Lake Oroville Spillways Emergency Recovery

Board of Consultants Memorandum No. 3 – March 31, 2017

Prepared by the California Department of Water Resources

Summary & Response

Question 1

The BOC response for Question 1 continues the discussion from BOC Memorandum No. 2 regarding the ongoing exploration. The BOC describes the exploration program and resulting findings as they were described to them by DWR. Seismic geophysical lines are part of the exploration program which provides engineers and geologist insight into the quality of the foundation rock. Preliminary geologic information described by the BOC will eventually be used in the design of the new features, in addition to help with construction procedures.

Question 2

The BOC response for Question 2 continues the discussion from the BOC Memorandum No. 2 regarding the design criteria. DWR proposed a maximum flow criteria of 270,000 cubic feet per second (cfs) for the upper chute of the gated spillway, which is significantly higher than the record flow.

Complete repair of the emergency spillway is not anticipated by November 1, 2017. However, work will continue on the emergency spillway to ensure it can safely pass the original design flow criteria by November 1. It should be noted that the emergency spillway design flow of 371,000 cfs is in addition to the capacity of the gated spillway. The priority is to complete the work on the gated spillway.

The BOC describes the Probabilistic Seismic Hazard Analysis, MCE (Maximum Credible Earthquake) and other earthquake parameters as they were described to them by DWR. These terms which refer to the level of design for the potential earthquake loads that will be used to design the various concrete structures. The BOC considers the earthquake parameters proposed by DWR reasonable and appropriate.

Question 3

Responses to Question 3 are consistent with comments made by the BOC and in most cases, are a repeat of what has already been documented in Memorandum No. 2.

DWR is proposing to completely reconstruct the lower chute area. However, the BOC notes the all work may not be completed by November 1, 2017, and therefore describes various techniques that can be used as back-up plans. Many of these techniques will depend on the amount of work that can be completed by November 1. If the entire gated spillway chute cannot be completed by November 1, the end of the gated spillway chute where damage occurred will be buttressed with concrete the spillway can be used. There are other intermediate steps that can be taken depending on the progress of the work. In all cases, the spillway will be able to be used for all expected flows by November 1, 2017.

Question 4

Self-Explanatory

Question 5

Question 5 relates to many construction methods and details that could be considered to complete the project in a timely manner.

Question 6

Naturally occurring asbestos is present in various parts of the state, and is monitored on many large earth-moving projects. DWR continues to monitor air quality to ensure that it is safe for workers and nearby residents. The BOC recommends continued air quality monitoring.

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OROVILLE EMERGENCY RECOVERY – SPILLWAYS
Board of Consultants Memorandum

DATE: Friday, 3/31/2017

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. 3

INTRODUCTION

On March 30, 2017, the Independent Board of Consultants (BOC) met at offices of the California State Department of Water Resources (DWR) at 1:00 pm 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 presentations continued on March 31st and the meeting ended with a reading of the BOC's report at 4:15 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 lists.

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 the field exploration program?

Response

The field exploration program, tasked with providing geological and geotechnical information to support the Oroville spillway mitigation, is ongoing with exploratory boreholes still being drilled in the areas of the Flood Control Outlet (FCO) spillway chute (aka – Gated Spillway) and above the slope left of the FCO Chute. The seismic geophysical lines were planned to begin this week. Detailed

comments regarding the FCO spillway, left slope above the FCO Chute, and Emergency Spillway are listed below.

FCO Chute spillway: The presentation discussed findings of the concrete coring in the chute floor that is investigating the rock/concrete interface. While preliminary, since the drilling is not yet completed, this is important information that may shed light on the piping potential of material the concrete was placed upon. Initial drill coring results show slab thickness varying from 2.0 to 3.2 ft. It should not be inferred that this thickness is indicative of the entire slab thickness. Analysis of historical construction photographs continue to show that the concrete slab was placed on a variety of materials that ranged from clean, hard, bedrock to highly weathered rock that appeared soil-like. These borings are being drilled to depths of 15 to 30 feet to determine the depth to fresh rock and, hence, the required depth of the new anchor embedment.

Left slope above the FCO Chute: Exploratory borings are being drilled on top of the unstable slope on the left of the FCO Chute. These 100-ft-deep-borings are for determining depth of soil, and rock weathering zones that will be used in stabilizing this slope. These borings will be converted into monitoring wells and inclinometers. This slope must be stabilized before work to mitigate the scour hole can commence.

