

## Lake Oroville Spillways Emergency Recovery

# Board of Consultants Memorandum No. 4 –April 11, 2017

Prepared by the Department of Water Resources

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## Summary & Response

### Question 1

Question 1 relates to the construction work that is just beginning adjacent to the lower chute of the gated (flood control) spillway. The slope is being laid back to provide a safe working environment for future work in the lower chute.

The “slope” is the massive rocky area adjacent to the gated spillway. “Laid back” refers to cutting back the slope to make an area for the construction crew and equipment.

### Question 2

Recent exploration reveals the foundation of the upper chute is better than the foundation under the failed section. Previous BOC reports concluded the best option is to replace the upper chute slab, rather than placing a concrete overlay on it.

The BOC concurs with DWR’s approach to replace portions of the upper chute in the first season, and replace any remaining slabs in the second season. Although the BOC concurs with the recommendation to replace the entire chute, they recommend that repair measures should be completed for any slabs not replaced in the first season.

### Question 3

Material that eroded from the hillside adjacent to the gated spillway and deposited in the river was removed and stockpiled. This material will be used to make roller compacted concrete (RCC). The contractor is now preparing this material so it can be used for the RCC. The BOC describes the details on how best to prepare this material so it can be used efficiently.

### Question 4

Question 4 refers to the exploration that is currently being completed to evaluate the foundation rock of the spillway and slopes adjacent to the lower spillway chute. The evaluation of the information is not yet complete.



**Question 5**

The BOC concurs with the preliminary design on the gated spillway chute that has thus far been completed. The BOC notes that the proposed design of the spillway is the current state of the practice, and therefore updates and corrects a number of the design details that were included in the 1960s design.

**Question 6**

The BOC describes the details that were presented to them regarding the slope work that is being completed adjacent to the lower spillway chute. This work is being completed to allow workers in the lower chute area.



# OROVILLE EMERGENCY RECOVERY – SPILLWAYS

## Board of Consultants Memorandum

DATE: April 10 - 11, 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. 4

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### **INTRODUCTION**

On April 10 and 11, 2017, the Independent Board of Consultants (BOC) met at offices of the California State Department of Water Resources (DWR) for a presentation of design criteria, further development of design concepts by DWR and the status of Construction Contracts No.1 and No. 2. The meeting ended on April 11 with a reading of the BOC's report at 4:30 pm. An agenda for the meeting is attached. All BOC members were present. The BOC met with representatives of DWR Engineering Division, DSOD, FERC, and industry consultants that are working on the Oroville Spillway Recovery project; the attendees at the meeting are shown on the attached Attendance List.

The BOC has reviewed the status of past comments and recommendations in the log and this is included in the attachments.

### **QUESTIONS FOR THE BOC**

- 1. Does the BOC have any recommendations or comments on Construction Contract No. 1?**

*Response*

The contractor for Construction Contract 1 has been working onsite for about 3 weeks. The work has focused on the left slope modification (left of the FCO chute spillway) and testing for the RCC aggregate and mix design. The BOC's comments on RCC are contained in our comments on Question 3. [REDACTED]

[REDACTED]

[REDACTED] The excavations maintain a safe distance from the steep slope, and as such, efforts to stabilize the steep portions have yet to commence. The removal of soil and weathered rock has been by excavators and no blasting has occurred to date.

A summary of the kinematic analysis of the slope stability was provided. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] See

additional discussion on this in Item 6 – Stabilization of Slopes.

**2. Does the BOC have any recommendations or comments on Construction Contract No. 2?**

*Response*

The Board has the following comments on Construction Contract No. 2

Alternative Approach for Construction of the Upper Spillway Chute Section

The Design Team presented a detailed review of construction documents that included photographs taken during foundation preparation of FCO spillway chute slab, the Division of Safety of Dams (DSOD) and DWR inspection reports during construction, and the results of borings and core holes drilled through the spillway chute slab during the current field investigations. On the basis of this review, the design team concluded that the foundation conditions under the upper spillway chute are different from and better than those encountered under

the failed section downstream [REDACTED]  
[REDACTED]

On the basis of this assessment, the project design team informally presented the BOC with an option that is being considered as an interim repair measure for the upper spillway chute. This modification of the sequence of construction would keep the existing structure in place, and, with appropriate strengthening, measures that could be completed in the first construction season, would allow the interim design flows to pass over this upper section during the coming flood season. The motivation for adopting such an approach is to replace the currently proposed “remove-and-replace” option of the upper spillway chute (which has been slated for the 2017 construction season) which is likely to present challenges in being completed by the November 1<sup>st</sup> deadline. This alternative option would allow completion of the reinforced concrete lower spillway chute (founded on an RCC-backfilled foundation) and the scour hole repair to be accomplished during the 2017 construction season.

