

Lake Oroville Spillways Emergency Recovery

Board of Consultants Memorandum No. 2 – March 17, 2017

Prepared by the California Department of Water Resources

Summary & Response

Question 1

Question 1 relates to presentations made by DWR regarding the proposed and ongoing exploration program to ensure engineers have a detailed understanding of the geologic conditions of the site. A geologic exploration program includes drilling holes into the ground to determine the rock's characteristics. The BOC concurred with the approach that DWR was taking in evaluating the geologic conditions. The BOC reminded the DWR geologists to "think broad" when evaluating the geologic conditions.

Question 2

Question 2 relates to presentations made by DWR regarding design criteria. Prior to designing detailed plans and specifications, there needs to be an understanding regarding the criteria that will be used to ensure the project meets its objectives. DWR presented the various criteria that will be used during the design which is based on various standards for dam design. The BOC concurred with the design criteria and will make further comments as more detailed criteria is established.

Question 3

Question 3 relates to preliminary design concepts that were presented to the BOC. Prior to completing detailed design, it is customary to develop various concepts and to determine which concepts make the most sense and which should be pursued further. The concepts are broken out into three main components of the project, including the upper chute of the gated spillway, the lower portion of the gated spillway chute (this is the area that received the most damage), and the emergency spillway.

Two preliminary concepts were presented for the upper chute of the gated spillway. The alternatives included:

- Placing a temporary concrete overlay of the existing chute, since the entire chute cannot be replaced in one season; and
- Removing and replacing the slab as time permits.

The BOC expressed the opinion that replacing the slab is a better option.



The BOC also had the opinion that it would be difficult to completely replace the lower chute in one season, but noted that there are alternatives available if the entire chute was not replaced in the first year.

The BOC recommended a final design of a fully-lined emergency spillway may be needed, but also noted further exploration and investigations are needed prior to selecting a final design.

It is important to understand that at this phase, all discussions revolve around preliminary information and take place at the conceptual level.

Question 4

DWR had been in contact with several potential contractors to expedite the process. The BOC concurred with this approach.

Question 5

Self-Explanatory

Question 6

The BOC gave opinions regarding the damaged spillway, and postulated possible causes to concrete cracking. It should be noted that the BOC was referring to failure mechanisms after the initial failure. The BOC recommended that future designs consider air slots based on these observations.

The BOC reiterated comments made in Question 3 that the entire upper chute should be replaced rather than use a temporary concrete overlay, and noted it may not be possible to replace the entire upper chute in one season.

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OROVILLE EMERGENCY RECOVERY – SPILLWAYS

Board of Consultants Memorandum

DATE: Friday, 3/17/2017

TO: Mr. Ted Craddock, Project Manager
Oroville Emergency Recovery – Spillways
California Department of Water Resources

FROM: Independent Board of Consultants for
Oroville Emergency Recovery – Spillways

SUBJECT: Memorandum No. 2

INTRODUCTION

On March 17, 2017, the Independent Board of Consultants (BOC) met at the Sacramento office headquarters of the California State Department of Water Resources (DWR) for a geologic site briefing presentation of remediation draft design criteria and further discussion of development of design concepts by DWR. An agenda for the meeting is attached. All BOC members were present. The attendees at the meeting are shown on the attached Attendance List.

The following pages contain the BOC's responses to the questions posed as listed on the attached agenda.

QUESTIONS FOR THE BOC

- 1. Does the BOC have any comments or recommendations pertaining to the geology briefing?**

Response

Based on the presentations made to the BOC, during today's meeting, the BOC has several comments that are listed below. First, as stated one week ago, the BOC continues to believe that the DWR plan presented during BOC Meeting 1 is a reasonable approach to obtain necessary data regarding: 1) the Emergency Spillway structure; 2) the outflow path for the Emergency spillway flows; 3) the wall areas adjacent to the Gated Spillway Chute; 4) the rock quality underlying the Gated Spillway Chute and the interface between the concrete chute and earthen materials; and 5) the slope left of the Gated Spillway Chute that is above

the deep eroded channel. By listing these 5 elements and seeing the large area on map (see Figure 1, from the geology presentation), it is evident that this exploration program is broad-based, provides important information that will be used in multiple designs, and the data must be obtained in a very short time. Thus, it is important that an open and flexible approach be maintained as this program continues. By its very nature, exploration may discover new things that we did not know and that will need to be pursued. Maintaining good, open, and on-going communications between the engineering geologists in the field and the design engineers in the office is challenging during any construction project, but given the unusual fast pace of this project it is even more important.

