

# OROVILLE RISK ANALYSIS

## PUBLIC SUMMARY OF 2020 PART 12D SAFETY INSPECTION RESULTS

### BACKGROUND

The Federal Energy Regulatory Commission (FERC) requires several types of safety investigations and assessments on the dams that operate with a FERC license. The most rigorous assessment is the Part 12D Safety Inspection and review which FERC requires licensees to conduct every five years. In the case of the Oroville Dam complex, the 10<sup>th</sup> Part 12D Safety Inspection was completed in 2020. In addition to that planned review, the 2017 spillway incident led to federal legislation that directed FERC to require the Department of Water Resources (DWR) to request the United States Society on Dams (USSD) to nominate independent consultants to prepare a Level 2 Risk Analysis (L2RA), consistent with FERC's risk informed decision-making guidelines. The Legislation also called for the L2RA results to be utilized to inform the Part 12D Safety Inspection of Oroville Dam complex.

The Part 12D Safety Inspection was performed by independent consultants, Dr. Lelio H. Mejia, Ph.D., P.E., G.E., of Geosyntec Consultants, and Dr. David S. Bowles, Ph.D., P.E., P.H., D.WRE, F.ASCE, F.AWRA, of RAC Engineers, together with the Board Member, Mr. Drew Kennedy, P.G., C.E.G., of Gannett Fleming. The individuals were retained through a Request for Qualifications process and approved by FERC. All three individuals also fulfill a requirement under the California Water Code to convene a Board (referred to as the Director's Safety Review Board) of three consultants at least every once every five years to report to the Director on the operational performance of Department-owned dams. The Part 12D Safety Inspection reports were generated for Oroville, Bidwell Bar Canyon Saddle, and Parish Camp Saddle Dams and satisfy both the federal and state requirements.

DWR submitted the Part 12D Safety Inspection Report and the L2RA analysis report to FERC and the Division of Safety of Dams in August 2020. DWR has developed this overview document to summarize the findings, conclusions, and recommendations from the Part 12D reports.

The findings, conclusions, and recommendations in the Part 12D reports are based on a review of pertinent documents provided by DWR, information presented to the Board by DWR in various meetings, field inspections of the facilities, insight gained during a series of L2RA workshops, and review of the L2RA Report. These activities occurred from November 2018 through May 2020. As required by the federal legislation, the Level 2 Risk Analysis results served as major input to the Part 12D Board's assessments.

### Key Conclusions and Outcomes from Part 12D Reports:

- The independent consultants concluded that the Oroville Dam complex facilities are safe and reliable for continued operation. The report provides a series of recommendations regarding continued monitoring and analysis of each facility.

- In response to the independent consultant’s recommendations, and as required by the Part 12D Safety Inspection process, DWR staff will review and develop a plan and schedule for each recommendation and will make summaries of DWR actions and timelines available to the public as they are developed. The plan and schedule will be developed in consideration of other dam safety and SWP aging infrastructure projects to ensure DWR remains focused on the highest risks to public safety.
- Several of the recommendations align with studies to reduce uncertainty or risk reduction measures identified by the Level 2 Risk Analysis and/or the Oroville Dam Safety Comprehensive Needs Assessment (CNA).

## Oroville Dam 10<sup>th</sup> Part 12D Report Recommendations

The recommendations of the Tenth Part 12D Board for Oroville Dam, Bidwell Bar Canyon Saddle Dam, and Parish Camp Saddle Dam are presented below. The Board was asked by DWR to categorize its recommendations in accordance with the Priority Levels listed below. These levels were developed in a joint effort between DWR, the Board, and the Tenth Board for the Part 12D Safety Inspection of the Thermalito Dams Complex. The levels were transmitted in final form by DWR to the Board on October 8, 2019.