Emergency Spillway: Field investigations for the Emergency Spillway have yet to be completed; only the seismic geophysics is in progress. However, the identification of a preferred mitigation alternative (i.e., downstream cutoff wall, RCC buttress, and RCC splash pad) was discussed and this may impact the future field investigations. Even though anchors drilled through the ogee monoliths may not be pursued, it is still prudent to obtain geotechnical information about the weir's foundation conditions; and, although the RCC foundation is planned to be taken to the same depth, the adequacy of this foundation must nonetheless be verified.

The northern 800+feet of the Emergency Spillway approach and weir foundation were created by excavating a 50-ft-high bedrock hill. Thus, some of the exposed ground surface in this area is on rock that varies in its weathering [redacted] If the DWR recommended design option moves forward then knowledge of rock weathering depths all along the weir and cutoff wall alignment should be determined in advance of finalizing the design.

If the seismic geophysical lines prove useful in determining rock weathering depths, then consideration should be given to extending geophysics to provide coverage to the northern 800 feet of the Emergency Spillway and also to provide some information on weathering depth downstream of the cutoff wall.

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

Response

In its previous two reports, the BOC provided comments and recommendations on draft copies of the Design Criteria Memoranda. The BOC has reviewed the revised drafts (dated March 20 and 27, 2017) and generally concurs with the revised documents as addressing earlier comments provided by the BOC.

In summary, the BOC understands that the design objectives for the "Oroville Emergency Recovery – Spillways" Project are: a) for the "Interim Repairs" to allow the Flood Control Outlet (Gated Spillway) chute to pass a peak routed outflow of 270,000 cfs based on the anticipated first year hydrologic criteria; and b) the long-term repairs are to allow the chute to pass its portion of the Probable Maximum Flood (PMF) peak outflow of 300,000 cfs.

The Emergency Spillway's "Interim Repairs" are designed to allow the spillway to pass peak flows of 30,000 cfs, with a peak reservoir elevation overtopping the spillway weir crest by about 3.3 feet. The long-term repairs are designed to allow the Emergency Spillway to pass peak a PMF flow of 371,000 cfs.

The BOC concurs with the Project's flood design criteria, but notes that while the FCO spillway chute can be designed to pass its portion of the extremely rare PMF flows, the Emergency Spillway repairs may not be capable of passing a 16-foot-overtopping and a peak flow of 371,000 cfs without significant erosion damage downstream.

The structural design criteria Memo indicates that: "Interim repairs will be designed based on a Probabilistic Seismic Hazard Analysis (PSHA) with a 144-year return period. Permanent restoration structural features will be designed to the Median (50^{th} percentile) MCE with a maximum water surface elevation of 901 feet. The targeted seismic structural performance criteria will be essentially linear elastic structural behavior; no instabilities, minimal cracking, and no permanent deformations.

The BOC considers these criteria to be reasonable and appropriate.

Deterministic ground motions at the dam site, as reported in the Supporting Technical Information Document (STID), were estimated at the 50th percentile level from a magnitude 6.5 earthquake on the Cleveland Hills fault. The peak ground acceleration (PGA) was estimated at 0.57g. The Cleveland Hills fault is reported to have a low slip rate of about 0.05 mm per year. The Division of Safety of Dams (DSOD) provides a "Consequence Hazard Matrix" that uses the consequence of dam failure and probability of earthquake hazard (described by the slip rate on the controlling seismic source) to select the appropriate statistical level for deterministic ground motions. The Consequence Level for a dam is defined by the Total Class Weigh (TCW), which is a function of the dam height, the reservoir capacity, and the downstream consequences of failure. The TCW for Oroville Dam is 36, which classifies it as "Extreme Consequence." According to DSOD's Consequence Hazard Matrix, for an "Extreme Consequence" dam and a seismic source with a low slip rate of less than 0.1 mm per year, ground motions should be selected between the median (50th percentile) and 84th percentile levels. The choice of what statistical level to use is guided by the results of probabilistic seismic hazard analyses (PSHA). To guide this selection, the USGS hazard maps from the 2014 National Seismic Hazard Mapping (NSHM) Project were queried for the Oroville Dam site, with a site Vs_{-30} (the shear wave velocity in the upper 30 meters of rock foundation underlying the dam) of about 1,200 meters per second. It should be noted that the actual Vs_{-30} of the foundation rock underlying the dam, based on recently measured velocities is about 2,400 meters per second. The value of 1,200 meters per second used to query the USGS hazard curves was because the ground motion prediction equations (NGA West-2) used in the hazard analyses all have a maximum limit of 1,200 meters per second for Vs_{-30}. According to the USGS 2014 NSHM, the median PGA of 0.57g from the Cleveland Hills fault has a return period of greater than 10,000 years. Thus the BOC judges that selection of the median level of ground motions for the long-term design of repair measures that are related to dam safety is considered reasonably conservative and appropriate.

