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Canyon Lake Dam Reconstruction
Phase I Engineering Services

Project No. PW08-1743

City of Rapid City Public Works Department

Engineering Services Division
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upstream weir. The two weirs are connected with a concrete slab, forming a stilling basin to provide energy dissipation and creek bottom erosion protection. The downstream weir drops roughly 3 ft, where the Rapid Creek channel has a short transition to a natural stream cross-section.

Outlet Structures

Canyon Lake Dam has two valve controlled outlet structures that cross under the auxiliary spillway embankment. One is an 18-inch pipe that outlets into a channel that drains to the small pond complex in Canyon Lake Park downstream of the dam. The other is a 36-inch pipe that outlets into the large pond complex, which is also downstream of the dam and offset approximately 80 ft from the north side of the spillway. At the time of the writing of this report, there is a project being undertaken to replace the outlet structures, line the outlet pipes, and install a bypass pipe that will convey flow from Rapid Creek upstream of Canyon Lake to the 36-inch outlet pipe. The bypass pipe will allow Rapid City to lower the pool elevation by diverting Rapid Creek flow (up to 30 cfs) into the bypass pipe upstream of Canyon Lake. The lowered pool condition will allow removal of silt from the lake and performance of maintenance and repair on the lake shoreline, the primary spillway, and outlet structures.

Downstream Intakes

The spillway channel has two gated 24-inch diameter intake pipes located at the downstream end of the first stilling pool. One of the pipes provides an outlet for draining the stilling pool and the other supplies water to the Leedy Ditch.

Project History

The following provides a history of significant events, maintenance, findings, and issues at Canyon Lake Dam leading up to the restoration project.

1972 Old Canyon Lake Dam overtops and fails during the Rapid City Flood.

1976 Construction of existing configuration of an earthen dam embankment with buried auxiliary fuse-plug and primary concrete spillway.

1985 U.S. Army Corp of Engineers (USACE) inspection identifies seepage and boils in stilling basin and voids between clay core and concrete crest structure.

1986 Canyon Lake Spillway Maintenance Project installs a one-ft wide, four-ft deep cutoff wall at the upstream face of the spillway, cleans and reseals concrete joints, and fills voids beneath concrete structure with sand. Subsequent USACE report notes continued seepage under the spillway and identifies sinkhole upstream of the structure.

1989 Trees removed from dam embankment areas. South Dakota Department of Environment and Natural Resources notes seepage through joints in the spillway.

1995 Continued seepage noted in inspection reports.

1996 A maintenance project is completed that cleans and reseals joints on spillway. Holes are drilled in the concrete for grout to be injected into voids, but no grout is installed because no voids are encountered immediately beneath the spillway.

2005 An underwater survey and dye testing project indicates a direct connection between three upstream sinkholes and downstream boils. An inspection report notes that the center of the spillway appears to have settled and several cracks have appeared in the spillway and basin walls, along with seepage noticeable through the weep holes and a boil in the basin area.

2006 A maintenance project is completed consisting of construction of a filter berm to cover several of the largest boils downstream of the spillway with coarse rock and riprap to reduce the piping of foundation materials from beneath the spillway.

2007 A boil is observed in the downstream apron along with a significant leak in the concrete spillway face.

2008 A repair seepage control measure consisting of bentonite placement in voids and sinkholes upstream of the dam is completed.

2008 South Dakota Game, Fish and Parks contracts the design of the Canyon Lake By-Pass System.

Section 10

Findings & Recommendations

Findings

Stanley Consultants, Inc. and FMG, Inc. were retained by the City of Rapid City to complete Phase I Engineering Services for the Canyon Lake Dam Project. These services included data collection (structural inspection, hydrologic and hydraulic analysis, geotechnical investigations, topographic survey and property boundaries) and engineering evaluation of the existing project structures and the proposed reconstruction alternatives. A detailed description of the tasks, assumptions, analyses and findings are presented in previous sections of this report. The significant findings are summarized by the following:

- Canyon Lake Dam has ongoing seepage issues at its primary spillway that have incurred investigation and repair costs and compromised the service life of the structure. The existing spillway configuration was found adequate for hydraulic capacity and geotechnical stability. However, the original design lacked measures for constructing a "tight" and long lasting seal between the soil and bedrock interfaces within the spillway foundation. The original design also did not appear to account for the potential of large voids forming in the bedrock foundation. These factors may have contributed to the failure of the original seepage control and drainage system, leading to the history of seepage problems that the dam has experienced.
- The geotechnical investigation and geophysical survey determined the bedrock profile under the spillway, verifying that its southern section overlies bedrock while the northern section overlies alluvium. The spillway foundation is comprised of highly fractured limestone bedrock and alluvium containing cobbles and boulders. The variable composition of the underlying soil and bedrock will make construction of a seepage barrier challenging.

