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May 29, 1997
Revised June 6, 1997

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DAM SAFETY

Jordan, Jones & Goulding, Inc.
2000 Clearview Avenue, NE
Atlanta, GA 30340

Attention: Mr. John W. Britton, P.E.
Project Manager

Subject: Report of Preliminary Geotechnical Engineering Evaluation
Lake Petit Dam / Pickens Co.
Big Canoe, Georgia
PGC Project No. 97089

Dear John:

Piedmont Geotechnical Consultants, Inc. has completed the authorized preliminary geotechnical engineering evaluation of the subject site, and is reporting our findings herein. This study was generally outlined in our Proposal No. P6237 dated July 29, 1996 and authorized by you. The following paragraphs will briefly describe the evaluation procedures utilized, observations made during two separate visits to the site during this phase of study, a review of historical information concerning this dam, and will present our preliminary geotechnical conclusions and recommendations concerning various aspects of this project.

EVALUATION PROCEDURES

Our firm's involvement in this project, assisting your firm in the evaluation of this dam, has been prompted primarily by several deficiencies noted in the most recently published annual inspection report of the Georgia Safe Dams Program dated April 15, 1996. In particular, item numbers 5 through 8 of that letter describe seepage related concerns, and possible deficiencies with the principal spillway system of this dam. This annual inspection report recommended that the owner obtain the services of an engineer to evaluate certain deficiencies, and report back to Safe Dams on these items.

On July 23, 1996 the undersigned met with Mr. Mark Kilby, P.E. of your firm, and Mr. Troy Ledbetter of Big Canoe to perform a brief reconnaissance of the dam. This visit resulted in our proposal to you dated July 29, 1996 that generally recommended a sequenced approach to assessing these apparent deficiencies. From the July 23, 1996 reconnaissance, visual confirmation was made of the unexplained existence of fairly broad areas of apparent seepage on the lower portion of the downstream slope of the dam. Several corrugated metal outlets, assumed to be associated with the original internal drainage system for this dam, were observed at and beyond the headwall for the low level discharge drain. In addition, several corrugated plastic outlet pipes were observed draining into the concrete ditch on the first berm up from the bottom of the dam. These were suspected to be drains added after the original construction. The area of the cited principal spillway concerns near the control section of this spillway were observed. Other possible concerns identified were the potential age of the corrugated metal internal drainage system and indications of possible leakage into the low level drain conduit.

Our proposal recommended that a thorough review of any available design and historic information concerning this project be made, and that a more thorough visual reconnaissance of the dam site be performed. The historic data review would potentially include such items as the original design drawings, any construction records, records of any modifications made subsequent to the original construction of the dam, and a review of the Safe Dams Program file concerning this project. In addition, it was suggested that reported monitoring wells, which could not be located during the July 23, 1996 visit, be located and repaired, as needed, prior to our subsequent visit to the site. We also suggested that the damaged outlets for the corrugated plastic drains be repaired and flushed, to potentially enhance the performance of this drain system. Our proposal suggested the possible need for an additional phase of evaluation to better assess the phreatic conditions through this dam, and a possible reassessment of slope stability if changes to the originally intended phreatic surface exist.

HISTORICAL INFORMATION

Prior to our second visit to the site, your firm obtained copies of pertinent information contained in the Safe Dams Program files concerning this project. You have provided us with a copy of this information. This included a copy of the Phase I Inspection Report performed in 1979. During our second visit to the site on May 13, 1997, copies of the original design drawings were provided to us. In addition, we had the opportunity to further discuss the history of this project with Mr. Troy Ledbetter of Big Canoe. We understand you have also made telephone contact with Mr. Tom Robertson, P.E. of Cranston, Robertson, Whitehurst concerning any information that may be contained in their files concerning this project.

The original design drawings were prepared by Baldwin & Cranston Associates, Inc. (now Cranston, Robertson, Whitehurst) with drawings dated November, 1971. These drawings indicate the following pertinent information:

1. The dam is approximately 125 feet tall, and was designed with a 3.5H:1V upstream slope and 2.5H:1V downstream slope sections separated by several berms.

2. The low level discharge conduit is shown as a 30 or 36-inch diameter AWWA C-301 concrete pressure pipe (both sizes are shown on various drawings).

3. The cross-section and profile of the dam depict several boring locations that were apparently performed. Detailed information concerning subsurface conditions is not included; however, there is general indication that the dam is founded on shallow partially weathered rock and rock. A keyway along the centerline of the dam was to be extended to rock.

4. The internal drainage system designed for this dam is depicted as a trench drain extending down both abutment slopes and across the valley bottom, and located well within the downstream slope of the dam. The valley portion of the drain is shown approximately 230 feet downstream of the centerline of the dam, which places the drain approximately 1/3 to 1/2 the distance from the downstream toe to the crest of the downstream slope. Within the abutments, the drain is a nominal 4 foot by 4 foot section of granular material without piping, with a similar cross-section across the valley bottom including an 8-inch diameter asbestos cement perforated pipe. Two outlets running along either side of the low level discharge conduit extend to the impact basin, and consist of solid asbestos cement pipe. No other internal drainage system components are shown in conjunction with this design. Gradation ranges for the aggregate drain material are noted on these drawings; they essentially range from 1-1/2 inch down to the number 200 sieve size material, with a broad range for each of the various sieve sizes between these limits.

