OROVILLE EMERGENCY RECOVERY – SPILLWAYS
Board of Consultants Memorandum

DATE: July 17, 2018

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

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

SUBJECT: Memorandum No. 19

INTRODUCTION

On Monday July 16, 2018, 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 the Department of Water Resources (DWR) and their consultants for updates on construction progress and tracking of future work.

At 9:00 am, the BOC, representatives from the DWR Division of Engineering, the Division of Safety of Dams (DSOD), the Federal Energy Regulatory Commission (FERC), DWR Division of Operations and Maintenance, and industry consultants working on the Oroville Spillway Recovery project toured the FCO Spillway Chute, the FCO dentates, and the Emergency Spillway area to observe construction progress. The following construction features were observed:

1. Foundation preparation of the upper section of the FCO spillway (see Figure 1);
2. The completed reconstruction of the surface of concrete chute slab (28E) near Sta. 21+00;
3. Placement of chute slabs in the middle section of the FCO chute (see Figure 2);
4. Surface preparation of the FCO dentates (see Figure 3, top photo); and
5. Excavation and foundation preparation for the RCC apron on the left side of the Emergency Spillway (Phase 2).

At 12:30 pm, the BOC returned to the Oroville Field Division Office Main Conference Room for additional updates on the:

1. Geologic investigations and mapping for the left RCC emergency spillway apron foundation, and the foundation for the FCO's upper chute;

2. Summary of Emergency Spillway Design Revision No. 8 to plans and specifications including drainage details for RCC aprons, monoliths and buttresses;
3. FCO Design, Revision No. 9 to plans and specifications including FCO chute longitudinal drains, exterior wall drains and backfill, minor modifications to wall footings to fit within existing rock-cut chute, and provisions for instrumentation for cavitation and aeration.

On Tuesday July 17, 2018 at 8:00 am, the BOC met at the Oroville Field Division Office Main Conference Room to deliberate and prepare their report. Descriptions and comments made on the individual presentations and the BOC's responses to the DWR questions are included in this report.

A reading of the BOC's draft report was made to representatives from DWR Engineering Division, DSOD, FERC, DWR Division of Operations and Maintenance, and industry consultants working on the Oroville Spillway at 12:00 pm. The meeting was adjourned following the reading of the report. BOC members present were Eric Kollgaard, John Egbert, Kerry Cato and Paul Schweiger.

QUESTIONS FOR THE BOC

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

   Response:

   Substantial progress has been made since the last BOC visit to the site on May 29, 2018. Notable construction milestones include:

   1. Completed demolition and most of the foundation cleaning for the upper section of the FCO spillway chute;
   2. Placed drain forms for most of the transverse drains in the upper section of the FCO chute;
   3. Drilled, grouted, and tested the slab anchors in the middle section of the FCO chute;
   4. Placed 24 slab monoliths, 24 wall footing monoliths, and 3 wall monoliths in the middle section of the FCO chute;
   5. Completed ~60 percent of the surface preparation work for rehabilitating the FCO dentates;
   6. Completed most of the foundation preparation for the remaining Emergency Spillway RCC apron;

7. Stockpiled imported fine aggregate for RCC; and
8. Began RCC placement for Phase 2 of the RCC apron.

Select photographs of construction work observed by the BOC are presented on Figures 1, 2 and 3.

Comparing the completed work with the construction schedule shows that the project is ahead of schedule. The BOC was pleased to learn that the RCC placement for Phases 2 and 3 of the Emergency Spillway apron is on track to be completed by November 1, approximately one month ahead of schedule. This will avoid potential delays due to wet weather that can occur as the wet season begins.

The BOC was pleased to see the new concrete slab moist curing method being employed in the middle FCO chute. This method is an improvement over the previous conventional moist curing approach. This, along with the new system used to screed the slabs, will help provide a durable long-term concrete surface. The completed RCC apron for Phase 1 of the Emergency Spillway appears to be of excellent quality. The finish on the exposed RCC stepped surface is exceptional.

As noted above, the major work items for 2018 are ahead of schedule. The Contractor's production rates are based on actual experience from the 2017 construction season. For example, FCO chute slab placements for 2018 are scheduled at 30 slabs per week (the maximum 8-week average), the same as the 2017 actual production. Likewise, FCO wall placements are scheduled at 11 walls per week (the maximum 6-week average) again matching the actual production rate achieved in 2017.

