Lake Oroville Spillways Emergency Recovery

Board of Consultants Memorandum No. 13 – October 20, 2017

Prepared by the Department of Water Resources

Summary & Response

Question 1

Question 1 relates to the construction schedule. The Board of Consultants (BOC) is acknowledging and commending the Design Team and Contractor for the remarkable progress made and schedule implemented to meet the November 1st deadline.

Question 2

The first part of question 2 relates to the secant wall which is being placed downstream of the emergency spillway and beneath the ground. The wall is being placed by first drilling large diameter holes, then filling the holes with concrete and steel in order to construct the wall beneath the ground. The discussion is in regards to exploratory borings which are small diameter holes drilled into the ground. These exploratory holes are investigated to understand and confirm that the wall will be placed to solid rock.

The second part refers to groundwater conditions around the chute spillway. Instrumentation including piezometers were previously installed around the chute spillway. Piezometers measure the water pressure under the ground. The groundwater will continue to be studied. The purpose of studying the groundwater, among other things, is to understand any potential future water pressures beneath the chute spillway.

The third part of question 2 refers to a sophisticated monitoring program that is being used to measure ground movements in and around the construction area. A slope inclinometer is an instrument that is drilled into the ground to help understand if rock slopes are moving. This instrument is used in conjunction with ground-based radar to understand all of the ground surface movement around the site.

Question 3

Question 3 relates to the Probable Maximum Flood (PMF) calculations currently being completed by DWR consultants. PMF calculations are performed around the country and the world to estimate extreme storms. The PMF is considered the maximum flood that could theoretically occur at a particular site. These extreme storms are usually reserved for very large dams that have large populations downstream. The results of the study are used to size spillways to ensure dams can safely pass these theoretical extreme storms without adversely affecting the dam structure.

Question 4

Question 4 relates to a reservoir operation plan for the 2017/2018 flood season. Multipurpose dams that have flood control as one of their purposes generally have operation requirements that dictate how the reservoir would be operated during major storms (Water Control Manual). The entire chute spillway could not be completely rebuilt in one flood season. Therefore, the chute spillway was designed to be able to safely release 100,000 cfs in the lower part of the chute without any damage. In order to meet this design requirement and limit flows below 100,000 cfs, an operation plan which includes maintaining the reservoir lower than normally required is being developed. This plan is designed to maintain flows less than 100,000 cfs even under the strongest storms that have historically occurred. The BOC has reviewed the plan and agrees and compliments DWR and their consultant for the work that has been completed.

Question 5

Self-Explanatory

Question 6

Question 6 is related to question 4 noted above. After reviewing all of the information and inspecting the resulting chute spillway, the BOC agrees that the RCC spillway will perform better than was even anticipated during original design. Although there is no intention to use the emergency spillway during the 2017/2018 season, the BOC recognizes that when completed the construction of the secant wall and RCC buttress will also probably exceed original design expectations.

OROVILLE EMERGENCY RECOVERY – SPILLWAYS
Board of Consultants Memorandum

DATE: October 20, 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. 13

INTRODUCTION

On Thursday October 19, 2017, the Independent Board of Consultants (BOC) met at the Department of Water Resources (DWR) Oroville Field Division Office Main Conference Room at 8:00 am for presentations made by DWR and their consultants for updates on the following:

- general construction progress;
- roller-compacted concrete (RCC) construction;
- geologic and groundwater investigations;
- Probable Maximum Flood (PMF) study; and
- the 2017-2018 Flood Season Operations Plan.

At 12:30 pm the BOC toured the dam site to observe construction progress. The following construction features were observed:

- repairs to the concrete slabs of the FCO Spillway chute between Stations 13+00 and 20+30;
- RCC and structural concrete placement within the FCO Spillway;
- construction of the FCO Spillway slabs,
- construction of the temporary FCO Spillway RCC gravity training walls including the shotcrete treatment for the inside face of the RCC walls;

- erection of the steel reinforcement and forms for segments of the permanent FCO Spillway training walls;
- construction of the upstream and downstream transitions between the conventional reinforced concrete FCO Spillway chute and the RCC FCO Spillway chute; and
- start of excavation at the northern portion of the Emergency Spillway RCC apron.