- **Priority Level 1** – Recommendation addresses a severe deficiency that, if not remediated immediately by DWR, endangers the safe operation or structural integrity of the facility or may threaten the safety of operating personnel or the public. The recommendation may justify emergency action by DWR.
- **Priority Level 2** – Recommendation addresses a matter for which action is necessary to reduce the risk to the safe operation or the structural integrity of the facility or the safety of operating personnel or the public. The recommendation may necessitate further evaluation of an identified risk.
- **Priority Level 3** – Recommendation addresses a sound and beneficial suggestion to improve or enhance the safe operation or structural integrity of the facility.

There are no Priority Level 1 recommendations for Oroville Dam and appurtenant facilities. There are twenty-five Priority Level 2 recommendations and fourteen Priority Level 3 recommendations.

Priority levels were assigned to the recommendations only considering Oroville Dam complex, and not taking into account the entire State Water Project (SWP) portfolio of dams. Reference to the appropriate sections of the report is provided (in parentheses) at the end of each recommendation.

## Recommendations Regarding the Suitability of the Project for Continued Safe and Reliable Operation

There are no new recommendations to enhance the suitability of Oroville Dam and appurtenant facilities for continued safe and reliable operation. The dam and appurtenant facilities are suitable for continued safe and reliable operation.

## Recommendations Regarding the Project Description

In general, the project description in the November 2018 Supporting Technical Information Document<sup>1</sup> (STID) is adequate. The Board has identified some improvements to the description as listed Recommendation R-39.

- R-1.** The Board recommends that DWR evaluate the feasibility of a program to: a) obtain samples of the core materials for example by drilling and sampling test borings 30 to 60 ft. into the upper vertical section of the core beneath the crest and/or excavating bulk samples from the core material borrow areas; b) subjecting selected in-situ and/or reconstituted samples to specialized tests and conventional tests for measuring the susceptibility of the materials to internal erosion, and to conventional index tests; and c) based on the results of the field exploration and laboratory testing, further assessing the susceptibility of the core materials to internal erosion under seepage gradients representative of those that may exist at various elevations within the dam. Examples of specialized tests include the Hole Erosion Test (HET) and the Erosion Function Apparatus (EFA) test, whereas conventional tests might include, for example, the pinhole and crumb tests. A plan for implementation of the field and laboratory testing program should be developed based on the feasibility of the program. The Board recommends that DWR present the results of the feasibility study and the implementation plan in a report for review by the Board. R-1 is a Priority Level 2 recommendation.
- R-2.** The Board recommends that DWR perform a stochastic flood event modeling study to improve the estimates of flood hazard with uncertainty bounds and consideration of inputs from regional precipitation analysis and paleohydrology, as appropriate, for use in future risk assessments. R-2 is a Priority Level 2 recommendation.
- R-3.** The Board recommends that in performing the nonlinear finite element analyses of the Flood Control Outlet (FCO), DWR assess the stresses and strains in the structure and foundation for loads associated with a full range of floods. The seismic and flood loading analyses should include the following, as appropriate:
  - a. Explicit modeling of the radial gates and evaluation of hydro-dynamic interaction and interaction between the monoliths and the rock foundation and abutments.
  - b. An assessment of the effectiveness of the proposed bracing design related to installation of a bulkhead in one of the FCO bays.

---

<sup>1</sup> The Supporting Technical Information Document contains Critical Energy Infrastructure Information and is not publicly available.

- c. Evaluations of the stability of the spillway road bridge deck under earthquake loading.
- d. Evaluation over a range of seismic loadings to identify the threshold for significant damage.
- e. Consideration of existing cracks in the structure, the 3D extent of the structure, available strength data for the structure and the foundation, and duration of strong earthquake motion.

R-3 is a Priority Level 2 recommendation.

**R-4.** The Board recommends that DWR excavate a shallow trench at the contact between the FCO Monolith 31 and the dam embankment, taking appropriate precautions to ensure no harm to the dam, to examine this contact for the existence of cracks and to examine and test the embankment materials adjacent to the FCO for susceptibility to internal erosion, as appropriate. R-4 is a Priority Level 2 recommendation.