RCC production for the Emergency Spillway Phase 1 work averaged slightly more than 4,700 cubic yards per day (approximately 300,000 cubic yards total). Peak RCC productions in the FCO Chute during 2017 often exceeded 5,000 cubic yards per day. The 2018 production rate has been somewhat limited due the Contractor's onsite production of sand for the RCC mix. That situation was remedied by importing sand. The contractor should now be able to increase daily production to rates achieved in 2017, and complete Phases 2 and 3 RCC placement in the Emergency Spillway by November 1, 2018.

The BOC understands that the quantity of RCC required for Phases 2 and 3 of the Emergency Spillway is in the range of 350,000 to 375,000 cubic yards. The BOC recommends that the Design Team continue to update the RCC volume required for Emergency Spillway, Phases 2 and 3, as excavation to suitable foundation proceeds and geological investigations reveal the need for additional excavation.

Figure 1. Photos of the foundation preparation at the upper section of the FCO chute.

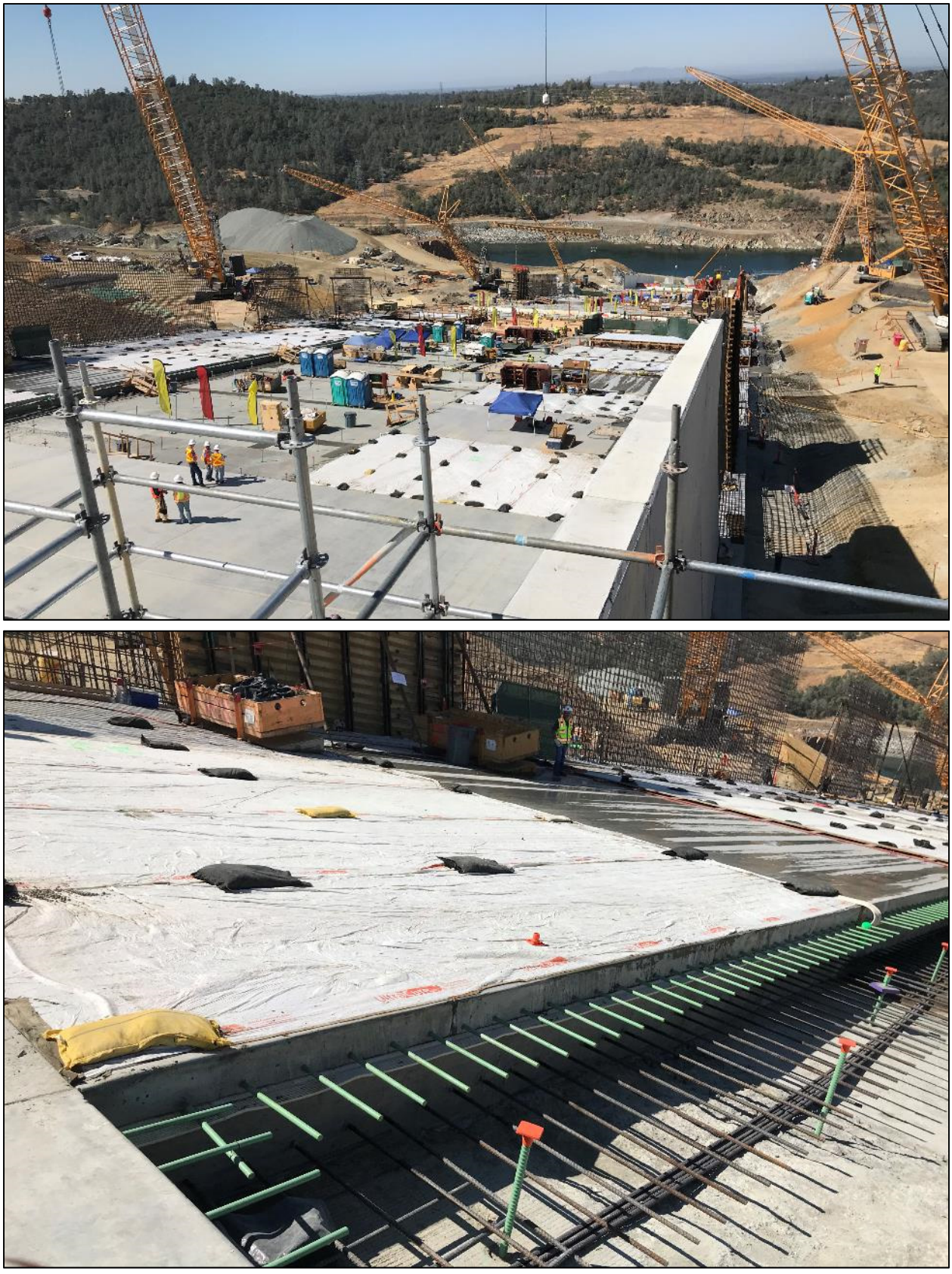

Figure 2. Photos showing slab construction at lower section of FCO chute.

Figure 3. Photos showing FCO dentates and left side of Emergency Spillway RCC foundation preparation.

2. *Does the BOC have any recommendations or comments on the geology update?*

Response:

A presentation was made to the BOC regarding geologic assessment of the spillway foundations. The presentation included geologic mapping of the uppermost FCO chute foundation, the area of the Emergency Spillway buttress and apron foundation downstream of the overflow monoliths; and a discussion on drainage mitigation in this same area of the Emergency Spillway. A Technical Memorandum regarding additional monitoring wells in the emergency spillway was submitted for review.

Bedrock conditions in the upper FCO spillway show an overall slightly weathered to fresh rock surface. This is not surprising as this area of the chute was created by excavating more than 60 feet deep in a bedrock ridge composed of amphibolite. As observed throughout the FCO foundation, local weathering at depth tends to be controlled by the presence of continuous bedrock shears. In these areas, the bedrock is more easily excavated and results in greater thicknesses of backfill concrete and longer slab anchors. The BOC observed one such area in the right side of the FCO spillway near Station 20+00 (see Figure 4). The BOC was pleased with the effort being made to prepare and treat the deeper shear and weathered zones within the upper FCO chute and with the quality of the bedrock foundation.