Representatives from the DWR Engineering Division, the Division of Safety of Dams (DSOD), the Federal Energy Regulatory Commission (FERC), and industry consultants working on the Oroville Spillway Recovery project attended the meeting and participated in the tour of the dam site.

Descriptions and comments made on the individual presentations are contained in the section that follows.

The BOC met on October 20, 2017 at 8:00 am to deliberate and prepare their report. A reading of the BOC's draft report was made to representatives from DWR Engineering Division, DSOD, FERC, and industry consultants working on the Oroville Spillway at 11:30 am. The meeting was adjourned at 12:00 noon.

BOC members present were Eric Kollgaard, John Egbert, Kerry Cato, Faiz Makdisi and Paul Schweiger.

QUESTIONS FOR THE BOC

1. **Does the BOC have any recommendations or comments on construction progress?**

   Response

   The Contractor has made remarkable progress since the last BOC meeting held on September 22, 2017, and is on schedule to complete construction of the required FCO Spillway features by the November 1, 2017 deadline. The critical construction work in the FCO Spillway chute including the RCC slab and walls, shotcrete for the RCC walls, the structural slabs and walls, and repairs to sections of the existing concrete slabs in the upper FCO spillway chute, is progressing at a rate equal to or exceeding the production rates required for timely completion. The structural wall concrete production increased significantly as the Contractor mobilized additional experienced crews from another project. The Contractor's onsite personnel has been increased to 750 full-time staff to meet the November 1st deadline.

The remaining RCC work includes constructing transitions at Stations 28+00 and 39+00, and final chute cleanup and placement of the RCC overlay with the enriched RCC mix (4,000 psi in 28 days). Subsequent to a 14-day water cure period, a surface hardener will be applied to selected areas of the RCC overlay.

The BOC commends the Design Team and the Contractor for this significant accomplishment. The degree of preplanning and scheduling directed by the Contractor and Design Team toward completing the work in the FCO Spillway is impressive and demonstrates the Contractor's and Design Team's commitment to completing the project on schedule.

2. Does the BOC have any recommendations or comments regarding the geology and groundwater monitoring update?

Response

The presentation covered more than site geology and groundwater. The BOC comments address all subjects presented.

1. **Secant Wall Installation**. The BOC was given an update on the secant pile cutoff wall installation at the Emergency Spillway. Along the axis of the cutoff wall, 6 additional geotechnical exploratory borings have been obtained, bringing the total along this alignment to 17 borings. The purpose of the borings is to obtain samples for determining rock strength and to confirm rock conditions at the planned secant pile tip depths. The rock testing work shows the difficulty in assessing rock strength in rock that has pervasive discontinuities. In the testing apparatus, the rock sample specimens were observed to routinely fail along discontinuities.

   The Contractor now has access to areas in the deep channel that were previously inaccessible due to the transmission lines. The Contractor's rate of secant pile installation is acceptable. It appears that the secant wall will be completed in late January, 2018.

2. **Groundwater Monitoring:** The BOC was given an update on the site groundwater conditions in the FCO area. Results from existing instruments were discussed in a presentation that included maps that showed groundwater surface contours. The groundwater surface appears to represent a subdued expression of the surface topography and shows that groundwater moves downslope toward the Feather River. A map showing locations of 15 new open pipe piezometers that are being installed near the FCO Spillway and onsite

borrow area was presented. These piezometers are being installed in areas near the FCO chute to gain a better understanding of how groundwater moves through the rock foundation. Being able to compare current baseline data readings with those when the FCO Spillway chute experiences flows is important. The BOC believes the current and planned monitoring program is prudent. Further, the BOC continues to interpret this rock foundation as being relatively tight in regard to groundwater flow interaction between surface flow and groundwater flow. Exceptions may exist in local areas where fractured rock or shears exist.