**R-5.** The Board recommends that the seismic loads on the FCO trunnion beam anchorages be determined from the ongoing and planned analyses of the FCO, including the presence of the gates. Updated analyses of the capacity of the trunnion anchorages should be performed considering possible non-uniform distribution of load amongst the anchor rods in any one anchorage during large seismic or flood loads using advanced methods of analysis. The implications of the analyses, considering non-uniform load distribution amongst anchor rods, should be assessed in terms of the available margins of safety against progressive failure of the trunnion anchorages during each of the identified loading conditions. DWR should also consider the development of programmatic plans for addressing ageing of the anchorages as a result of stress-induced corrosion of the anchor rods and other effects that might lead to increased fracture and loss of anchor rods with time. Such plans could include funding a research program oriented towards developing reliable methods to monitor and assess the condition of existing anchor rods, replacement of suspected failed anchor rods, and/or rehabilitation of the trunnion anchor systems. R-5 is a Priority Level 2 recommendation.

**R-6.** The Board recommends that DWR conduct additional ultrasonic inspections of the FCO anchor rods after significant seismic events, as determined by DWR on the basis of the available capacity of the anchorage system. Ultrasonic inspections following significant seismic events should be added to the Earthquake Inspection Form in the Dam Safety Surveillance and Monitoring Plan (DSSMP).<sup>2</sup> R-6 is a Priority Level 2 recommendation.

**R-7.** The Board recommends that DWR undertake a detailed reliability assessment of the operability of the FCO gate system, including consideration of the following: historical performance, condition assessment, human factors, available statistics by others on performance of similar equipment, effects of potential debris accumulation and loading, and seismic loading specific to the FCO gate system. The study should also assess the need for tracking of all gate movement

---

<sup>2</sup> The *Dam Safety Surveillance and Monitoring Plan* contains Critical Energy Infrastructure Information and is not publicly available.

including expanding the current record-keeping to incorporate all gate movements and incidents. R-7 is a Priority Level 2 recommendation.

- R-8.** Given the importance of the Hyatt Powerplant for making low-level releases that can affect dam safety, the Board recommends that DWR undertake a detailed reliability assessment of the Hyatt Powerplant operating mechanical equipment, electrical systems, controls, and switchyard, with due consideration of their past performance, condition assessment, human factors, available statistics by others on performance of similar equipment, seismic loading, and outcomes of the seismic walkdown recommended by the Ninth Board. The reliability assessment should also include an evaluation of previous load rejection testing and, if previous testing has not been performed within the past 5 – 10 years, new load rejection testing and modeling to verify that the system continues to provide satisfactory performance. R-8 is a Priority Level 2 recommendation.
- R-9.** The Board recommends that DWR develop procedures to inspect the rock bolts and gunite in the crown of the Hyatt Powerplant periodically and after significant seismic events. Post-seismic inspection should be added to the Earthquake Inspection Form in the DSSMP. R-9 is a Priority Level 2 recommendation.
- R-10.** The Board recommends that DWR perform a desktop screening evaluation of the sleeve-type pipe couplings downstream of the turbine shutoff valves (TSVs) in the Hyatt Powerplant, downstream of the RSVs in the RVOS, and downstream of the 30-inch (in.) valve in the Palermo Outlet to determine whether they are the same manufacturer, type, and steel grade as a sleeve-type pipe coupling that experienced a sudden failure at a separate non-DWR facility. Should the couplings match, the Board recommends that DWR perform hardness testing of the middle ring in each coupling to evaluate whether the steel is unacceptably hard, which could lead to brittle fracture and failure. R-10 is a Priority Level 2 recommendation.
- R-11.** Given the importance of the Hyatt Powerplant for making low-level releases that can affect dam safety, the Board recommends that DWR undertake a detailed reliability assessment of the Hyatt Powerplant Intake operating mechanical equipment, electrical systems, and controls, with due consideration of their past performance, condition assessment, human factors, available statistics by others on performance of similar equipment, seismic loading, and outcomes of the seismic walkdown recommended by the Ninth Board. R-11 is a Priority Level 2 recommendation.
- R-12.** The Board recommends that DWR confirm the existence of, or develop, a contingency plan in the event a shutter gantry crane for the Hyatt Powerplant Intake Structure becomes disabled. R-12 is a Priority Level 2 recommendation.
- R-13.** The Board recommends that DWR perform an updated seismic structural and stability analysis of the Hyatt Powerplant Intake Structure for a range of seismic loading and using current FERC seismic criteria, taking into account the results of the updated seismic hazard analyses. R-13 is a Priority Level 2 recommendation.