The BOC considers the geologic and geotechnical criteria for the appropriate excavation and preparation of foundations for the various project features to be reasonable and appropriate.

The BOC considers the use of a 28-day concrete strength of 5,000 psi, and reinforcing steel f_y of 60,000 psi to be appropriate. The use of rock anchors and dowels with PTI Class I corrosion protection for all permanent features is considered a requirement.

3. Does the BOC have any recommendations or comments on the Alternatives Analysis or selection?

Response

FCO Upper Chute: The BOC concurs with DWR's recommendation to remove and replace the FCO's upper portion of the chute and training walls. It is, however, doubtful that the entire length of upper chute all the way to Sta. 28+00 can be replaced in the first construction season, and therefore the portion that is not replaced must be strengthened as necessary to serve through the first winter flood season. Construction contract package 2 should have language specifying a minimum length to be completed and stating that this must be located at the start of the chute immediately downstream of the FCO structure. Provisions to prevent the demolition of the existing concrete chute from getting too far ahead of the concrete placement should be added. It is vital that a continuous concrete replacement chute in this upper portion of the spillway be completed and available at the start of the flood season.

It was pointed out that it will be necessary to protect the downstream end of the upper chute where it drops off into the first erosion hole. This could be protected with a conventional concrete or RCC buttress to prevent any further back cutting in the event the first flood season's discharges must be routed down the eroded gully. This work will be coordinated with the construction being done for restoration measures of the lower portion of the FCO Chute channel.

FCO Lower Chute: The BOC agrees with DWR's recommended concept for the FCO's lower chute restoration which contemplates completing the reconstruction of the foundations for the continuation of the reinforced concrete chute to connect with the terminal energy dissipater. This RCC emplacement would also be built up at the sides of the channel to support the retaining walls.

The DWR is recommending that the upper scour hole be left open during the RCC construction until it can be confidently determined that the entire lower spillway chute length would be completed before the November 1 deadline. This would be considered a fallback position for discharging flow down the eroded gully if the channel is not ready by the onset of the flood season. The BOC believes that the possibility of needing to route discharge down the gully is small. The BOC anticipates that the filling of the upper scour hole with RCC to restore the chute channel will take care of the requirement that the end of the upper chute must be protected.

Lining of the RCC chute channel with reinforced concrete and the construction of the training walls will be accomplished during the second construction season. The flood discharges during the next flood season will therefore pass from the reinforced concrete paving in the upper chute portion onto an RCC surface on the lower channel section. The BOC has previously stated that RCC can probably withstand flow without extensive damage. However, the discharge velocities in this lower part of the chute are over 100 fps [redacted] If allowed to progress, a portion of the newly placed chute could be lost. The BOC believes some surfacing means should be used on the top lift of RCC that can provide a smooth surface. Transverse joints in the top lift of RCC will need to be carefully formed to avoid disturbance to flow. The BOC suggests that the RCC test pad include some preparation and testing of surface preparation to obtain a hard, smooth finish free of bug holes, tracks and undulations.

The BOC is pleased that the measures recommended for restoring the FCO Chute during this initial restoration to accommodate the interim criteria will serve for the long-term restoration as well.

Emergency Spillway: The BOC supports the Recommended Alternative EM-2A (RCC Buttress, RCC Splash Pad and D/S Cutoff Wall) as the mitigation option. One advantage of this measure is that it can be installed in phases with the 1,700-ft-long downstream cutoff and the replacement of the 800-ft-long small overflow weir being the only elements required by November 1, 2017. The addition of the RCC buttress downstream of the larger ogee monoliths and the RCC splash pad (that covers the area between the weir and the downstream cutoff wall) can be installed later; it is conceivable that this RCC work could occur after November 1. The BOC recommends continued analysis of the scour potential for flow downstream of the northern 800 feet of the cutoff wall.