Figure 4. Example of local more highly-weathered zone (between green paint lines) in FCO bedrock foundation.

The BOC is pleased with the thoroughness of the geologic mapping for the FCO chute and the Emergency Spillway apron. This type of documentation is important for future evaluation of spillway performance.

A revision to Technical Memorandum (SRT-ORO-GO-12F Revision 1) was prepared to describe additional planned monitoring wells in the Emergency Spillway area. It describes the location and specifications for ten new exploratory borings. These borings were placed: to replace observation wells removed due to construction activities; to obtain new data in areas where groundwater seeps have appeared after excavation lowered the rock surface; or to obtain thickness data in areas of significant fill placement. The total number of borings and/or monitoring wells in the Emergency Spillway area is about sixty.

3. Does the BOC have any recommendations or comments on FCO design revisions 8 and 9?

Response:

Design Revision No. 8 was previously presented to the BOC and a reference copy was distributed at this meeting. The BOC was provided Design Revision No. 9 Plans for the FCO chute and an unsigned copy of Design Revision No. 9 Plans for the Emergency Spillway both of which includes a general Drawing Document update covering minor revisions and additions included in the 2018 construction work. Presentations were made to the BOC and these revisions and included the following:

1. The location and details of the vertical drains for the Emergency Spillway RCC apron.
2. The general configuration of the Phase 2 Emergency Spillway RCC apron and the drain collector piping through the secant pile cutoff wall.
3. The layout and details of the drain connections to the existing Emergency Spillway monolith drains and collector drains beneath the added RCC buttresses feeding to outflow pipes exiting through the RCC apron.
4. The configuration of the pervious drain rock around the backfill drain piping around the FCO wall footings was changed to improve constructability. It was discussed that the narrow area between the wall and the existing excavated rock slope does not provide sufficient space for the standard footing design and drain lines as presently depicted on the drawings. Because of the difficulty of trying to steepen this rock slope, and the impacts it would have on the

construction schedule, adjustments were made to the wall footing and placement of the drain pipes.