The Safe Dam Program files included a Phase I Inspection Report dated July 24, 1979. This report generally indicated the following:

1. The dam was constructed in 1972 by Lothridge Construction Company. The hydrologic/hydraulic assessment of this dam indicated that the existing spillway capacity is adequate to meet the current Safe Dam Program requirements. The conduits which pass through the double box culvert principal spillway system at the left end of the dam (looking downstream) existed at the time the Phase I study was performed.

2. Modifications to the dam were reported as including a series of corrugated ABS plastic drain pipes placed in 1976 to address apparent seepage on a lower portion of the downstream slope.

3. A slight amount of seepage was observed at that time near the left abutment along the lower portion of the downstream slope. The surveyed cross-section of the dam is depicted with downstream slope sections ranging from 1.9 to 2.1H:1V, and a similar number of berms to the original design drawings. However, the spacing vertically between the berms, as well as the width of the individual berms varies from top to bottom on the downstream slope.

The information which we reviewed from the Safe Dams Program files which was gleaned by your firm and provided to us included a series of annual inspection reports generally dated between 1985 and 1996. In general, these annual inspection reports depict similar problems throughout the period of involvement of Safe Dams in this project. Most significantly, this involves the apparent seepage which has been an ongoing observation along portions of the lower slope sections of the downstream slope, as well as toward the left abutment contact low on the downstream slope. There was some indication of the existence of monitoring wells on the downstream slope, and the ABS plastic drain outlets, with the recommendation that any data concerning the wells be provided and that the drain outlets be periodically repaired/cleaned out to restore their function. The only other piece of significant information provided was a letter dated March 31, 1980 from Mr. Tom Robertson of Baldwin & Cranston responding to a letter dated February 14, 1980 from the Safe Dams Program questioning the downstream slope configuration. Apparently, the designed 2.5H:1V slope between berms versus the average of about 2H:1V depicted on the Phase I cross-section was the discrepancy noted that Safe Dams requested the original designer consider. This particular letter from the original designer indicates that the average slope of the sections between berms was very close to the 2.5H:1V original design based on their then recent field survey measurements. Information concerning the final resolution of this issue apparently not available in the Safe Dams Program files.

Some possible additional historical information concerning this project is pending. During our more recent visit to the site on May 13, 1997, we met with Mr. Ledbetter and requested that he attempt to obtain information from individuals previously involved with this project concerning the purpose and design for the ABS plastic drains that are observed, as well any additional information that exists concerning the observation wells. In addition, since both the wells and the drain outlets had only been repaired just prior to our more recent visit to the site, we suggested that maintenance personnel periodically take readings in the wells and observe the seepage area above the plastic drain outlets to determine if any changes are occurring with time. Subsequent to our more recent visit, we understand that you have contacted Mr. Robertson by telephone to request any additional information that may be contained in their files concerning geotechnical aspects of this project. In particular, any information concerning subsurface explorations, laboratory testing programs, seepage evaluations and stability calculations would be useful. As of the writing of this report, this pending information has not been provided. We note that Mr. Ledbetter suspects that the ABS plastic drains were added by Big Canoe maintenance personnel, and are likely placed at a very shallow depth below the slope face. No other significant information concerning this project has been provided.

SITE OBSERVATIONS

Our most recent visit to the site was conducted on May 13, 1997. The undersigned met with you to perform this reconnaissance. We also met with Mr. Ledbetter, Mr. Bill White, and other maintenance personnel of Big Canoe. The weather was clear and cool at the time of our visit; no rain had occurred at least two or three days prior to this visit. We briefly met with Mr. Ledbetter prior to observing the dam, and then went to the maintenance office to locate and review the original design drawings. Mr. White located these drawings, and a copy of these documents was made while we visited the dam site.

Shortly before our visit, we understand that three observation wells on the downstream slope of the dam were located and repaired. In addition, the outlet ends of the ABS plastic drain pipes were repaired, and the drains flushed, in an attempt to restore their function. Most of these outlets had been damaged based on observations made during our visit last year.

We understand from discussions with Safe Dams and Mr. Kilby of your firm that any concerns related to the hydraulic capacity of the spillways for this dam have generally been resolved. Apparently, Safe Dams has determined that the conduits which pass through the principal spillway box culverts were accounted for in the H&H calculations performed during the Phase I inspection program. There was some concern that these pipes may have been added and were not accounted for in the H&H analysis; however, this has now apparently been resolved.

Our reconnaissance of the dam site indicated the following:

1. Water was flowing through the principal spillway channel at the time of our visit. All of the water was entering the channel from the cold water release pipes which extend deep into the lake. No water was observed flowing over the weir at the entrance to the spillway.