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

Response

The BOC has the following comments on Construction Contract No. 1. This contract was recently awarded to Teichert Construction and they are presently mobilizing to the site. The purpose of this contract will be to improve site access to the spillway areas and perform local site preparation. There was discussion about possibly making changes to this contract to address unforeseen issues as they arise. Given the necessity of getting a contractor operational in the field,

perhaps before a few elements were fully investigated and designs completed, it is no surprise that some needed changes have arisen. The BOC believes that shifting as much work to this contract as possible is prudent if it can further expedite work in the subsequent Contract No. 2 that has yet to be awarded.

A major element of Contract No. 1 addresses stabilizing the eroded slope on the left side of the lower FCO Chute. Once the slope is stabilized, workers in Contract 2 can safely work beneath the stabilized slope to clean out debris and perform any foundation preparation for concrete backfill activities. It is important to expedite analysis of the near vertical slopes that abut the left side of the chute in the Station 29+00 to 31+00 area. If blasting and shaping (or even if removal is deemed necessary) of this rock monolith is determined to be necessary then adding a blasting task to Contract No.1 and performing that work immediately may provide more options for contract 2 in regard to scour hole mitigation. Another related issue is the cleanup and stabilization of the unstable eroded area on the right side of the upper scour hole; currently this is not included in Contract 2, but thought should be given to cleaning and exposing the geological conditions in this area as soon as possible, as it will also be part of the scour hole backfill foundation.

The aggregate testing and mix design analysis being performed as part of Contract 1 is an extremely important aspect of determining the future production rates of RCC. As this could be a critical path item to some of the proposed options in Contract 2 (e.g., complete versus partial backfill of the scour hole), we endorse these efforts.

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

Response

The BOC can well understand the opinions expressed by Contractors when shown the scope of work in the draft Construction Contract No. 2 that there are a lot of “priorities” for completion before November 1 in this job. Contract No. 2 as written, attempts to cover all the needed work to restore the FCO Chute to full operation. It should be recognized that this will likely require two or more work seasons and some clarifications will no doubt be needed in the contractual language to explain this.

During the meeting, the question was raised as to whether the grade line of the spillway chute could be raised by the additional slab thickness to avoid having to

excavate an additional thickness of foundation for the thicker slab. The BOC is of the opinion that this would be possible and would not be difficult to achieve with a short transition and a vertical curve. However, the thickness of the original concrete chute slab appears to vary widely from the specified thickness, and the condition and suitability of the underlying foundation will not be known until the concrete is removed. It would be premature to change the line and grade at this time.

In general, the BOC believes the details of the chute concrete, anchorage, drainage and reinforcing are well conceived as shown on the drawings. It was noted by the BOC that some of the RCC construction details shown on the draft plans are appropriate for dam construction but unnecessary for building up the new foundation for the chute.

It appears that making the initial placement of concrete in the upstream scour hole may be hazardous for workers because of the danger of rock falls. The BOC agrees that flowable concrete can be used in the bottom and that the large rock pieces that ended up on the bottom of the scour hole can be left in place and incorporated in the fill. Plum stones might also be used. When the level of concrete placement reaches a height at which suitable space becomes available for safe RCC placement, the operation can be changed.

The issue of drainage under the backfill behind the training walls was discussed. If the replacement of the chute and training walls is only partially finished before November, the outfall from these new drains needs to be determined.

The under drainage planned for the slab is, in general, satisfactory. Slabs are planned as approximately 30-ft by 30-ft panels and will be placed in checkerboard fashion to allow proper curing time prior to pouring of adjacent slabs. Loads used in the structural design include full dynamic pressure under the slabs. Both transverse and longitudinal joints will be provided with water stops. Water stops between slabs were apparently not included in the design of the original spillway and the lack of them was no doubt an important factor in the February failure of the slab on the FCO Chute. It will be very important to have constant construction inspection when slab concrete is poured to assure proper imbedding of the water stops.