This point can perhaps be illustrated using this interaction. During the meeting, a suggestion to rotate the entire geophysical array by 45° was made. The idea for the rotation would be to move the East-West seismic lines so they will cross the dominant northeast oriented rock fabric foliation orthogonally. It is worth asking if an exploration plan maximizes data collection efforts. In regard to the suggestion made during the meeting, it should be noted that if one set of seismic lines cross foliation orthogonally, then the other set will parallel the foliation (so does the rotation minimize the value of the parallel set?). However, at this site it appears that shears and not foliation are the major controlling factor on localized weathering. The point is that the investigation program goals must be kept in mind when developing these plans or when suggestions are made to alter the field program.

A second comment on the investigation program involves the part of the geology presentation that discussed the historical documents on the chute geology. This presentation emphasizes the importance of accurate As-Built geologic documentation and final foundation treatment. [REDACTED]

[REDACTED]

[REDACTED] This reaffirms the BOC's position that if at all possible, the removal and replacement option of the chute should be pursued.

Finally, the role of the BOC is to advise and offer opinion to those involved in the day-to-day design and exploration; we cannot see all the data you see and the details regarding how each of your decisions is made. What we can do is encourage you to keep the big concepts in mind as you become wrapped up in time-dependent details. Thus, keep asking the big questions. For example, it was pointed out that there was a spring about 200 ft right and upstream of the Sta 29+00 chute erosion. Do we know why it is there? Is it significant? If so, will this exploration program address why it is there and what causes it. If it is a shear, then the geophysics should pick it up, but what is its trend, depth, etc. Continue to develop your site engineering geologic models (yes, we need to do so even on 49-year-old projects) and use this exploration program to answer not only the many small questions, but also the big questions that no one thought to ask. We got to this point because of a crisis, but while we are here use this as an opportunity to learn as much about the engineering geology as possible.

2. Does the BOC have any comments or recommendations on the Draft Design Criteria?

Response

The BOC heard presentations from the Design Team on brief summaries of the following draft design criteria: Roadway and Site Plan Design Criteria; Geologic and Geotechnical design; Structural design; Hydrology & Hydraulics Design.

It is the BOC's understanding that the general objectives of the selected design criteria for the project features are intended to provide guidelines to help ensure that repairs of the various project components are designed in a consistent manner to meet short-term dam safety requirements. Design criteria were also presented for components that are intended to serve for the long-term design life of the project.

It is also the BOC's understanding that selected design criteria will follow the regulatory guidelines of the FERC and DSOD, and, where applicable, design guides of the USACE and the USBR.

Design objectives for the short-term "interim repairs" were selected to pass a total projected outflow of 304,000 cfs. The Gated Spillway is to be designed to pass 271,000 cfs; the Emergency Spillway will be retrofitted to pass the balance of 33,000 cfs.

Structural components that will be designed to function for the short-term were to be designed for seismic ground motions for return periods of 144 years, based on the results of probabilistic seismic hazard analyses. For long-term structures, design criteria are based on deterministic median (50th percentile) estimates for maximum magnitude earthquakes on controlling seismic sources.

The BOC considers the above criteria as reasonable and appropriate however it recommends that project components whose failure could lead to development of a potential failure mode that would result in uncontrolled release of the reservoir should be designed to the same criteria adopted for the dam embankment.

A summary of geologic and geotechnical design criteria were presented for the geotechnical design of foundations and for geotechnical components and features that would support the design of structural repairs of both spillway structures. These included criteria for excavation and preparation of acceptable foundations, identification of competent rock formations that would serve as foundations, design of slopes and stabilization measures of currently eroded slopes to prevent further erosion; and providing criteria for identifying depth to competent rock that would serve to anchor the existing or newly constructed Gated Spillway chute slab, or the required depth of anchors for stabilizing the Emergency Spillway pier structure.

The BOC notes that the seismic design criteria presented for the design of geotechnical components provide for ground motions based on return periods of 2475 year. For consistency these ground motions should be compared with the median estimates specified for the structural components of the project. The BOC also notes that acceptable factors of safety for the design of slopes were specified as 1.5 for static loads, and 1.1 for seismic loads. For seismic loads, acceptable performance should also be specified based on acceptable deformation.

The BOC generally concurs with the presented criteria summary, but will provide additional review and specific comments once it receives the detailed design criteria documents.

3. Does the BOC have any comments or questions regarding the Design Team's approach for further development of the design concepts?

Response

The DWR staff is still working on refining the options for restoration concepts with the view to presenting the selected design by March 31st. In today's meeting, the presentations made clear that the remediation of the upper section of the spillway chute has priority and will be repaired or replaced such that the first 500 to 1000 feet of the chute and training walls can safely discharge the full flow allotted to the gated spillway. The BOC concurs with this decision but points out that in the event of large spillway discharges some additional erosion damage may be expected to occur to the foundation rock in the downstream portion of the spillway or to concrete placements which may have been previously completed.

