CBC Aids WVDEP with Fresh Water Reservoir - Chief Logan State Park

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Authorization to proceed with the evaluation of the Chief Logan dam was given in a letter from Dr. Eli Laidley McCoy, Director, WV Division of Environmental Protection, dated January 29, 1997. At the time the Chief Logan embankment was zoned a dam consisting of a central clay core with upstream and downstream miscellaneous soil and rockfill shells. The crest elevation of the embankment is 886 feet, the overall height of the embankment is 58 feet from the upstream toe to the crest, and the normal pool elevation is 870 feet. The embankment was constructed during June, 1995, through December, 1995. CBC was hired to to find out why the dam was not holding water creating the desired fresh water reservoir.

The embankment was to impound water for a recreation lake with a surface area of 6.47 acres as measured at normal pool. The design called for the embankment to have a keyway cut to rock beneath the entire cohesive core. A cohesive core with 0.25 (horizontal) to 1 (vertical) side slopes, a minimum top width of 10 feet, and a variable bottom width based on depth of embankment was designed as a seepage barrier in the embankment. The upstream and downstream shells were to be constructed of miscellaneous material (unclassified fill) consisting of any nonorganic soil or rock material available from the site excavations with a top size of 18 inches. It was specified that the clay core be compacted to 95% of the maximum standard Proctor dry unit weight at a moisture content not less than 2% below or greater than 4% above the optimum moisture content. The upstream and downstream shells were to be compacted with a 20 ton vibratory roller. No compaction specification was specified by the design engineer for the shells. The principal spillway for the structure consists of a 16 inch nominal diameter ductile iron pipe with a 55 foot tall concrete riser consisting of a double chamber reinforced concrete drop inlet, and an upstream compartment that measures 5 feet by 3 feet, and a downstream compartment that measures 4 feet by 2.5 feet in plan dimensions. A gate placed in the drop inlet structure controls the pool level and allows for decanting of the lake. An approximately 60 feet wide emergency spillway was to be excavated on the right abutment looking downstream. The spillway was designed with a crest elevation of 875 feet. The embankment was completed during December, 1995, and the first filling of the reservoir was begun on April 15, 1996.

The first filling of the lake was attempted between April 15 and June 7, 1996. It was noted during that time that large amounts of seepage occurred once the filling of the lake exceeded about the half full elevation of the reservoir. Reportedly, the seepage occurred through the underdrain, the pipe from the seepage diaphragm around the decant pipe, around the decant pipe, through the dam itself, and at the left abutment looking downstream through the groin ditch. The reported seepage rates according to Triad's monitoring report dated June 19, 1996 are as follows:

SEEPAGE (gal/min.)	LOCATION
210	Dam Internal Drain
270	Old Creek Channel Drain
75	Around Principal Spillway (Pipe)

The reservoir pool elevation of 870 feet was reached on May 16, 1996, and maintained until June 1, 1996. Once the large amounts of seepage were noted, the gate in the decant structure was opened, and the lake was emptied. The lake was emptied by June 7, 1996, and remained empty until this engineering evaluation was concluded at which time the lake was again filled to about 75% full in order to evaluate the seepage and phreatic surface through the embankment. The decant riser was found, upon inspection, to contain honeycombed areas, and the reinforcing bars inside the structure were observed to be exposed in some locations. This study was instituted to determine the following:

- reason for seepage through and beneath the structure
- evaluation of decant riser
- design of remedial action.

CBC Evaluates Leakage

The reinforced-concrete intake structure was visually examined by CBC Engineers and Associates, Ltd., personnel on June 3, 1997, with the assistance of L.J. Hughes and Sons personnel. The intake structure was accessed via a small row-boat provided by the Chief Logan Ranger's office. Upon entry into the interior of the structure through the top of the structure. The interior walls were noted to be wet below the level of the pool, and are apparently stained with iron oxide (Photograph to the right). It was also noticed throughout the interior of the chamber that there are numerous zones of "honeycombed" concrete, some of which have apparently been patched. Also revealed by our visual examination is the presence of apparent "cold-joints" that are now leaking water into the chamber from the pool. The amount of flow through the cold-joint appears to be significant, based on the magnitude of the staining on the interior chamber walls. Zones of efflorescence were also noted along the apparent cold-joints. There is also a significant concentration of relatively large shrinkage cracks in the concrete walls.