- R-14.** The Board recommends that DWR develop an emergency response plan to address and shut off a potential uncontrolled release from the Palermo Outlet. R-14 is a Priority Level 2 recommendation.
- R-15.** Given the potential for unintended consequences that could have dam safety implications, such as those experienced during the recent testing of the fire suppression system, the Board recommends that once fire suppression installation and improvements for Hyatt Powerplant are complete, DWR reflect these changes in its operating orders as appropriate. R-15 is a Priority Level 2 recommendation.
- R-16.** The Board recommends that DWR perform a landslide hazard assessment on the downstream left abutment slope, particularly in areas where slope grading or drainage modifications have been made, to evaluate the potential and likelihood for slope instability of sufficient volume to impact the Hyatt Powerplant access tunnel portal, ACC, Switchyard, and/or Palermo Outlet and Canal. R-16 is a Priority Level 3 recommendation.
- R-17.** The Board recommends that DWR evaluate the potential and likelihood for reactivation of landslides identified in the reservoir rim landslide inventory, and the initiation of new failures in areas of weak weathered bedrock underlying steep slopes, to generate a surge of water that could overtop Oroville Dam (either as a landslide-generated impulse wave or the release of water temporarily impounded by a landslide debris dam blocking a reservoir arm). The Board also recommends that DWR perform a landslide hazard assessment to evaluate the potential and likelihood for a large-volume landslide to mobilize along the Feather River downstream of Oroville Dam, resulting in a rise of the diversion pool due to a partial or complete blockage of the channel. R-17 is a Priority Level 3 recommendation.
- R-18.** The Board recommends that DWR inspect the exposed portions of the Hyatt Powerplant Intake Structure channel walls after significant seismic events. As appropriate, DWR should also perform a post-seismic remotely operated vehicle (ROV) inspection of the submerged section of the intake. Post-seismic inspection of the channel walls should be added to the Earthquake Inspection Form in the DSSMP. R-18 is a Priority Level 3 recommendation.
- R-19.** The Board recommends that DWR perform a debris hazard assessment to improve understanding of debris sources during major floods, debris characteristics, relationship to flood severity and other causative factors, and the potential for causing loss of FCO discharge capacity or damage to the FCO structure or gates. R-19 is a Priority Level 3 recommendation.
- R-20.** The Board recommends that the scopes, urgency and priority of all investigations and studies, including improved life-loss estimation, and, as appropriate, other types of consequences estimation, should be developed using risk insights and should provide outcomes in a form that will be useful to support future quantitative risk analysis (e.g. considering a range of loading conditions and uncertainty in key parameters). This recommendation would be best implemented if DWR developed a framework for a range of levels of risk analysis including, where appropriate, application of quantitative risk analysis, with consideration given to uncertainties, as a tool for a) understanding and evaluating the risk associated with potential

failure modes for the Oroville Dam Complex, including system interactions considerations, and b) evaluating the effectiveness and justification for risk reduction alternatives to develop a comprehensive risk reduction plan. R-20 is a Priority Level 3 recommendation.