The BOC favors doing the total replacement of this portion of the spillway chute and walls in the first construction season from May to November of 2017 in preference to repairing the existing chute and walls by anchoring and placing an overlay which would then at some time in the next few years be totally removed and replaced with a properly designed chute placed on satisfactory rock foundation. The BOC believes it would not take appreciably more time to put in the new slab than doing a repair with an overlay.

The lower portion of the spillway chute is not expected to be able to be completely restored to the final condition during the May to November construction season. Two options are being studied in the planning of this portion. The first concept is to rebuild the foundation for the lower section of the chute with conventional concrete or RCC. This chute foundation would be wide enough that RCC can be brought up on both sides to serve as training walls. Flows would then be allowed to use the unfinished RCC lower spillway chute during the 2017/2018 flood season with the expectation of finishing the reinforced concrete chute and training walls during the next construction season. [REDACTED]

The other option is to make use of the eroded channel on the left side to carry some of the excess flow of large spillway discharges while the existing downstream chute carries a smaller portion and handles the lower discharges by itself. The eroded hole at the break in the chute would be configured to be a plunge pool by constructing sort of a side channel weir with RCC that allows flows over a certain discharge to be sent down the eroded gully. Some backfill

concrete would be needed to improve the lower chute and provide some training wall structure to keep this flow in the chute.

The BOC favors the first option and believes the alternative concept requires about the same construction time and effort as the first but has greater probability of erosion damage to the chute foundation and greater likelihood of depositing material in the river channel.

The hydraulic operating criteria make use of the emergency spillway only for passing flows greater than the capacity of the gated spillway. The emergency spillway is then counted on to be able to pass 33,000 cfs in the event it should be necessary to pass the Interim Design Flood of 304,000 cfs. Repairs have been made to the gullies that eroded in the apron downstream of the emergency spillway weir by dumping riprap and using slush concrete and shotcrete. Further protection by construction of cutoff walls at selected locations may be warranted if deemed necessary.

[REDACTED]
[REDACTED]
[REDACTED] It is questionable whether the nappe would adhere to the concrete with large flows over this crest and negative pressure would almost certainly occur. It is noted that no splitters on the crest are provided for aeration. Further, the condition and quality of the foundation materials are not well understood. The BOC believes the best solution would be to construct a stepped buttress on the downstream side of the weir using RCC. This could provide the needed improvement of stability and would provide energy dissipation in flow passing over the structure.

The channel downstream of the emergency spillway still remains an issue regarding its erodibility and is still under investigation as to the final long-term solution. The same is true of the means of energy dissipation before the flow enters the river. If a well-controlled passage of extreme flood flows without severe erosion of the hillside downstream of the emergency spillway is the objective, the BOC is of the opinion that an auxiliary gated spillway with fully lined chute and designed energy dissipation may be a preferred solution. It is recommended that such an option be included in the studies.

4. Does the BOC have any comments or questions regarding the contractor outreach?

Response

In general the BOC concurs with the approach for an early contractor selection (see the response to Question 5 below).

5. Does the BOC have any comments or questions regarding the draft project schedule?

Response

Further attention has been given to the schedule for the project. Potential contractors have been contacted and some pre-qualifying has been done and at least three potential contractors have been briefed about the project. Consideration is now underway to identify possible contracts. The BOC recommends that the number of different contract packages be minimized in order to reduce potential interference between contractors and reduce mobilization time. For example it would be wise to have clearing, grubbing, and grading of haul roads and constructions for work on the emergency spillway be together in one contract package. Doing so could minimize interference between contractors and optimize the contract schedule.

6. Does the BOC have any other comments or recommendations for the Design Team?

Response

Three photos of very low flow on the upper chute taken after the chute failure, clearly show a hole on the left side of the spillway approximately at or near the construction joint near station 29+00. The second photo shows flow occurring at very small depths (probably due only to gate leakage). At this very low flow, what appear to be roller waves, or possibly disturbances due to flow over construction joints or cracks are clear. The third photo shows the hole that developed shortly after initial failure. In this photo, the damage to the chute is totally downstream of the construction joint. Later photos show the damage has taken place on the upper side of the construction joint and has migrated to approximately station 29+00.

These photos show that failure was initiated at the hole at the left side of the chute near station 33+00. The failure, likely occurred as a result of high velocity flow (in the range of 85 to 90 feet per second), penetrating under the slab,

causing a strong uplift force and causing the slab to lift, eventually causing all or part of the slab to break away. Subsequent erosion of foundation material caused progressive failure both upstream and downstream.