There are differences between treatment of construction-joints on Drawings S-401 and S-403. [redacted]

[redacted]

Drawing S-401 shows no features for drainage between the leveling concrete and the chute slab. For some designs it may be desirable to consider installation of some form of drainage in this location. Some typical designs use a wrapped half-round slotted drain for such an application. It is not clear whether leveling concrete as shown on Drawing S-401 will be used for the upper chute since the condition of the foundation is not fully understood. The BOC is not in favor of introducing this additional interface and prefers the slab concrete to be placed on the properly prepared rock surface.

For the final construction of the reinforced concrete chute slab on the lower portion where the slab will be placed on RCC, a drainage system design could be considered. It was stated that undulations in the surface of the RCC would apparently be limited to 2 inches in depth. This limitation in the surface of the RCC would be rougher than useable for installation of drainage pipes as well as greater than desirable for the flow velocities anticipated. The BOC does not advocate the use of an under drainage system where the chute slab is placed on the RCC foundation portion of the lower spillway section.

Considerable discussion regarding under drainage design for spillway chutes took place. [redacted] The idea was not supported by the BOC for the upper chute restoration. Although many cracks developed in the original slabs, the new slab will be thicker, panel dimensions will be much smaller, and will be more heavily reinforced. These provisions will make the slab much less prone to developing such shrinkage or temperature cracks.

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

Response

The BOC has comments on other items as listed below.

Provisional Air Slot: In previous meeting comments, the BOC suggested that it could be advisable to add a designed air slot near the beginning of the steep slope. Although cavitation was probably not the root cause of the slab failure, it may have aided in the progress of the slab failure. Adding air could aid in aerating the flow on the steep slope and dampening the added damaging effects of cavitation. It may be advisable for these air slots to be analyzed in the hydraulic model tests that are currently taking place.

Asbestos: About two weeks ago, the local Air Quality Management District at Oroville discovered the occurrence of asbestos in an air quality sample. The amount was small, but this finding has produced concern about this potential health hazard to construction workers and nearby residents. Initial site investigation reports indicate that the amphibolite metamorphic rocks at the site are not a significant source of asbestos. We understand that DWR is conducting their due diligence study of this issue. This study should include testing of air samples in the crushing and borrow handling areas as well as any areas where rock excavation or rock handling is planned.

BOC RECOMMENDATIONS SUMMARY

M3-1 The BOC concurs with the Project's flood design criteria, but notes that while the FCO spillway chute can be designed to pass its portion of the extremely rare PMF flow, the Emergency Spillway repairs may not be capable of passing a 16-foot-overtopping and a peak flow of 371,000 cfs without significant erosion damage downstream.

M3-2 The BOC considers the structural design criteria based on 144-year return period ground shaking for interim repairs, and median deterministic ground motions for long-term repairs to be reasonable and appropriate.

M3-3 The BOC considers the deterministic median peak ground accelerations estimated for the design of long-term dam safety-

related features to be reasonably conservative and appropriate considering the very long return periods associated with these deterministic levels.

M3-4 The BOC considers geologic and geotechnical criteria for the excavation and preparation of foundations for the various project features to be reasonable and appropriate.

M3-5 The BOC concurs with the proposed strength criteria for the concrete and reinforcing steel elements, and for the use of corrosion protection for rock anchors.

M3-6 The BOC recommends that rock-weathering depth be determined for all elements of the Emergency Spillway (monolith section, 800-ft long weir section, and 1,700-ft cutoff wall) prior to the design being finalized. Weathering depth and, hence, scour potential downstream of the northernmost 800-ft of the cutoff should be estimated.

M3-7 The BOC concurs with the restoration methods recommended by DWR for the upper chute section.

M3-8 The Contractor should be made aware that the length of upper chute that is restored by Nov. 1 must connect with the portion still to be replaced to operate during the flood season.

M3-9 [redacted]

M3-10 The BOC concurs with the plans recommended by DWR for restoration of the chute channel in the lower spillway chute portion.

M3-11 The surface of the RCC channel which will be subject to high velocity flow needs to be smooth [redacted] It is suggested that the RCC test pad provides a means to investigate surfacing methods.

M3-12 The BOC has no objection to changing the line and grade of the upper chute lining if this offers an advantage.

M3-13 The BOC points out that under drainage provisions for the lower chute slab on RCC foundation has yet to be designed.

M3-14 The BOC does not favor the use of a leveling concrete course below the reinforced concrete spillway chute slab.

Respectfully submitted,

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