2. There appears to be several utility lines that cross the top of the dam and are located within the emergency spillway section. An apparent sewer easement that runs in an upstream/downstream direction through the left edge of the emergency spillway was observed. Much of the emergency spillway channel downstream of the crest roadway is heavily wooded.

3. Mr. Toby Johnson with Big Canoe indicated that the low level drain valve has not been operated to his knowledge in the last several years. Therefore, the operational condition of this valve is uncertain.

4. The three monitoring wells were observed and measured during this visit. We designated well W-1 the well on the uppermost downstream berm, W-2 on the second berm from the crest, and W-3 on the third berm from the crest. Water was measured in W-1 at a depth of 9.4 feet below the ground surface. W-2 was measured at a total depth of 14.9 feet where a slight amount of wet mud was encountered. W-3 had water at a depth of 1.4 feet below the ground surface, with the bottom of this hole measured at about 10.4 feet.

5. A total of six berms exist on this dam, including the roadway "berm" at the downstream toe of the dam. The upper three berms are earthen, with the next two berms down from the top having concrete lined ditches along the upstream edge of these berms. There is also a concrete flume at the upstream edge of the roadway as well.

6. Apparent seepage was exiting from the face of the slope section between berms 4 and 5, counting from the top down, which is between the two berms that have the concrete lined ditches. This general wetness was observed primarily to the left of the center of the dam, extending toward the left end of the dam (looking downstream). The wetness was generally

on the lower half of this slope section, with no real discreet flows being observed. There is a general wetness, with some minor pooling of water in shallow surface depressions. There are indications of some rutting from the mowing equipment through this area; the ground is soft underfoot in this particular area. This location is immediately above the ABS plastic outlet pipes.

7. The ABS plastic drain outlets are located on the fifth berm down from the top, which is the first full berm above the road at the downstream toe. There are approximately 10 outlet pipes that have recently been refurbished by the owner. Apparently, new outlet extensions have been placed, and all of these outlets are now dripping or flowing a small amount of water into the concrete lined toe ditch. The ditch has been cleaned, and water is obviously being collected and conveyed to both abutments of the dam from the high point of this ditch in the middle. On the left end, the water is being dumped into the woods, and then flows down the abutment hillside. On the right end of this concrete flume, the water is dumped into a vertical corrugated metal standpipe, and then apparently is conveyed to the downstream channel through one of the numerous corrugated metal pipes that exist.

8. As indicated, several corrugated metal pipes outlet into the channel downstream of the low level discharge impact basin. During our visit to this site last summer, it was suspected that these outlets were a combination of surface drainage outlets, as well as internal drainage system outlets built into the dam during it's original construction. However, after reviewing the original design drawings, it appears that the internal drainage system that was originally designed outlets into the impact basin headwall on either side of the low level drain pipe. Therefore, the function and origin of these corrugated metal drain pipes, which are of various diameters, is unknown. All were generally flowing a small to a significant amount of water at the time of our visits.

9. An attempt was made to observe the interior of the impact basin for the low level drain pipe. There is a relatively narrow gap between the impact wall and the top slab on this impact basin. The undersigned viewed into the interior of this structure, and could discern the low level drain pipe centered in this headwall, with the upper portion of the two internal drain outlets able to be discerned on either side of the low level drain. The actual flow emanating from any of these three pipes could not be directly observed. However, based on observing where the flow is exiting the impact basin downstream of the impact wall, combined with listening to the sound inside of this impact basin, we suspect that the majority of the flow is coming out of the right toe drain outlet. This would be the drain that would collect the right abutment slope as well as the valley drain at the base of the dam. During our visit last summer, we suspected that the rust colored stained discharge from this impact basin may have been related to leakage into the low level drain pipe. However, a more likely explanation appears that this may be discharge from the internal drainage system.

Immediately following our visit to the site, we retrieved the copies of the original design drawings from the maintenance office, and then met again briefly with Mr. Ledbetter. We reviewed our observations with him, and requested that he attempt to obtain any additional information concerning the plastic drain outlets from the individuals previously involved in the project. We also requested that they continue with monitoring the observation well levels, as well as the wetness observed on the downstream slope face. We also suggested that they consider flushing the 8-inch drain outlets that exit into the impact basin headwall. Mr. Ledbetter indicated that to his knowledge the bottom drain had never been operated.

PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

The following preliminary geotechnical conclusions and recommendations are provided based on our site observations and the limited information concerning this project that has been obtained to date. This direct data has been combined with our previous experience on similar projects. It must be understood that in the absence of detailed information concerning several aspects of what will be addressed in the following sections, and the limited scope of our evaluations to date, some unknowns remain regarding these items. As a result of our conclusions, additional more detailed follow-up studies have been recommended.