The replacement of the upper chute with the new design for the chute slab and training walls could proceed from the lower end as time allows in 2017 with the completion of the entire new lining in 2018. A major benefit of this sequence of construction would be the provision of a fully concrete-lined chute capable of carrying the interim design flood discharge during the coming 2017/2018 flood season.

The BOC considers this option a feasible alternative, provided repair measures to the existing chute consider the following measures:

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

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

With these provisions made, the BOC would agree that the revised sequence of construction is the preferable plan for restoration of the FCO spillway to full functionality and recommends this construction plan be adopted.

**3. Does the BOC have any recommendations or comments on the RCC mix and production planning?**

*Response*

The results of the investigations for crushing the eroded rock recovered from the river channel as aggregate for RCC have shown that the crushing methodology used in the initial tests does not produce suitable material. However, useful information was obtained by the tests. The tests have demonstrated that washing of aggregate will probably be necessary. The results of crushing using a cone crusher to produce the sand fraction show that this type of crushing equipment is not suitable. The samples from these early tests have a high percentage of flat particle shapes and elongated pieces. Another type jaw crusher will be needed. The decision on the type of crushing equipment will be left to the Contractor for Contract 2.

The test program has produced a stockpile of 6-inch minus material that the Contractor for Contract 2 can use to setup his own crushing methodology. This work needs to be accomplished as soon as possible in order to start the RCC test program. The BOC looks forward to seeing the results of this test program.

An RCC test mix is specified in the Contract 2 documents. [REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]

The Contractor will be required to demonstrate his means and methods for placing RCC on a 25% slope. Although RCC dams have been constructed in other countries using the sloping lifts placement, American contractors are generally not familiar with this type of RCC construction. [REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]

The RCC test pad is expected to be done in June. The BOC would appreciate the opportunity to witness the placement of the RCC test pad.

**4. Does the BOC have any recommendations or comments on the geologic/geotechnical exploration program?**

*Response*

The BOC received a status update of the on-going field exploration program that includes mapping, drilling, surface geophysics, and instrumentation. As of this meeting 23 of 56 exploratory borings, 10 of 13 FCO concrete cores, and 6 of 16 seismic lines have been completed.

The geologic characterization and coring undertaken in the upper chute to date, were summarized. The five borings described were drilled in areas where shears were located with the results that somewhat deeper weathering and poorer rock quality were encountered. [REDACTED]

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

[REDACTED] This has an impact on the necessary required removal volume and excavation depth in this local area. The BOC recommends that the amount of additional excavation required, and its effect on the schedule, be determined.

The exploratory borings that are being drilled to evaluate steep slopes on the left side of the FCO spillway are in progress. [REDACTED]

[REDACTED] it should be noted that this borehole is located along trend of some of the shears mapped in the deep scour hole. [REDACTED]

[REDACTED]  
[REDACTED]

[REDACTED] Also the effect of such features on slope stability should be evaluated.

Four cores of concrete and rock obtained from the floor of the FCO chute were described. [REDACTED]

[REDACTED]

[REDACTED] Locations of the aforementioned concrete borings were guided by targeting anomalous GPR (Ground Penetrating Radar) results and areas designated on the foundation cleanup maps as not well cleaned (reference Construction Geology Report C-38). [REDACTED]

[REDACTED]





The completed six seismic geophysical lines are just now being processed so no technical details were presented. Since the last meeting the line layout was expanded to include coverage of the emergency spillway, and specifically lines that parallel the weirs and the cutoff call. The BOC endorses these attempts to determine rock weathering depths along these alignments. Due to the “noise” interference that is created by the increasing use of onsite construction machinery and the upcoming spillway flow at the end of the week, it appears that the geophysical data obtained this week will be all that can be feasibly obtained before Construction Contract 2 is in full force. The BOC awaits the results of this program.