Repairs had been made to the spillway slab several times since its completion in 1968. The most recent documented repair took place in 2009. Locations of numerous existing cracks and spalls were shown in the report. The spalls were probably caused and enlarged by freeze-thaw damage. Some of these holes were quite large and extended as deep as the reinforcing steel. The hole that triggered the failure was probably of the latter type.

If cavitation damage had a role in the slab failure it was probably minor. If cavitation did occur, it would have been damped by aeration in the disturbed flow leaving the gated structure. The thick piers cause large rooster tails downstream of the thick columns downstream of the gates. The waves caused by the piers are efficient aerators. This effect has been used by the Chinese as an aeration device on their design of steep high-velocity chutes and have been found to be effective in preventing cavitation damage. In their design, the channel between the thick walls is actually narrowed slightly to increase the air entrainment. The Chinese call these spillways “Flared Chutes” or “Flared Spillways.”

The BOC believes that the aeration produced by flow past the Gate-Structure walls, is sufficient for this spillway. [REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

The BOC encourages further consideration of total replacement of the chute floor and walls in the upper chute. The construction schedule might be impacted by doing so, but there are a number of flaws beneath and on the top of the floor slab that should be corrected that it would be wise to choose total removal and reconstruction. If the schedule for total reconstruction cannot be accommodated, total repair of cracks and spalls is certainly required. The method and techniques of repairs should be carefully considered in order to judge whether there are any desirable changes in material and technique that would add confidence to duration and/or functionality of the repairs.

Some other minor comments are:

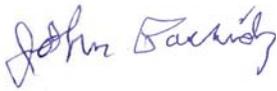
- It would be useful to have station numbers painted on the training walls large enough to be easily seen in video footage taken by drones during spillway operation.
- It was pointed out that excavation of the chute foundation to place a thicker slab would require careful blasting. The BOC suggests investigation of whether the rock in this foundation could be brought to grade with the use of mechanical equipment such as pavement breakers.
- If the reservoir level is above the gate sill elevation in the spillway control structure, Care-of-Water is an item to contend with in the construction contracts.

BOC RECOMMENDATIONS SUMMARY

- M2 – 1 There is a need to keep a flexible approach as the exploration program proceeds and to maintain open on-going communications between the field and the design staff in the office.
- M2 – 2 [REDACTED]
- M2 – 3 The BOC considers the seismic criteria presented are reasonable and appropriate but recommends that any project components where failure might lead to uncontrolled release of the reservoir be designed to the same seismic standards adopted for the dam itself.
- M2 – 4 There should be consistency in the ground motions specified for geotechnical components compared with median estimates specified for the structural components of the project.
- M2 – 5 Acceptable performance for project components under seismic loading should be based on both factors of safety and acceptable deformations.
- M2 – 6 The BOC points out that by giving first priority to remediation of the upper portion of the gated spillway chute, some further erosion of and damage to the foundation rock for the lower chute section must be accepted.
- M2 – 7 The BOC recommends that the chute paving and training walls of this upper chute section be completely rebuilt on properly cleaned and prepared bedrock foundation during the 2017 May to November construction season instead of

- repairing the existing chute with a reinforced concrete overlay and delaying construction of a long term replacement.
- M2 – 8 For the interim reconstruction of the lower portion of the spillway chute in the 2017 construction season, the BOC recommends that the foundation of the chute and side walls be repaired using conventional concrete and RCC backfill to allow discharge to safely flow in the RCC surfaced channel with the expectation that designed concrete lining and walls will be added in the next construction year.
- M2 – 9 The BOC recommends as part of the remediation for the interim period, that the concrete overflow weir monoliths on the emergency spillway be strengthened by a stepped RCC buttress on the downstream face to add stability and provide energy dissipation to the overflow discharge.
- M2 – 10 The long-term solution to provide for passage of extreme flood flows in excess of the capacity of the present gated spillway will require further study and exploration to determine the best plan for the emergency spillway. A second auxiliary gated spillway should be included as one of the options for a long term solution.
- M2 – 11 Construction contracts should be packaged to minimize interference between contractors working on separate portions of the remediation efforts.
- M2 – 12 The BOC reiterates that it is vital to construct the restored spillway chute on a rock foundation of known quality properly prepared with suitable drainage [REDACTED]
[REDACTED]
[REDACTED]
- M2 – 13 The BOC recommends that an air supply slot be built into the reconstructed chute at the location where the slope changes to a steeper incline.
- M2 – 14 Marking chute stations on the training walls visible in video taken by drones would aid in interpreting surveillance imagery.
- M2 – 15 [REDACTED]
[REDACTED]
[REDACTED]
- M2 – 16 Care-of-Water may need to be an item in the construction bid documents.

Respectfully submitted,



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