3. **Slope Monitoring and Radar:** The BOC was given an update on the current slope monitoring and the plan of using ground-based radar scanning to monitor surface movement. A slope inclinometer in the rock processing plant area shows minor slope movement (on the order of 0.5 inch). While this movement is minor, the rock processing plant is a critical component to RCC production. To enhance monitoring, a ground-based radar scanning unit will be installed to obtain real-time movements of the ground surface. Areas of interest to be monitored include the rock processing plant, the slopes of the new onsite borrow areas, and the slopes of the arena cut area on the right side of the FCO Spillway chute. The BOC endorses this monitoring plan and looks forward to future updates.

Figure 1. Photograph showing area of project site that will be monitored using radar.

3. Does the BOC have any recommendations or comments on the PMF update?

Response

Probable Maximum Flood (PMF) studies for Oroville Dam have been reviewed and revised several times since the dam was designed in 1965 due to enhanced understanding of atmospheric conditions that lead to the probable maximum precipitation (PMP), improved hydrometeorological monitoring, improved watershed rainfall-runoff-routing model capabilities, and changed atmospheric, hydrologic, hydraulic, or operational conditions. DWR, acting on the recommendation of the FERC Part 12 BOC, authorized their consultant to re-estimate the PMF in 2016, just before the spillway incident occurred. To support design of the restored spillways, work on the PMF estimation was accelerated. The procedure used to update the PMF along with the results of the updated PMF study, were presented to the BOC.

The procedure to update the PMF included:

1. developing an HEC-HMS model of the Feather River watershed above Lake Oroville;
2. calibrating the model to four historical events with snow accumulation and melt included in the analysis;
3. developing the final HEC-HMS model parameter set;
4. verifying the HEC-HMS model using a fifth storm event;
5. computing PMP depth using Hydrometeorological Report No. 59 (HMR 59) methods (NWS 1999);
6. developing 72-hour storms using the computed PMP and various historical and synthetic storm patterns;
7. developing antecedent snow conditions and air temperature boundary conditions to simulate snow accumulation and melt during the PMP storms;
8. configuring the HEC-HMS simulations using the calibrated and verified model, PMP boundary conditions, air temperature boundary conditions, and antecedent snow conditions described above;
9. simulating PMF runoff for each storm scenario and computing inflow to Lake Oroville;
10. routing each inflow hydrograph through Lake Oroville by simulating reservoir operations using an established HEC-ResSim model of the lake and dam;
11. reviewing results and adopting a PMF inflow hydrograph that results in the highest maximum reservoir pool elevation to use for continued design and analyses; and

12. computing wind-wave setup and run-up potential.

The adopted PMF inflow hydrograph has a peak of 743,800 cubic feet per second (cfs). Routing this flow through the reservoir using the recently updated outlet rating curves results in a maximum pool elevation within the existing freeboard of the dam, even when the reservoir routing is performed assuming a full pool El. of 901 feet at the start of the PMF event. Wind-wave setup and run-up potential was assessed as not being a significant factor during large winter storms such as the PMF.

The BOC believes the PMF update study is thorough and the level of detail is appropriate for a dam of such significance. The BOC is in agreement with the approach used to update the PMF and believes the findings of the study are reasonable and conservative. The BOC commends DWR's consultant for their effort and the quality of the analyses.

4. Does the BOC have any recommendations or comments on the 2017/18 Flood Season Operation Plan?

Response

The proposed plan outlines operations from November 1, 2017 through April 30, 2018 that limit the interim preferred FCO spillway design release to 100,000 cfs while ensuring downstream flood protection meets the existing US Army Corps of Engineers (USACE) flood control requirements set forth in the 1970 water control manual (WCM) for Lake Oroville. The Plan provides a strategy that guides operations through approximately 99.5% of anticipated hydrology and an emergency contingency plan that guides operations for rare flood events. The primary objectives of the plan include:

1. providing equal or greater flood protection for the downstream entities;
2. safely passing the standard project flood (SPF) from the 1970 USACE WCM developed for Oroville Dam and Reservoir without activating the Emergency Spillway;
3. avoiding gated FCO releases greater than the interim preferred design outflow objective of 100,000 cfs; and
4. not increasing the frequency at which critical pool elevations, releases or downstream flow levels are exceeded; and

5. operating Lake Oroville to accommodate an early start to the 2018 construction season.