Principal Spillway

Some minor deficiencies were identified in the Safe Dams letter of April 15, 1996, as presented as their item numbers 7 and 8. These concerns primarily dealt with an apparent crack in the bottom of the spillway approach just downstream of the weir control section, and possible water flowing under the weir wall. Our observations during these two visits to the site indicate that in all likelihood, the suspected water flowing under the weir wall is actually entering the principal spillway through the cold water release pipes. As a result, the actual normal pool for the lake is really being controlled by the invert elevation of these multiple pipes where they pass through the weir. Therefore, during low flow conditions, the top of the weir is actually exposed slightly above normal pool level. Since there is the appearance of water entering into the area immediately downstream of the weir, we suspect that there was concern that this water may actually be coming under the weir wall. However, our observations would indicate that no obvious water is flowing under this weir.

In addition, the crack or discontinuity in the bottom slab appears to be nothing more than an irregularity in the concrete finish in this area. There is the appearance that a small area of concrete patching has been performed, creating this irregularity. We attempted to probe into this opening by hand, and found it to be very shallow. With the water jetting over the top of this irregularity, there is the appearance that water may be emanating from this opening. However, we suspect this is nothing more than surface turbulence. We have suggested that maintenance personnel remove the flow from over this area to more directly observe this discontinuity, and then to patch the irregularity to provide a more uniform configuration. It may also be appropriate to lower the lake level during low flow conditions a few inches to remove any water from entering the principal spillway from the cold water release pipes and to observe if any water is continuing to enter the channel. If this exercise indicates that potential problems remain from possible uncontrolled discharges from other sources, we should be contacted for additional evaluation. However, based on observations during these two visits, it appears that this spillway is currently functioning as intended.

Low Level Drain

Based on our visit to the site in July 1996, we had some concern that leakage may be occurring into this conduit. The type of pipe utilized in the construction, as well as the general configuration of the internal portions of the dam were unknown at that time. Our concerns stem from the rust colored discharge emanating from the impact basin; such observations are generally associated with seepage. As indicated in the previous section of this report, we now suspect that the discharges may actually be emanating from the internal drainage system outlet conduits within this impact basin. Direct observation is difficult.

Relative to the low level discharge conduit system, and the associated impact basin, we suggest that the following be considered by Big Canoe:

1. The low level drain valve should be operated to assure that it is still operational in an emergency situation. When the valve is opened, it should be allowed to flow for a sufficient time to flush the interior of the low level drain conduit.

2. In conjunction with the above items, the vegetation and sedimentation should be removed from the impact basin. Assuming that the impact basin has been constructed to the dimensions depicted on the design drawings, the opening above and below the vertical impact wall should be of sufficient size to allow direct access into the interior portion of the impact basin. Currently, it appears that the slot beneath this vertical wall is completely closed off with sediment. Some temporary pumping of the pool that may be left within the bottom of the impact basin may be necessary to facilitate further inspection.

3. Once the impact basin has been cleaned and made accessible, the interior should be accessed, and the discharge end of the low level drain conduit as well as the internal drainage system conduits should be directly observed to assess flow conditions. We recommend that personnel from our firm as well as JJ&G be present to assist with these observations. These observations may indicate that the rust colored staining is either emanating from the low level drain, one or both of the internal drain outlets, or both. Such discharges from the low level drain may indicate possible problems with the pipe joints or the condition of the pipe within the dam. This type of discharge from the internal drain outlets may be of no significant consequence; however, it may suggest the possible need for flushing the interior of these pipes.

4. Depending on the outcome of this visual evaluation of the impact basin conduits, additional work in this area may be needed. Should questions remain concerning the condition of any of these conduits, it may be recommended that a utility contractor specializing in conduit

inspections be retained by Big Canoe to video the interior of some or all of these pipes. This would help to resolve any questions that may remain concerning the integrity of these conduits and their joints. In addition, it may be recommended that the internal drainage system outlets be flushed with a sewer jet either prior to or subsequent to video examination, if it is indicated that any significant partial or total clogging of these conduits exist. Information gathered through these examinations and operations should be shared with our firms, as well as the Safe Dams Program, to determine if any additional work is needed.

Seepage

The primary geotechnical concerns which have resulted in our involvement in this project relate to item numbers 5 and 6 of the April 15, 1996 letter from the Safe Dams Program. Our review of the historical information that is currently available concerning this project indicates that apparent seepage has been an on-going problem since shortly after the original construction of this dam in the early 1970's. We understand that the plastic drain pipes and associated drainage system was likely added to the dam in 1976 to address these seepage related concerns. The Phase I inspection report of 1979 notes some problems with seepage. The various annual inspection reports from Safe Dams since that time continue to indicate some apparent observed seepage on the lower portion of the downstream slope.

Uncontrolled seepage on a dam is undesirable. Seepage in and of itself is not uncommon, but must be controlled within the embankment and foundation to prevent any uncontrolled exit that may cause internal erosion of the dam or it's foundation. Therefore, it is prudent to evaluate the apparent seepage and to address remedial recommendations that may help resolve this problem on a more permanent basis.

