedial measures are described below.

Operation and Maintenance Plan

A formal operation and maintenance (O&M) Plan should be in place for the impoundments. The purpose of the plan is to provide standard procedures for maintaining the embankments and appurtenances so that a safety deficiency does not develop or can be detected. The following are some key components of the plan.

- Vegetation maintenance including frequency of mowing
- Tree and brush removal and control
- Burrowing rodent and other animal control
- Repair of damage caused by animals

- Operation and testing of pipes and valves
- Monitoring of instrumentation such as piezometers, staff gauges, flow meters, slope inclinometers, and settlement plates
- Systemized procedures for plotting and managing the data to make the data useful and easy to evaluate
- Threshold reading levels for critical instruments

The plan should also include a formal inspection program that includes the following components:

- Daily, weekly, and monthly inspections by trained facility personnel
- Training program for inspection personnel
- Annual inspection by third-party professional engineer experienced in dam engineering and accompanied by facility personnel
- Inspection forms to document and track identified deficiencies
- Standard procedures to follow up on and correct deficiencies

The O&M plan should be updated annually.

POTENTIAL REMEDIAL MEASURES

The ultimate outcome of the currently proposed USEPA regulations will impact the future requirements for the use of CCP impoundments. Significant modifications such as composite liners or restriction on use for storage of CCP materials may be required at some point. Until then, the facility owner may elect to continue operating the impoundments in the same manner. However, in some cases where significant dam safety deficiencies have been identified or where the owner wants to be proactive in reducing the potential for a failure, remedial measures may be warranted. In other cases, closure of the impoundments may be the more-prudent approach. However, closure requirements for impoundments are also not clearly defined at the current time.

The following are examples of remedial measures that can be taken to address common safety deficiencies.

- Uncontrolled seepage
 - Place graded filters and berms on exterior slope
 - Install seepage cut-off walls such a soil-bentonite wall
- Improve static and seismic slope stability
 - Flatten slopes
 - Add stability berms
 - Reinforce embankments using deep soil mixing, jet grouting, etc.
- Protect against erosion of interior slopes

- Add riprap with appropriate bedding and filter layers
 - Place articulated concrete block mats
- Improve erosion resistance of exterior slope
 - Maintain healthy grass cover
 - Flatten slope
 - Install turf reinforcement matting
- Reduce potential for or protect against overtopping during storm events
 - Redirect stormwater flow
 - Enlarge or modify spillway to increase discharge capacity
 - Raise embankment crest to increase the freeboard
 - Install overtopping protection on crest and exterior slope

Before embarking on any remedial measures, the owner needs to do a thorough evaluation of the need for remedial measures based on the severity of the deficiencies, potential risk and consequences of failure, and cost.

CONCLUSION

As evidenced by recent failures at CCP and other residue disposal facilities, there is an inherent risk in operating these facilities. It is prudent for the owner to evaluate the condition of these impoundments, the potential for a failure, and the consequences of failure. Through this evaluation, short-term and long-term risk management procedures can be focused on the critical areas.

REFERENCES

[1] FEMA, Federal Guidelines for Dam Safety, Hazard Potential Classification System for Dams, FEMA 333, April 2004.