Inclinometers and piezometers (about 10 of each) installed in boreholes should be remotely accessible on Dashboard by later this week. A plan to install a piezometer underneath the FCO chute was described; however, since this only results in one instrument at one location and requires considerable expense and labor, the consensus was that the effort should not be pursued.

As this was a status report of ongoing field activities, the BOC awaits the completed results.

**5. Does the BOC have any recommendations or comments on the spillway design?**

*Response*

The BOC has the following comments on spillway design:

**Design Provisions for the Lower Chute**

The spillway chute design is in general, well done. Some design details are the same as those developed for the Folsom Auxiliary spillway, which operated for the first time during the same storm that led to the failure of the Oroville service spillway in February. It could be valuable to the design team to determine if any

lessons learned from the recent experience at the Folsom spillway in passing the February flood.

The designs developed have corrected a number of problems that were inherent in the original design. [REDACTED]

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

Historical photos and construction reports indicate that there were locations where the surface of the [REDACTED]

[REDACTED]  
[REDACTED]  
[REDACTED] Water methods should continue to be used as well.

The joint details, shown in DWRG S-403, as used on the Folsom Auxiliary spillway appear to be satisfactory.

[REDACTED]  
[REDACTED]  
[REDACTED] Proper attention is given to cleanout provisions for cleaning all lengths of the drain piping. All bends in the cleanout piping should be specified as “long-radius” bends in order to provide for ease in using the cleanouts. No drain piping should be installed without cleanout provisions.

The BOC recommends that, in the lower chute, where the new slab will be placed on RCC, [REDACTED]

### **Design Provisions for the Existing Upper Chute**

Since the lower chute is to be constructed first, the existing upper chute needs to be updated to provide confidence that it will provide satisfactory operation during the next rainy season. Part of the rehab considerations should be complete surface restoration of all surface defects. That will include patching of all holes and other surface defects. Patching of these holes should include dressing the holes to remove all loose material, painting the interior of the hole with epoxy to provide adequate bond, and then filling the hole with concrete. Proper dressing or grinding is then required to produce a smooth surface.

Addressing cracks is particularly important. All cracks should be chipped out and then filled with an epoxy grout. The finished patching should then be dressed to provide a smooth watertight surface.

### **RCC Design Details**

The reinforced concrete chute slab and training walls that will be placed on RCC surface at the lower spillway portion have somewhat different details than the slab and training walls placed on a rock foundation. It is intended that joints will be built in the RCC by the usual methods employed for dam construction. The RCC joints will be spaced to match the spacing of joints in the slab. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]



The BOC recommends that the RCC shoulders that were to be constructed to the height of the training walls for support of the reinforced concrete wall be omitted since it is now intended that the reinforced chute lining of the lower spillway section will be completed during the 2017 construction season. Therefore, the same training wall design, used where the chute lining is on rock foundation, can be used throughout the length of the lower chute. The RCC section can thereby be made somewhat smaller and there will be no transition sections needed for the wall design.

The RCC placement has assumed uniform side slopes at 1.0 H to 1.0 V with the slope being smoothed and compacted by tamping equipment during placement. The BOC agrees this is an acceptable solution and eliminates forming. On the right side of the upper erosion hole, suitable foundation rock has not been uncovered for properly founding the RCC toe. It appears that considerable excavation of overburden and highly weathered rock will be needed to expose suitable foundation. To avoid this excavation, the contractor may elect to form this side of the RCC vertically or on a steeper stepped slope. Precast concrete blocks have also been used as forms to construct steep slopes on some RCC construction.

A section of the RCC buttress designed for the Emergency Spillway weir blocks was shown during the presentation but the details were not discussed at this BOC meeting. The BOC endorses the use of a buttress to stabilize the weir blocks instead of anchors and believes the stepped downstream face of the RCC buttress will provide some energy dissipation to the overflowing discharge.

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

### Stabilization of Slopes

The design team presented results of field investigations to help characterize rock quality and strength in the vicinity of erosion holes next to the failed slab to aid in the design of slope stabilization measures to provide for safe access for placing mass and RCC in the erosion holes that will form the foundation for the lower spillway chute.

Both surface mapping and the results of core drilling provided rock weathering profile, discontinuities, and joint spacing that would help in performing kinematic and stability analyses of proposed slope inclinations.