There are several pieces of information concerning the actual construction and performance history of this dam that are currently unknown. In particular, the design of the supplemental drainage system that was apparently added at the slope section between berms 4 and 5 is unknown. Mr. Ledbetter has indicated that it was likely placed by maintenance personnel in a shallow excavation. Therefore, it is unlikely that these drains extend deep into the embankment or foundation. There has also been obvious episodes of damage to the outlets to these drains as indicated previously in this report. Currently, the drains all appear to be functioning; however, their recent repair may not have allowed sufficient time to stabilize the phreatic water surface conditions associated with these drains. As a result, during our most recent visit to the site, apparent uncontrolled seepage remains on the downstream slope face.

While the original design drawings have now been reviewed, we currently have no information concerning the actual construction documentation concerning this dam. Therefore, we can only assume at this time that the dam was built in accordance with these design drawings. As such, it appears that the intent was to control any developing phreatic surface through this dam with the single line of trench drain that was placed well within the downstream slope of the dam at it's base.

The location of this drain, combined with the apparent zoning design of the dam that included a clay core and more pervious shells was likely assumed to result in a phreatic surface that would extend in some fashion between the normal pool level contact at the upstream slope down to the internal drain at the base of the dam. While the exact shape of this phreatic surface could vary considerably between these two points, being affected by the relative permeabilities of the various materials the water is passing through, the vertical to horizontal permeability ratios, and other factors, any reasonably assumed phreatic surface between these two points would be well within the downstream portion of the dam, a considerable distance from the downstream slope face. This of course assumes that the internal drainage system as originally designed was sufficient to handle whatever seepage profile develops. To date, no seepage evaluation has been made available concerning the original design that may have included a flow net analysis that justified the recommended internal drainage system design. That is, we would need more specific information about the in-place materials in the dam (clay core and pervious shell) to successfully analyze this phreatic surface profile. This information could help determine if the original design was adequate to actually control any developing seepage.

Another factor that has been considered is the possibility that with time, the internal drainage system originally constructed has become less efficient in handling the seepage as a result of possible partial clogging. However, it appears that the currently observed seepage related problems manifested themselves within no more than about four years subsequent to the construction of the dam. While some possible long-term lessening of the efficiency of this drain system is still possible, we currently suspect that either minor variations in the actual construction of the dam, or the actual performance related to anticipated performance of the originally designed dam are different than anticipated. The original design indicates that the conduit system is asbestos cement pipe. The portion of this system across the valley bottom was perforated; the size of the perforations are unknown. The aggregate drain system was apparently a single material type as opposed to the more typical multi-layered filtered systems traditionally and currently utilized in dams. That is, the broad range of gradations were apparently intended to not only filter the soils that were in contact with the trench drain, but also to provide adequate permeability to allow unrestricted flow of the collected seepage. These single material type drains are typically difficult to control during construction due to problems associated with segregation of the wide range of aggregate sizes involved. Experience and the literature would indicate that these type drains are difficult to construct without segregation. In addition, the hydraulic capacity of these drains, particularly in the abutment areas where no piping is included, may be problematic. An additional unknown is where within the broad range of possible gradations specified the actual materials fell. This could have some impact on the relationship between the fines in this filter material and the perforation sizes in the pipe, and the hydraulic capacity of these materials to collect water. There is also no information concerning the quantities of water being discharged from this drain with time; such information would help to determine whether the drains are clogging with time.

The exact history of the three observation wells that have recently been repaired is also unknown. We are uncertain at this time how these wells were constructed, and for what purpose. We understand your firm has recently had discussions with Mr. Robertson concerning these wells.

According to Mr. Robertson, we understand that five wells were originally installed in a line including the three wells that have recently been repaired and monitored. With the dam construction having occurred in 1972, data concerning these wells provided by Mr. Robertson indicates the five wells were installed in 1973. This data indicates records for the upper three wells, which corresponds to those recently read by our firm. Information concerning the status of the lower two wells is uncertain. Since these wells were all located in a line on five consecutive berms, we recommend that Big Canoe attempt to locate the two missing wells. This may require some limited excavation. The information provided by Mr. Robertson indicates that water levels read in 1976 and 1977 in the well we have designated as W-1 ranged from 13.5 to 14.7 feet below the ground surface, at W-2 from 16.5 to 16.6 feet, and in W-3 from 9.5 to 12 feet. While these data vary somewhat from the more recent readings, all of this information suggests that shallow water existed below the downstream slope face as early as about one year after the construction of the dam. The relationship of these well water levels to the pool elevation at the time of the readings is unknown; there has been some indication that the lake took approximately one year to fill initially. Therefore, these readings may have occurred about the time the lake filled. Any additional information concerning the historical information concerning the original design and construction of these wells would be useful. In the absence of this information, and based strictly on the three wells observed, it appears that all three wells were installed to shallow depths. Since they have only recently been repaired, the water levels measured may be elevated due to surface water infiltration that may have occurred prior to the repair process proper. As a result, we have suggested that maintenance personnel monitor the water levels in these wells periodically to determine if they are dropping to a more stable level.