- R-21.** The Board recommends that within the unified framework for condition assessment, risk management, and strategic planning of capital investments, which DWR is adopting for SWP infrastructure, the implementation of the corresponding process for the Oroville Dam Complex provide for appropriately considering “non-breach damage (Potential Failure Mode’s (PFM)”, non-life loss PFMs, not-estimated PFMs and other cases listed in Section 3.2.1.1.4a in addition to “breach/life-loss” PFMs. This will require developing methods for weighing life-loss as well as non-life loss consequences, and in the case of not-estimated PFMs, developing methods for assigning urgency and priority to investigations and studies that will provide initial estimates for their risk to better inform DWR’s decision making for prioritizing and justifying risk reduction associated with these types of PFMs. R-21 is a Priority Level 3 recommendation.

#### **Recommendations Regarding the Surveillance and Monitoring Plan**

- R-22.** The Board endorses DWR’s plans to install new piezometers in the core block and dam downstream shell and foundation in accordance with the June 2019 DWR report, *Proposed Piezometer Installation at the Dam Toe*, and the May 2019 Comprehensive Needs Assessment (CNA) technical memorandum, *Installation of New Replacement Piezometers in Oroville Dam*.<sup>3</sup> The Board recommends that DWR add two piezometers to the six piezometers currently planned at the downstream toe. These additional piezometers should be placed upstream of the seepage barrier in a similar configuration to P-200A and P-200B for measurement redundancy. R-22 is a Priority Level 2 recommendation.
- R-23.** The Board recommends that DWR clean the existing drainage grout gallery drains, including removal of calcification. The Board also recommends that DWR consider developing an appropriate schedule for periodic maintenance of the drains and reflect that in the DSSMP. R-23 is a Priority Level 2 recommendation.
- R-24.** The Board recommends that DWR investigate the seepage that is occasionally observed to emanate in the area of the backfill concrete at the west interface between the FCO and the dam embankment, when the reservoir is at high stage. The Board recommends that DWR consider implementing a method to measure potential seepage during high reservoir levels, facilitate monitoring, and increasing the inspection frequency at this location when the reservoir surface is at or above El. 895 ft. The Board also recommends that monitoring of seepage flows at this location be added to the DSSMP. R-24 is a Priority Level 2 recommendation.
- R-25.** The Board recommends that DWR install and maintain an accelerometer on the FCO crest. R-25 is a Priority Level 2 recommendation

---

<sup>3</sup> The reports *Proposed Piezometer Installation at the Dam Toe* and the May 2019 Comprehensive Needs Assessment (CNA) technical memorandum, *Installation of New Replacement Piezometers in Oroville Dam* contain Critical Energy Infrastructure Information and are not publicly available.

**R-26.** The Board recommends that DWR perform a high-density 3D survey of the embankment and abutments using laser scanning and/or photogrammetry methods, and a bathymetric survey of the submerged portions of the embankment, of a sufficient resolution and precision for comparisons with future 3D surveys to allow detection of overall changes in the embankment geometry. An initial survey should be performed to establish an appropriate baseline. Subsequent surveys should be performed as needed and after significant events, such as significant earthquakes and floods. R-26 is a Priority Level 3 recommendation.

**R-27.** The Board recommends that the embankment and spillways DSSMPs and Dam Safety Surveillance and Monitoring Reports (DSSMR)<sup>4</sup> be updated as appropriate to:

- a. Include information on:
  - i. How the reservoir and tailwater levels are monitored and the activation of alarm systems following a significant change in the elevation of either.
  - ii. The frequency of the manual survey measurements at the FCO headworks.
  - iii. The level of accuracy for the automated survey measurements of the FCO headworks.
  - iv. The level of accuracy for the vertical survey measurements of embankment settlement.
- b. Address the typo in the y-axis label of the upstream El. 815 ft. bench cumulative settlement plots (C.56 and C.57 in the 2018 embankment DSSMR). The y-axis is currently labeled *Settlement Since 6/1/1970 Survey*, but this label should be revised to read *Settlement Since the August 1967 Survey*.
- c. Add clarifying text to the plots of the upstream settlement in future embankment DSSMRs explaining the reference base difference, to avoid future confusion resulting from the greater settlement of the upstream bench El. 815 ft. compared to the crest.
- d. Plot all relevant survey data in future Spillways DSSMRs to allow for understanding of the movement of the FCO headworks structure over time.
- e. Reflect the changes to the seismic response and notification procedures outlined in SOO PC 700.6 in Section 7.1.8 of the DSSMP and update the post-seismic inspection checklist as appropriate.
- f. Add post-seismic inspection of the FCO bridge supports.
- g. Add a periodic and post-seismic inspection plan for the RVOS.