5. Assorted minor details for the location and cable runs for permanent FCO piezometer installations.
6. Provision of instrumentation monitoring facilities for anticipated future hydraulic measurement of flow and aeration in the FCO chute is included. [redacted]

The BOC appreciates being updated regarding the design revisions and understands that additional details are pending. The BOC generally concurs with the designs revisions that are being made.

4. Does the BOC have any other recommendations or comments on the Emergency Spillway design revisions?

Response:

1. Emergency Spillway Modifications.

As the reconstruction of the FCO nears completion, and full design service capability has been achieved, the question remains whether the Emergency Spillway has reached a comparable level of serviceability. The BOC believes that, with the completion of the secant cutoff wall, the crest cutoff wall, the RCC buttresses for the overflow weir monoliths, and the RCC apron, the Emergency Spillway will provide adequate protection against downstream erosion breaching at this portion of the dam during overflow discharges. In effect, the design and construction provisions of the Emergency Spillway enacted will have ensured the safety of this portion of the dam structure.

While the functionality of the Emergency Spillway to protect the dam is not in question, there may remain a public perception after completion of the current construction, that the spillways of the Project have not been fully restored. In the public's view, the fact that the area below the secant pile cutoff is left in its more or less natural state could give the erroneous impression that this is not an adequate or serviceable spillway.

The BOC believes the Emergency Spillway can be made serviceable to accommodate flood flows necessary to safely pass the PMF. Such an occurrence

would truly be an emergency, and the Emergency Spillway with the fully serviceable FCO can fulfill the objective of protecting the dam embankments from overtopping and the uncontrolled release of the reservoir.

To be fully functional as a serviceable spillway, the BOC believes the reach of the discharge channel carrying flow from the Emergency Spillway secant cutoff wall down to the river channel should be addressed. The minimum improvement measures recommended by the BOC include clearing trees and brush from the flow path and excavating (straightening and adjusting) a pilot channel to the Diversion Pool. This pilot channel is not envisioned as completely containing the discharge or limiting the inevitable erosion of overburden and weaker bedrock that will result from activation of the Emergency Spillway. The main purpose of the improvements would be to control the direction of flow and prevent uncontrolled erosion and flow direction deviation due to resistant rock ridges which could deflect discharge in an unfavorable direction, such as towards the FCO chute. Selective use of rock blasting, dental concrete, and RCC may be needed to shape the pilot channel and fill weathered shear zones.

To have a basis for design of the downstream channel improvements, it would be helpful to have a better understanding of the nature of flood flow discharges over the Emergency Spillway (i.e. the concentrations of flow over the varied apron surface and the direction and velocities of the major discharge streams). It appears that two major concentrations are likely, and that these join some distance downstream of the secant cutoff wall. To determine the behavior of flow over the Emergency Spillway, an updated two- or three-dimensional numerical hydraulic model study is recommended. The hydraulic model should include the spillway approach conditions from the reservoir into to the FCO and Emergency Spillways, and extend to the Diversion Pool. The model simulations should include concurrent flow from both the FCO and the Emergency Spillway for discharges up to the PMF.

The BOC is aware that studies of future needs of the Oroville Project are underway and that these studies may include consideration of a possible second service spillway. Since the BOC believes that the present Emergency Spillway can be made fully functional to pass floods, the BOC believes that replacement of the present Emergency Spillway should not be a sole reason for a second service spillway, but operational considerations might form a better rational as a basis for that need.

A final thought on the completion of the Emergency Spillway is that the BOC would prefer that the current erodible service road on the RCC apron of the Emergency

Spillway be located outside the footprint of the Emergency Spillway. If the service road remains within the footprint of the Emergency Spillway, the BOC recommends that it be incorporated into the RCC spillway apron as a permanent non-erodible feature.

2. Contraction Joints in Emergency Spillway RCC Buttress.

The BOC understands that the transverse joints in the Emergency Spillway weir monoliths (termed longitudinal control joint on Drawing S-708.1) will only be installed in the ERC buttress caps and not carried through the added RCC portion of the buttress below. Since the buttress RCC is dowelled to the concrete monoliths and is expected to have some degree of bonding, it is preferred that the location of the transverse crack, which will inevitably occur in the RCC portion of the buttress, be controlled. The BOC recommends that the usual means for inducing a joint in RCC by insertion of metal dividers be applied to the buttress RCC at the transverse joints matching the monolith joints. This will avoid stressing the bond between the RCC buttress and the concrete monolith. The downstream end of the joint provision is somewhat arbitrary since it would not be carried into the apron. Possibly some local reinforcement bars should be placed in the layers of RCC at the joint ends as potential crack inhibitors.