Two design slope profiles (Slopes 1 and 2) were presented in the vicinity of the large, deep erosion hole to the left of the failed portion of spillway chute. Slope 1 was in the immediate vicinity and to the left (east) of the upper end of the break in the slab. Slope 2 was to the left (east) and downstream of the upper end of the spillway break. Slope 2 was above the deepest point of the scour hole. At this location, the height of the erosion scarp is about 140 feet. Proposed design inclinations for these two slope stabilization sections were 2H:1V and 1H:1V. Both Wedge sliding and Flexural toppling analyses were performed for the two slopes. Results of analyses for slope 1 indicate an inclination 2H:1V (1.7H:1V between benches) would provide for a stable slope. Similar results were presented for Slope 2.

Proposed approaches were presented for laying back these slopes to a safe inclination that included the following:

1. Full slope layback
2. Fill-in the hole with Concrete
3. Provide a high concrete buttress against the slope
4. A combination of partial slope layback and partial fill-in with concrete.

Drilling and blasting was presented as an option for excavating and laying back the slopes to the stable inclination and for avoiding the potential for debris falling into the hole.

It is the BOC's understanding that these assessments are ongoing, and will be improved as more field investigation data becomes available to refine properties of the rock that feed into the stability analyses.

[REDACTED]

The BOC also indicates that the stabilization of these two slopes at this location, as well as laying back the slopes on the right side of the spillway chute training wall on the opposite side of Slope 1, (because of the highly weathered and sheared nature of the rock formation at this location) may create challenges for the schedule of completing filling of these erosional holes to allow for timely completion of the lower chute section. Specifically, the BOC notes that the FCO spillway will begin flowing on Friday of this week (April 14) and, except for a one-week hiatus, will flow continuously until about June 1. During this time, access to the scour hole and slope will be unavailable. [REDACTED]

[REDACTED]

[REDACTED] to begin placing RCC in this area by the planned date of July 1. While this task appears to be doable, completing it in the time allowed appears to be challenging. The BOC encourages the development of other options to continue work to proceed while the FCO spillway flows occur.

## **BOC RECOMMENDATIONS SUMMARY**

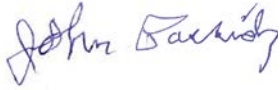
- The BOC recommends that efforts to investigate and stabilize the steep slope left of the big scour hole proceed so that stabilization efforts do not impact the start of RCC or cement-stabilization at the bottom of the scour hole that is scheduled to begin on July 1.
- The BOC suggests that consideration be given to allowing the Contractor the option of using vertically formed RCC walls in the deep scour hole, on both or just one side. On the right side its use could minimize the current extensive and deep excavation necessary to expose slightly weathered rock. On the left side, its use could minimize the need for personnel to work directly under the steep slope and could have an advantage on the construction schedule."
- The BOC endorses the sequence of construction now planned to finish the RCC and new concrete lining of the lower spillway portion during the 2017 construction season, and to construct the replacement chute on the upper section in 2018.
- The RCC aggregate production and the RCC mix strength testing are now turned over to the Contract 2 constructor. Results of this work are needed at an early date. The BOC would appreciate the opportunity to witness the RCC test pad placement.
- Demonstration of the Contractor's RCC placement means and methods will include construction of an RCC Test Pad. The BOC would wish to observe construction of the test placement.

[REDACTED]

[REDACTED]

- The BOC recommends that RCC shoulders for chute training walls be eliminated and the standard reinforced cantilevered training wall detail be used throughout the lower chute.
- The BOC endorses the use of an RCC buttress to strengthen the Emergency Spillway weir blocks and looks forward to further discussion on the design of this RCC buttress.
- The design details for the replacement chute and training walls have corrected problems that were inherent in the original design. The current design has much smaller and thicker concrete slab panels with increased reinforcement and anchorage, All joints have waterstops and a better underdrainage system is employed. Training walls designs are more robust and designed to meet seismic criteria. The BOC agrees that the design details are satisfactory for the replacement design.
- The existing upper chute condition needs to be further improved to provide assurance that it will provide satisfactory operation during the next rainy season. Rehabilitation measures should be taken to properly repair concrete spalls, seal cracks and joints and add anchorage.

Respectfully submitted,



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