In order to determine the leakage into the decant pipe proper, the gate valve was totally closed such that no water entered the pipe from the gate valve. Observations were made of the water flowing through the pipe. Subsequently, a small flow was noted to be coming through the pipe; however very little seepage was observed. Measurements made of this flow demonstrate that the flow was about one half gallon per minute. Consequently, little seepage is permeating into the pipe. The amount of flow could be due to the lack of a watertight seal of the gate valve. An area of the spillway was cleared off by Marcum Excavating to determine the nature of the blast-induced crack pattern in the bedrock in the spillway. A relatively large area was excavated to bedrock (Photograph to Left). Once the area near the centerline of the embankment was reached, the depth to bedrock increased. A test trench was excavated to the edge of the upstream bench. Bedrock in this area was found to extend to depths up to 10 feet beneath the existing site grade. A profile of the rock near the dam side of the spillway is shown in Figure 4-10. The actual rock line is plotted versus the original spillway plan elevation. From about the downstream edge of the crest of the dam trending upstream the rock apparently had been overshot by blasting or was at greater depths than the bottom of the spillway. The backhoe excavated a trench into the berm between the spillway and the dam. It was found that this berm was fill and not rock (Photograph 4-21). Photographs 4-22 through 4-24 show the excavation and the fill which had been placed in the spillway in this area. An area downstream of the crest of the embankment also contained fill material in which bedrock had apparently been overshot and a crater had been created. The entire area excavated by the backhoe was washed with high pressure hose utilizing the drill rig pumping equipment to expose the crack pattern for geologic mapping.

A grid pattern was then established by the CBC Engineer's geologist with white paint; cracks greater than 1 inch wide were marked yellow, cracks that measured 1/8 inch to 1 inch were marked green, and cracks less than 1/8 in width were marked blue for photographic purposes. The Photograph to the Left shows the marked cracks in the spillway. Photographs were also taken of the cracks during surveying activities used to map the crack pattern in the bedrock. It was relatively obvious from the profile, as well as the cross-sections of the spillway after excavating to bedrock, that a considerable amount of fill has been placed in the spillway, and that bedrock was not present at the flow depth of the spillway over a relatively large portion of the spillway. Cross-sections across the excavated area in the spillway (which were taken on 10 foot centers through the area excavated), and a profile in three different locations down the spillway were developed to illustrate the location of rock in the spillway. .

CBC Leakage Remediation

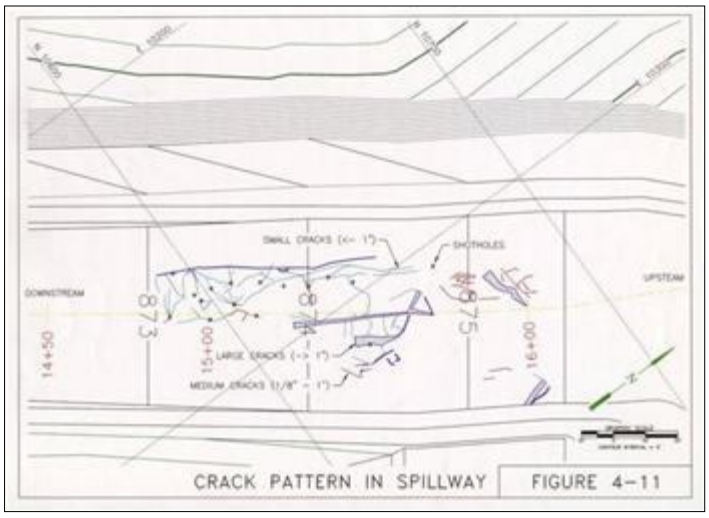
The causes of the leakage at the Chief Logan dam were:

- overblasting in the spillway area creating large cracks and fissures
- natural cracks and joints in the rock
- cracking of the clay core
- higher permeable zones in clay core due to more sandy material, oversized particles, and limbs in the core

Leakage Through the Dam

Based on the results of the subsurface exploration, laboratory testing, and our engineering analysis, the majority of the seepage (both through and under the embankment) is flowing through the fractured bedrock mass. However, based on the testing performed, there is flow both through the dam proper and through the rock beneath the dam. It is apparent from the testing and observation that there is a high probability of cracks extending through the core of the dam allowing considerable leakage. It is, therefore, necessary that the remedial action provide leakage control for both the clay core and the underlying rock. It was our opinion that a grouting program was the most economical overall method of repair. It was, therefore, proposed to grout both the rock and the upstream shell. The grouting is best done from the upstream pedestrian walkway as grouting in the core or the downstream shell could plug the filters and drains. The walkway is at an elevation approximately equal to the normal pool level; therefore, the zone between the normal pool elevation of 870.0 feet and the storm pool of 884.61 feet must also be treated. It was proposed to cover this area with an impermeable liner.