R-27 is a Priority Level 3 recommendation.

---

<sup>4</sup> The *Dam Safety Surveillance and Monitoring Reports* contain Critical Energy Infrastructure Information and are not publicly available.



- R-28.** The Board recommends that DWR document in the standard inspection checklist specific visual inspection of the dam crest for signs of embankment cracking. R-28 is a Priority Level 3 recommendation.

#### **Recommendations Regarding the Field Inspection**

The Board has no new recommendations regarding the field inspection.

#### **Recommendations Regarding the Operation and Maintenance Programs**

- R-29.** The Board recommends that DWR review the engineering design of the temporary bracing system recently used to prevent flooding of the core block during periods of high tailwater and assess the need to design and construct a more robust bracing system. R-29 is a Priority Level 2 recommendation.
- R-30.** The Board recommends that DWR evaluate the amount of release through the FCO required to initiate flooding at the RVOS or Hyatt Powerplant for current conditions, and develop a relationship between the tailwater elevations at the spillway plunge area and at the RVOS and Hyatt Powerplant for a range of spillway discharges. These relationships, once developed, should be incorporated into the FCO operating procedures. R-30 is a Priority Level 2 recommendation.
- R-31.** The Board recommends that DWR inspect the 24-in. air intake that accommodates displaced air from Penstocks Nos. 1 and 2 during normal intake gate operation and emergency closure. The inspection should be analogous to the inspection of the air supply and equalization tunnels for Diversion Tunnels Nos. 1 and 2. R-31 is a Priority Level 2 recommendation.
- R-32.** The Board recommends that an in-depth briefing on the outcomes of the L2RA process be conducted for senior DWR decision makers to enhance their technical insights for decision making relevant to potential issues associated with the performance of the dam. R-32 is a Priority Level 2 recommendation.
- R-33.** The Board recommends that DWR periodically conduct a skill-specific evaluation of DWR or on-call contractor resources necessary to address short-term needs associated with assessing, repairing, or intervening to bring to a safe condition, all facilities needed for critical dam safety-related operations during flood events, immediately following a seismic event, or other types of dam safety incidents. This evaluation should address the range of PFMs identified in the L2RA for Oroville, Parish Camp Saddle Dam (PCSD), and Bidwell Bar Canyon Saddle Dam (BBCSD), and consider the outcomes of studies conducted in response to Recommendations R-7, R-8, and R-11. R-33 is a Priority Level 3 recommendation.
- R-34.** The Board recommends that the installation, operation, and limitations of the FCO bulkhead bracing system documented in the 2018 report, *DWR Oroville Flood Control Outlet Bulkhead Bracing Analysis*<sup>5</sup> or a similar system, be included in the FCO Rapid Response and Recovery Plan,

---

<sup>5</sup> The report *DWR Oroville Flood Control Outlet Bulkhead Bracing Analysis* contains Critical Energy Infrastructure Information and is not publicly available.

once the bracing system is approved by FERC and California's Division of Safety of Dams (DSOD). R-34 is a Priority Level 3 recommendation.

- R-35.** The Board recommends that DWR consider implementing a simple backup measure to route power to the FCO gates, including establishing quick connections to a dedicated portable generator along with the necessary manual controls and procedures. R-35 is a Priority Level 3 recommendation.