Using a detailed iterative modeling approach, an interim flood management pool volume of 1.35 million acre-feet was selected that corresponds to an enhanced flood pool target of 800.0 feet for the months of November 2017 through March 2018. This elevation provides an additional 48.5 feet of vacant flood control storage – adding about 600,000 acre-feet to the current required 750,000 acre-feet of total flood control storage for that period.

The proposed operations strategy was tested using 59 historical ensemble traces for the operating period of October 5, 2017 through April 30, 2018, following the Plan Operations Strategy with satisfactory outcomes.

The BOC understands that the outflows detailed in the Operations Plan do not exceed the following downstream flow rates established in the 1970 Water Control Manual:

- maximum target flow at Marysville and Yuba City of 180,000 cfs;
- maximum target flow at confluence of the Feather River and Yuba Rivers of 300,000 cfs; and
- maximum target flow at Nicolaus, just downstream of the confluence of the Feather River and Bear Rivers, of 320,000 cfs.

The BOC recognizes that significant effort and careful deliberation went into developing the proposed interim Flood Season Operation Plan. The BOC believes the plan will meet the primary objectives, maintain dam safety, and provide the required flood control benefits for the period of November 2017 to May 2018. The BOC compliments DWR and their consultant for developing a thoughtful plan that demonstrates their commitment to public safety.

5. Does the BOC have any recommendations or comments on the site visit?

Response

1. During the site tour, the BOC observed the following:
    a. repair of reinforced concrete FCO upper chute slabs;
    b. placement of RCC;
    c. erection of steel reinforcement for spillway walls and slabs;
    d. placement of conventional concrete for walls and slabs;

e. installation of the shotcrete lining on RCC gravity training walls; and
f. start of excavation at the northern portion of the Emergency Spillway RCC apron.

The BOC took note of the intense effort under way on the structural concrete slab transitions at Station 20+00 and Station 39+00 along with the 8 transitions in the structural concrete walls.

The aforementioned work observed by the BOC appeared to be in conformance with the specifications and of high quality. Select photographs of observed work are provided in Figures 2, 3, 4 and 5.

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

Response

As stated in Appendix F, Extreme Hydrology Contingency Planning for the Lake Oroville 2017/2018 Flood Control Season Operations Plan, a storm event with a 0.2% to 0.5% chance of occurring could potentially trigger an outflow exceeding the interim FCO Spillway design capacity of 100,000 cfs. The BOC agrees with the Design Team's assessment that the partially reconstructed FCO spillway, including the 1,100-foot-long RCC chute, can physically pass an outflow of 150,000 cfs. Conceivably, a 0.2% probability extreme hydrological event could require use of the emergency spillway to avoid flows greater than 150,000 cfs through the FCO Spillway.

Mitigation measures are underway to allow safe operation of the Emergency Spillway for flows up to 30,000 cfs in the interim period. The BOC agrees that the construction of the secant pile cutoff wall together with the RCC buttressing of the emergency spillway weir and slope paving downstream adequately protects the integrity of the Emergency Spillway against flows up to the selected interim discharge of 30,000 cfs, and probably much greater. The BOC understands the DWR will be conducting an assessment of the conveyance of the Emergency Spillway flows downstream of the secant pile cutoff wall to the Feather River, and in particular estimating the anticipated extent of erosion of the overburden and weathered rock material within this zone due to various flood events up to the PMF. The BOC looks forward to reviewing this assessment and learning if actions are needed to mitigate this potential for erosion.

Figure 2. Photograph from the upper FCO Spillway looking downstream. Replacement of the permanent FCO structural concrete walls and chute slab is about complete with all of the floor slabs and all but 8 of the wall sections installed.