For purposes of this report, we have had to assume that these episodes of water level measurements in these three wells are representative of the phreatic surface conditions within the embankment. As a result, two of the three wells indicate water depths that are shallow relative to the slope face, with the third well indicating some moisture at the bottom of the well. This would indicate the possibility that the phreatic surface in the upper portion of the embankment exists within 15 feet or less of the slope face. Taking this one episode of well readings at face value, and considering the data provided by Mr. Robertson, combined with the observed seepage that appears to be exiting on the lower portion of the downstream face, leads to a plausible conclusion that the stabilized phreatic surface through this dam is existing at very shallow depths below the face of the downstream slope. Referring back to the idealized phreatic surface that might be considered from the original design of this dam, leads to the conclusion that the currently existing phreatic surface may be considerably higher and farther downstream than originally intended.

To date, this apparent seepage has been viewed strictly from the standpoint of uncontrolled seepage being undesirable, and the intent of any evaluation aimed to determine how best to eliminate and safely collect this uncontrolled seepage. The exiting seepage on the lower portions on the downstream slope can readily be resolved through the design and construction of appropriate filtered drains placed at relatively shallow depths below the downstream slope face. However, such an approach would not significantly lower the apparent phreatic surface, and would not resolve stability related concerns that will be addressed in more detail in the following section of this report. Therefore, we are making no specific recommendations at this time to deal with the observed apparent seepage.

We would also take this opportunity to discuss one additional possible seepage mechanism that may be occurring relative to the observed wetness. Typically, the uppermost level of the saturated zone in a dam is generally considered to be the phreatic surface. That is, below this level, a continuous medium of saturated material exists, with the pore pressure within the embankment materials represented by the head pressure to the phreatic surface above any point within the dam. With the type of material typically utilized for earth dam construction in this area, it is common for the horizontal permeability to be higher than the vertical permeability. This is typically accounted for in the seepage analysis on a new dam. This horizontal permeability preference can be exacerbated considerably by the inclusion of even relatively thin layers of more permeable material placed in horizontal lifts during the embankment construction. For this particular dam, the original design intent was to utilize a clay core zone with more pervious shell materials. Since available borrow materials typically vary considerably, sometimes even from load to load of the construction equipment, our considerable experience with dam design and construction indicates that it is fairly simple to unwittingly place a layer of more permeable material within the zone that is intended to be relatively impermeable. More than one such layer could occur. In addition, we have also seen a tendency that the best available borrow materials are often placed in the lower portions of a dam, with the upper portions of the embankment sometimes being constructed out of whatever materials remain available. If the more desirable low permeability materials were essentially depleted prior to topping out the core zone, it is possible that somewhat more permeable materials were actually placed in the upper portion of this core zone. This is somewhat different from the discreet more permeable layers that are accidentally incorporated into the construction; this is more of a gradual change in permeability from lower to higher vertically upward through the embankment.

Should the actual construction of this dam have resulted in this type of variability in the permeabilities of the material vertically through the dam, there is the possibility that the observed apparent shallow phreatic surface is actually water passing through a more permeable zone high in the embankment. In some such instances, it is possible that this shallower water is essentially "blinded off" from the deeper materials in the embankment, and as a result, also from the deep internal drainage system that was originally designed. Therefore, there remains the possibility that differing levels of phreatic surface exist for different zones within this embankment. While the occurrence of such conditions is more difficult to evaluate after the fact, this type of a phreatic condition would have less of a negative impact on the overall stability of the dam, particularly for deeper failure conditions within the dam. Shallow failure surfaces would still be negatively impacted similar to the condition that would be modeled with a general shallow phreatic surface. However, lower pore pressures in the lower portions of the downstream slope would not have as severe an impact on the stability for the deeper failure surfaces. Therefore, it may be warranted to investigate this possibility further during a subsequent stage of evaluate that will be recommended.

Stability

As alluded to in the previous section, our primary geotechnical concern for this project has shifted from the apparent seepage issue to concerns over the impact of this observed seepage on the stability of this dam. While the original stability evaluation of this dam, if one exists, has not been reviewed, it is likely based upon our experience on similar dams that any original assessment of stability during design anticipated a fairly deep phreatic surface profile through this dam. In addition, there appears to remain some possible discrepancy between the original designed downstream slope configuration, and that which currently exists. The original drawings depict 2.5H:1V slope sections between the berms; the Phase I inspection report identifies average 2H:1V slope sections between berms. Therefore, the overall downstream slope configuration may be steeper than originally intended. While the Safe Dams files indicate some follow-up correspondence from the original designer that attempted to resolve this issue, some uncertainty remains relative to the actual slope configuration. Site observations would tend to indicate that the slopes may be steeper than originally designed.