- A Ground Penetrating Radar (GPR) survey and concrete coring program identified voids under the concrete spillway slabs near the bedrock/soil interface at the center of the spillway, where seepage issues are believed to have been greatest.
- Based upon the hydrologic and hydraulic analysis, Canyon Lake Dam's existing primary and auxiliary "fuse-plug" spillway configuration are sufficient to safely pass the State of South Dakota's applicable design flood (½ PMF). The analysis computed a peak water surface of 3370.6 which is below the overtopping elevation of non-spillway portions of the dam. The fuse-plug spillway is engaged at approximately 3369, and the analysis showed the primary spillway could convey approximately 17,000 cfs before the fuse-plug spillway is engaged. The hydraulic model found the existing spillway geometry sufficient to force a hydraulic jump (dissipation of energy and reduction in velocity) prior to the end of the concrete apron in all studied flow conditions.
- Based upon geotechnical analysis, the Canyon Lake Dam structure, as designed, was found to have adequate global stability and the seepage exit gradients computed at the toe of the structure (downstream pond) are acceptably low, indicating sufficient energy dissipation over the length of the spillway provided that the subdrain systems are functioning properly. However, as indicated by inspection and dye testing, there are areas of either very high conductivity materials, void areas, or high permeability/leaking material interfaces, that have "by-passed" the originally designed and constructed system and resulted in unacceptably high seepage gradients. A set of project priorities and limitations were developed with input from the City and interested organizations. Using these project parameters, three feasible alternatives were developed for the restoration of Canyon Lake Dam.

Restoration Alternative 1 – Repair Existing Spillway

This alternative involves constructing a seepage barrier upstream of the existing spillway and making repairs to the south abutment wall and stilling basin weirs. Alternative 1 has an estimated capital cost of $2.0M and an estimated schedule having major construction starting in August of 2009 and ending in December of 2009

Restoration Alternative 2 – New Concrete Spillway

This alternative involves replacing the existing spillway with a new spillway with a seepage barrier and enhanced underseepage protection. A portion of the south abutment wall will be replaced or repaired and the stilling basin weirs will be repaired. Alternative 2 has an estimated capital cost of $3.5M and an estimated schedule having major construction starting in August of 2009 and ending in late-December 2009.

Restoration Alternative 3 – Rock Rapids Channel

This alternative involves removing the existing spillway, installing a sheet pile seepage cutoff, and constructing a gently sloping, rock rapids channel. The rock rapids channel will be comprised of varying sized rocks, placed to create a series of cascading pools down the length of the channel. Alternative 3 has an estimated capital cost of $4.1M and an estimated schedule having major construction starting in August 2010 and ending in March 2011.

- Alternative 1 has the lowest initial capital cost and shortest project schedule but will likely have the shortest service lifespan due to the age of the existing structures, uncertainties associated with the repair of voids that have been created beneath the spillway concrete and the degree of damage of the spillway underdrain system. This alternative could be used to bridge the gap between now and when additional project funding becomes available with repairs staged over the next 20 years until replacement is feasible.
- Alternative 2 provides a similar structure to Alternative 1 with subsurface and structural improvements that will provide a long service life and reduced maintenance. This alternative only utilizes the existing structures that are in very good condition. There are several options for repairing or replacing portions of the existing abutment walls and providing finishing treatments to the new spillway to aesthetically enhance the structure.
- Alternate 3 provides a more natural looking spillway, but has the highest cost and longest schedule to construct due to greater permitting and construction requirements. This alternative provides a more gently sloping spillway but there is greater uncertainty as to its ability to maintain cascading pools during normal flow conditions and its durability during high volume flow conditions, especially with debris present.

Recommendations

The rock rapids option, while being aesthetically interesting, will require a significant increase in initial capital cost and has the potential of introducing scheduling delays due to potential permitting issues associated with this significantly larger structure. Repair of the existing spillway provides a low capital cost alternative, that could be used to bridge the gap between now and when additional project funding may be available for construction of a new spillway. However, the voids found beneath the spillway during the geotechnical investigation suggest that repair of the foundation will be difficult to construct and difficult to verify. The uncertainties associated with these repairs, combined with the age of the 30 year old structure, will result in more frequent and costly maintenance than for the other alternatives.

Based on comparison of advantages and disadvantages of the three alternatives and their ability to meet the project parameters set forth, Alternative 2 is the preferred alternative for restoration of the Canyon Lake Dam. A new concrete spillway will allow a more comprehensive solution to the complex foundation problems at the site and will provide a new structure with longer service life and reduced maintenance.

The following provides a list of additional recommendations and considerations for the project as it moves forward towards final design:

- Preliminary estimates of the cost and constructability of grouting varied widely. Further consultation with construction contractors on the constructability and cost of grouting and sheet piling options for the spillway seepage barrier are needed to resolve which option(s) are most appropriate for this site. The seepage barrier is a major component of construction and the method and material used for construction will have a significant impact on the overall project cost.

- Consideration should be given to placing an additional sand/bentonite layer upstream of the spillway during the current pool drawdown to maintain/enhance the temporary seepage barrier constructed during 2008.
- It is important that Rapid Creek flow not exceed the capacity of the by-pass system for extended periods during construction. Ongoing coordination with the U.S. Bureau of Reclamation, owner of Pactola Dam, will be needed to schedule dewatering after releases from Pactola have been reduced. Long term precipitation forecasts should be taken into consideration and the contractor could consider installing additional temporary flow by-pass capacity if Rapid Creek flows are predicted to be higher than what is usual during fall and winter months.
- A concrete sidewalk currently runs along the top of the fuse plug embankment. The sidewalk could slow down erosion of the embankment, reducing the capacity of Canyon Lake Dam to safely pass its design flood. Timing of fuse plug erosion should be included in detailed design analysis. Consideration should be given to replacing the concrete sidewalk with a more erodible material such as pavers or aggregate and creating a "saddle" in the profile of the fuse plug crest to concentrate overtopping flows to more effectively initiate erosion.