Figure 3. Photograph showing remaining section of the FCO chute to be infilled with RCC (shown at the left) of the main scour hole with the permanent portion of the FCO structural portion shown on the right.

Figure 4. Photograph looking upstream in the FCO Spillway chute at the transition from the permanent structural concrete chute walls and floor slabs (foreground) to the completed RCC sections. The RCC was placed in the areas of the two big scour holes; the RCC filling of the upper scour hole is shown in Figure 3.

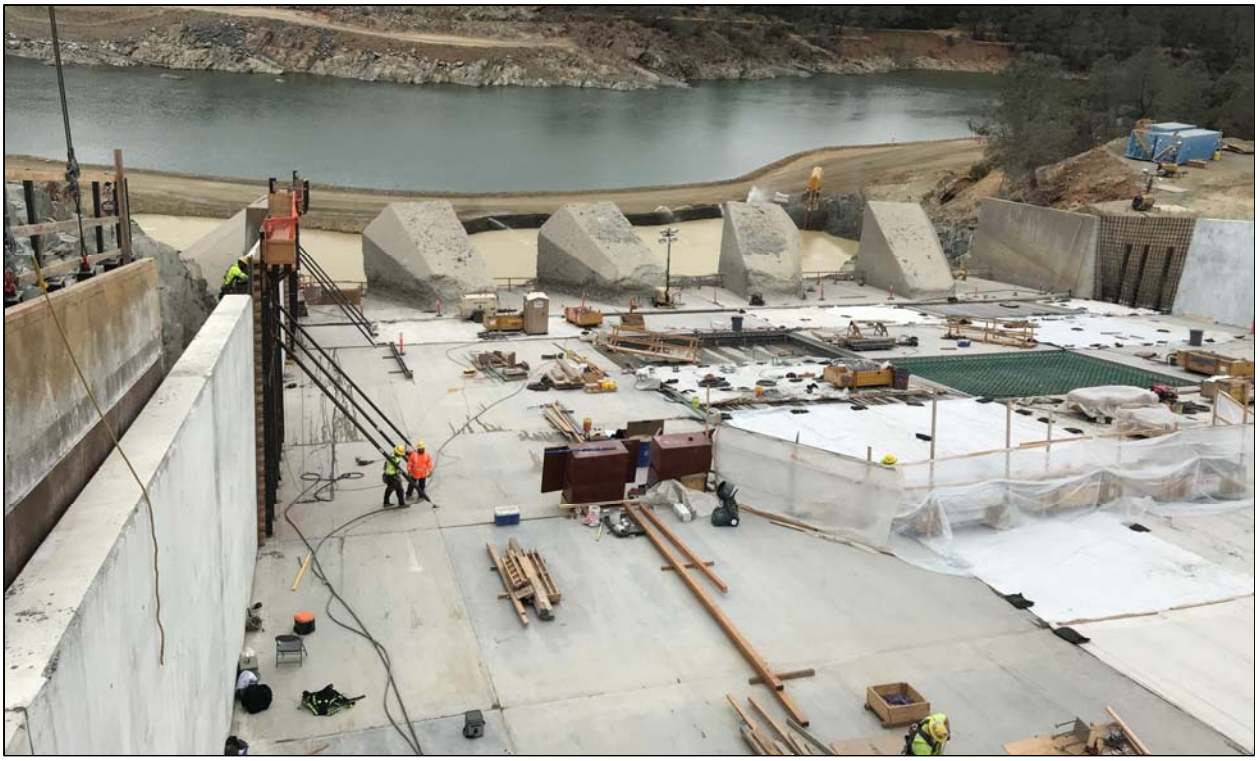

Figure 5. Photograph showing the two concrete slabs that remain to be completed in the replaced lower section of the FCO chute spillway.

BOC RECOMMENDATIONS SUMMARY

The BOC had no recommendations.

Respectfully submitted,

Eric B. Kollgaard **Faiz Makdisi** **Kerry Cato**

John Egbert **Paul Schweiger**