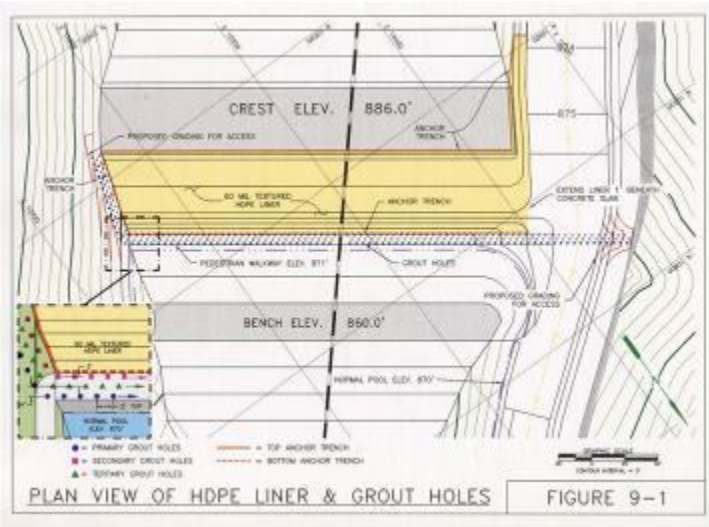
The rock cores obtained from the exploratory boreholes indicate that most of the rock fracturing contributing to the leakage is situated within about the upper 20 to 30 feet of the bedrock mass. Therefore, in order to remediate flow through both the rock and the clay core, it is recommended that a grout curtain be placed within the upstream slope of the dam to minimize seepage. This grout curtain should extend from the pedestrian path (located at elevation 871.0 feet) through the upstream shell of the embankment, to a depth of 30 feet below the soil/bedrock interface. Both the rock and the upstream shell will be grouted from this level in accordance with the procedures outlined below and in the specifications. In addition, a geosynthetic HDPE liner will be installed above the grout curtain (i.e., above elevation 871 feet) up to the maximum storm pool of the dam to minimize seepage during those time periods when the pool elevation is higher than elevation 870 feet.



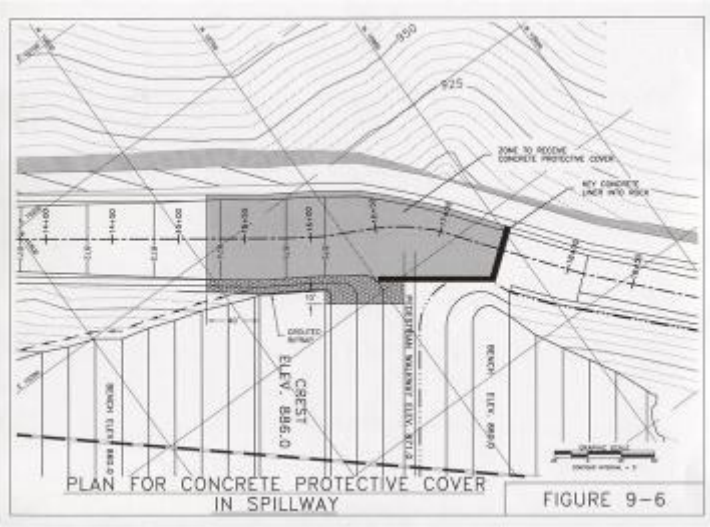
CRACK PATTERN IN SPILLWAY FIGURE 4-11

A relatively large portion of the spillway in the area of the crest of the embankment is not constructed in sound rock. Some considerable portion of the spillway bottom and the side slope adjacent to the dam consists of fill which was placed in these areas due to either the lack of bedrock in this locale, or due to the effects of overblasting the rock. If this area is simply refilled with earthen material it could erode out during a storm event. The velocities in this portion of the spillway during a PMP event are about 17 feet per second. This velocity is sufficient to erode out the earthen fill if it were not replaced. Also, the material as it currently exists does not appear to have been compacted. There are no records of compaction tests in any of the old fill that exists in the spillway. Observations performed during the excavation of the spillway indicate that there are large rock fragments and stones placed in the spillway area, which would not have permitted proper compaction even if compaction had been attempted during the original construction of the dam. This material in the spillway is composed of rocks of varying size, with a matrix of clays, and silts. This fine grained matrix will be highly erodable, and in our opinion would erode out during high storm flows through the spillway. In addition, the highly cracked nature of the spillway bottom would allow considerable flow of water into the embankment during storm flows, potentially creating a problem with erosion and/or piping of the embankment proper. For these reasons, the spillway should be repaired.

Based on our evaluation, it is recommended that the following methodology of repair be accomplished. The old fill material in the spillway in the location shown on Figure 9-6 should be removed down to solid rock all the way across the cross-section of the spillway. Dental concrete should then be used to fill any cracks and crevasses within the exposed rock surface. After the fill is removed, a high pressure hose should be used to wash down the rock and wash out any soil within cracks, and the dental concrete should be used to fill cracks and crevasses within the fractured rock mass of the spillway. Once this was accomplished, compacted fill that was compacted to a dry unit weight equal to at least 95% of the maximum dry unit weight as achieved by the standard Proctor test was brought back to a grade that was approximately 4 inches below the design finished grade of the spillway. Once the spillway area was filled to within 4 inches of grade, a reinforced concrete protective liner was to be placed. The reinforced concrete liner must measure at least 4 inches in thickness, and be properly reinforced. This extended over the entire bottom section of the spillway in the zone shown below. The liner was to be keyed into the undisturbed rock on the upstream edge to prevent piping of water beneath the liner. The side of the spillway adjacent to the dam is fill and was to be protected with grouted riprap.



PLAN VIEW OF HDPE LINER & GROUT HOLES FIGURE 9-1



PLAN FOR CONCRETE PROTECTIVE COVER IN SPILLWAY FIGURE 9-6

Should you have any questions about this Case Study please contact our ***Director of Marketing*** - **Joe Dennis** @ 937-428-6150.