While the actual slope configurations certainly can have an impact on the stability of the dam, what is of even more significance is the possibility that the phreatic surface for this dam exists at a relatively shallow depth below the downstream slope face. Our experience with numerous stability evaluations of dams would indicate that from a relative standpoint, the phreatic surface profile through this dam would likely have a more significant impact on stability safety factors than the specific slope geometry of the downstream face of the dam. It appears that the potential negative impacts of an elevated phreatic surface on the stability of this dam has not been previously addressed relative to the observed seepage issue.

While not specifically in our outlined scope of services, we have elected to provide a very brief and general assessment of the possible stability of this dam based on some known information and several unknowns that have had to be assumed. For purposes of this preliminary desktop study, we have looked at two general embankment configurations. The first involves the originally designed downstream slope configuration, with the second utilizing the Phase I inspection profile (2H:1V between berms) that was determined for the downstream slope. For the original design slope configuration (2.5H:1V between berms), we have assumed a linear phreatic surface extending from the normal pool shoreline to the internal drain at the base of the dam. No attempt has been made to refine this phreatic surface between these two points. For the Phase I profile, we have utilized the observation well readings and the observed apparent seepage exiting on the lower portion of the downstream slope to create a possible elevated phreatic surface that extends from the normal pool contact with the upstream slope in a linear fashion to the observed seepage location on the slope section between berms 4 and 5. From this point, the phreatic surface extends to the base of the dam along the downstream slope face. For both conditions, we have assumed drained effective soil strength parameters of cohesion equals zero and internal friction equal 32 degrees. These have purposefully been selected to represent the typical or above average values for the parameters obtained through extensive laboratory testing performed in conjunction with a number of new Category I dam designs in this state over the last 10 to 15 years. That is, these values have not been conservatively estimated as would be typical with assumed values by selecting lower values that would have a more negative impact on the stability. Such strength values assume that appropriate materials at the specified compaction criteria were actually placed during the construction of this dam. This obviously is an unknown at this time.

Based on these assumptions the steady-state seepage condition for the downstream slope stability was evaluated for both conditions. Subsequently, a seismic coefficient was introduced to determine the steady-state seepage with seismic evaluation for the downstream slope for both cases. Based on current Safe Dams guidelines, using the Uniform Building Code seismic coefficients, this site is located in zone 2 and has a basic seismic coefficient of 0.15g. Safe Dams currently requires that a critical structure multiplier of 1.25 be applied to these coefficients, resulting in a horizontal coefficient of 0.19 for seismic design. This seismic coefficient of 0.19 is likely substantially greater than what was formerly used by the design community at the time this dam was constructed.

The stability calculations were performed utilizing the widely accepted PCSTABL6 program. For the idealized as-designed steady-state condition of the downstream slope, a minimum safety factor of approximately 1.8 was calculated. This compares favorably with the minimum safety factor required by current Safe Dams guidelines of 1.5 for this particular condition. Applying the seismic coefficient to the analysis resulted in a minimum safety factor of approximately 1.1, which equals the minimum safety factor required for this particular analysis by Safe Dams rules and regulations. In all cases, the critical failure surfaces are deep circles that essentially involve the entire downstream slope of the dam from top to bottom. That is, these are not shallow surface sloughs. Therefore, based on these numerous assumptions, the originally designed embankment would generally be considered acceptable for downstream slope stability conditions.

These evaluations were repeated for the assumed as-built configuration and the elevated phreatic surface. This analysis resulted in a minimum safety factor of 1.1 for the steady-state seepage condition without earthquake and a minimum safety factor of 0.7 including the seismic coefficient. Both of these analyzed safety factors are well below the minimums required for a Category I dam in this state, with the seismic evaluation actually indicating failure of the downstream slope during a design seismic event. As with the idealized as designed configuration, all of the failure surfaces analyzed are deep and mobilize the majority of the downstream slope. Therefore, these represent massive slope failures.

As a result of these possibly overly simplified evaluations, which include numerous assumptions, it is our opinion that there is a significant concern which exists related to the stability of the downstream slope of this dam as it currently exists. While it is not our intent to be alarmist in this regard, it is apparent to us that for both the steady state and seismic conditions analyzed that the apparent elevated phreatic surface that we believe may currently exist could cause a significant negative impact on the possible stability of the downstream slope. From these very limited analyses, it is our opinion that the location of the actual phreatic surface has more of an impact on the calculated safety factors than does the resolution of the actual slope inclination. That is, even if it were determined that the as-built slope is essentially the same as designed, this elevated phreatic surface that has been assumed would still likely result in safety factors that are below acceptable values. Further refinement of the analyses is not warranted at this time since additional studies are needed to resolve the numerous assumptions that have had to be made.

Additional Services Recommended

Our evaluation of this dam to date indicates that additional studies are needed as soon as possible to obtain the needed field data to confirm the assumptions that we have made to date, and resolve certain of the unresolved issues. We recommend that a multi-faceted approach be undertaken as a follow-up phase of study to include at least the following:

1. We recommend that Jordan, Jones & Goulding establish an accurate surveyed cross-section of the embankment to resolve any unanswered concerns relative to the actual slope configurations. As a minimum, one cross-section across the central portion of the dam is required; we would suggest that three such cross-sections be developed to assure that no significant variations exist along the length of the dam.