Note: Following the reading of this report, the BOC was informed that it is the Design Team's intent to extend the contraction joints through the RCC buttress as recommended. This detail will be shown on the drawings.

3. Drilled Drains in Emergency Spillway RCC Apron.

The BOC endorses the addition of vertical drains drilled in areas of groundwater seeps. While the BOC is confident that the thickness of RCC apron in these areas will resist any potential uplift pressures, providing a method to relieve these potential pressures is appropriate. These include the currently unfilled areas on the left half of the Emergency Spillway, the nine targeted vertical drains in area of fresh rock on the far-right upstream side, as well as the sixty drains placed using interval-spacing across the downstream slope of the apron.

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

Response:

1. FCO Wall Backfill. The BOC understands that a grading plan for site restoration and landscaping is being prepared. The BOC looks forward to seeing

this plan to clarify how the FCO wall backfill will be placed in the portions of the spillway length where there are no rock slopes along the outside of the chute walls to confine the fill. These reaches are primarily in the RCC foundation placement portion of the FCO.

2. Documentation of Geologic Conditions. The BOC was informed that preparation of a Geologic Data Report is in progress and that it will be lengthy (i.e., several thousand pages). The report will be followed by a Project Geology Report (or reports), late in 2019. The BOC understands the rationale of first compiling the data and then performing more documentation and analysis. The BOC encourages the Design Team to prepare interim reports, or pieces of the report, based on what is known or can be developed in the interim. Such an approach could help address perplexing questions that could benefit the ongoing design and construction work. Examples of issues to report on include, but are not limited to:

1. How does the geologic data support or refute the concept of groundwater flow interconnectivity of the reservoir hydrology with the discontinuities in the downstream areas?

2. What do the geologic data indicate about future possible scour downstream of the secant wall in the eventuality that emergency spillway flows occur?

While presentations made to the BOC have touched on these issues, and other, topics, the BOC believes it is important to document these issues using the voluminous geologic data that has been collected to address engineering geologic issues important to this project.

3. *Backfilling Deep Erosion Features in the Emergency Spillway Using Concrete and RCC.* Presentations on the preparation and backfill of the large erosional channels created during the February 2017 Emergency Spillway flows was discussed in both the Geologic and Geotechnical Engineering presentations. The BOC appreciated the thoughtful and detailed analyses that appropriately incorporates the knowledge of three-dimensional rock weathering variation, discontinuity effect on this weathering, and how excavation and backfill operations use this information to produce a plan for backfill. The BOC believes that the ultimate rock surface being obtained for the RCC apron will provide a surface that meets design intents. In a few areas, very steep, almost vertical slopes were produced by the erosion event (see Figure 5).

Attempting to layback the slopes is unnecessary and the BOC endorses the backfill concepts discussed that use a combination of backfill concrete and RCC. The precedent for this approach was well established for the FCO spillway.

Figure 5. Erosional channel in Emergency Spillway apron foundation that will be filled with backfill and RCC concrete

BOC RECOMMENDATIONS SUMMARY

M19-1 The BOC recommends that the Design Team continue to update the RCC volume required for Emergency Spillway, Phases 2 and 3, as excavation to suitable foundation proceeds and geological investigations reveal the need for possible additional excavation.

M19-2 To be fully functional as a serviceable spillway, the BOC recommends that the reach of the discharge channel carrying flow from the Emergency Spillway secant cutoff wall down to the river channel be addressed. The minimum improvement measures recommended by the BOC include clearing trees and brush from the flow path and excavating (straightening and adjusting) a pilot channel to the Diversion Pool.

M19-2 The BOC prefers that the current erodible service road on the RCC apron of the Emergency Spillway be located outside the footprint of the Emergency Spillway. If the service road remains within the footprint of the Emergency Spillway, the BOC recommends that it be incorporated into the RCC spillway apron as a permanent non-erodible feature.

Respectfully submitted,

Eric B. Kollgaard	Absent **Faiz Makdisi**	**Kerry Cato**
John Egbert	**Paul Schweiger**	