2. Additional attempts should be made to retrieve whatever information may exist concerning the original design and historical information concerning this project. Recollections of individuals that may have been involved with the dam in the past may shed additional light on such items as the design of the apparent drains added in 1976, the history of the monitoring wells observed, the function of the apparent drain pipes that are observed at and beyond the downstream toe of the dam, and conditions actually observed during construction. The files of the original designer may contain information that was the basis for the original design, as well as construction records. Of particular interest would be any subsurface exploration reports, laboratory testing data, stability and seepage calculations performed during design, and construction monitoring records. The level at which the construction was monitored by experienced personnel and any documentation concerning the actual materials placed, tests performed, etc. may help resolve any questions concerning the internal composition of the actual dam. In addition, any information concerning the actual gradation of the filter material placed in the drain system would be helpful. Photographs during construction may be extremely beneficial.

3. On-going monitoring by the maintenance personnel of observation well levels, and a subjective assessment of any obvious changes in the level of wetness on the downstream slope face should be made to determine if any changes are occurring with time. This may be especially useful at this time since repairs to both of these items have recently been implemented.

4. More detailed information is needed to establish the actual phreatic surface through this dam. In light of the discussion that was presented previously in this report, it is our opinion that a series of observation wells and/or sealed piezometers are needed for this purpose. More specific details of the exploration program can be provided, if requested. However, we currently envision that at least a single line of instrumentation, and ideally two separate lines

of instrumentation be placed across the crest of the dam and down the downstream slope. The exploration and instrumentation program should attempt to determine phreatic levels at various depths within the embankment at all locations. To this end, we anticipate that borings drilled from the crest of the dam, possibly at both edges of the crest, and borings placed on most if not all of the berms along the downstream slope face would be needed. Rather than install an open top observation well at a single screened depth below the obvious upper zone of wetness encountered during drilling, we would suggest that either "nested" observation wells or multiple piezometers placed within a single borehole be considered. In this manner, short screened sections or remotely read piezometers could be placed at multiple depths within the subsurface profile of each location to determine if any variations in the phreatic surface levels exist at different depths within the dam. This instrumentation should be installed and read until stabilized values are obtained.

In conjunction with the instrumentation installation, the borings offer the opportunity to obtain Standard Penetration Resistance values while extending the borings to provide some indication of the composition and relative density of the materials within the embankment. In addition, where appropriate materials are encountered, several relatively undisturbed samples could be obtained and stored for possible future use in laboratory analysis, if needed. The cost of retrieving these undisturbed samples while the field evaluation is being performed is minor; the tubes should be carefully sealed and stored in a moisture controlled environment to prolong their shelf life, if considerable time elapses prior to their possible need for laboratory testing.

5. The results of the surveyed cross-sections, and phreatic surface determinations, could then be utilized in more detailed stability evaluations, again based on assumed strength parameters. Should this exercise result in more favorable, but marginal calculated safety factors, it may become necessary to perform the laboratory strength tests needed to establish the actual strength parameters of existing embankment materials.

These outlined additional studies, which are beyond our joint current scope of services, may help to resolve concerns related to slope stability issues. If so, this study would result in specific recommendations for remedial modifications needed to control the apparent seepage exiting on the downstream slope face. This would be a relatively minor renovation. However, if this exercise indicates that stability issues remain of concern, an additional phase of evaluation and actual design of remediation to correct any stability deficiencies would be needed. We would suggest that this be a separate phase of study, if needed. Any design modifications, even relatively minor changes to specifically address the seepage, would need to be reviewed and approved by the Safe Dams Program prior to implementation. Monitoring of any actual remedial construction would also be needed. These actual design and construction phase services are considered premature at this time; additional evaluations are first needed.

SUMMARY

Our authorized scope of services has resolved some of the minor issues identified by the Safe Dams Program, while determining that additional evaluations are needed to fully address the seepage, and in particular the possible stability concerns. We recommend that the owner review this report, and authorize the additional services recommended as soon as possible. While there are no obvious imminent signs of instability with this dam, it must be understood that this is a significant structure with a high downstream hazard potential. Preliminary assessments indicate that the steady-state stability conditions are below acceptable levels, and that instability may result during a design earthquake episode. Such events cannot be accurately predicted as to occurrence and magnitude. Therefore, the additional assessment should be undertaken as soon as possible. In the interim, the dam should be closely monitored, and any changing conditions immediately identified to us and the Safe Dams Program for further evaluation. We are prepared to provide a detailed proposal and budget estimate for our portion of any follow-up services needed. We appreciate the opportunity to provide these services to date, and look forward to the successful conclusion of the engineering evaluation of this dam. Should you have any questions concerning this report, or any of the services provided by our firm, please do not hesitate to contact me. We are available to meet with you, the owner, and representatives of the Safe Dams Program to further discuss our conclusions and recommendations concerning this dam.

Respectfully submitted,

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