#### **Recommendations Regarding the Supporting Technical Information Document**

- R-36.** The Board recommends that, once the embankment stability analyses currently in progress are completed, DWR undertake seismic analyses of the dam using up-to-date methods for analysis of seismic deformations. The analyses should consider a suite of motions representative of the design earthquake and a broader range of seismic loadings suitable for informing a risk assessment. They should also be performed for higher intensity ground motions to evaluate the sensitivity of the dam response and potential damage to lower probability events. The analyses should use an up-to-date characterization of the dam materials, considering all data examined in the recent studies of the dam materials by DWR. Properties representative of the various materials should be used, adequately representing the various subzones (e.g., subzones of increased sand content in Zone 3, subzone corresponding to vegetated area, etc.) disclosed by the recent studies. Parametric analyses should be performed to examine the sensitivity of the dam response to variability in material characteristics within the various dam subzones. The analyses should be performed using nonlinear analysis techniques and constitutive models that properly capture key aspects of material seismic behavior. Such aspects include cumulative shear and volumetric deformation under cyclic loading in saturated and dry conditions, and fabric degradation. Analyses should be performed to evaluate the potential for differential deformations along the length of the dam that may lead to longitudinal or transverse cracking of the embankment, particularly near the abutments, and at the interface between the core and the FCO structure. R-36 is a Priority Level 2 recommendation.
- R-37.** The Board recommends that DWR conduct an independent review of the safety margins against trunnion anchor failure of the gates under differential opening greater than currently allowed by COO 14. R-37 is a Priority Level 2 recommendation.
- R-38.** The Board recommends that DWR develop 3D digital models of the foundation geology of Oroville Dam, the FCO structure, and the Hyatt Intake Structure. An additional model of the Hyatt Powerplant cavern should be prepared. These models should incorporate pre-construction subsurface exploration, construction foundation geologic mapping, geologic data collected during the spillway chute reconstruction and piezometer installation, and any other relevant geologic data, such as shear zones and rock fracture sets mapped in the project excavations, including the Hyatt Powerplant. R-38 is a Priority Level 3 recommendation.
- R-39.** The Board recommends the following updates to the STID:

- a. A copy of the chapters of the L2RA Report pertaining to Oroville Dam and its appurtenant structures should be inserted into Section 1 of the STID for documentation purposes.
- b. Section 2.5 of the STID should be updated to reflect the recent modifications to the FCO chute and to the ES. In addition, the stated crest length of the FCO should be checked and corrected, as appropriate.
- c. Sections 2.9 and 2.11 of the STID should be updated to reflect the modifications to the pressure relief wall, the RVOS valves, and the RVOS baffle ring, and the corresponding changes in the operating limits (1,500 to 4,000 cubic feet per second [cfs]) for discharge flows (revised Standing Operating Order 100.29).
- d. The STID should be updated to reflect new information from recent studies that is pertinent to the description of the dam and its materials, construction specifications, geologic and seismic hazard studies, hydrology and hydraulic studies, and other pertinent documents.
- e. Since the Ninth Five-Year Part 12D Safety Inspection Report, several project-safety-related events have occurred and/or repairs have been made as listed in Section 2.4 of this report. The construction chronology in Section 3 of the STID should be updated to include this information.
- f. Section 4.4 of the STID currently states that the minimum flow requirement per gate is 1,000 cfs. Section 4.4 should be updated to include the revised minimum flow requirement of 700 cfs established in COO OR-14.
- g. Section 5 should be updated to include more detailed information from the recent spillway foundation investigations, including rock strength properties, weathering patterns, shear zone characteristics, and rock erodibility.
- h. The minimum freeboard stated in Section 6.2.7 of the STID should be corrected to reflect the embankment elevation on the right abutment where it meets the FCO monolith, which would determine first overtopping in the event of a high reservoir pool.
- i. The Board agrees with the static and seismic analyses program currently in progress. These analyses should be submitted for review by the Board and incorporated into the STID once they are completed.
- j. Figure 6-9 in the STID should be corrected by changing *Lesser of maximum inflow or 15,000 cfs* to *Lesser of maximum inflow or 150,000 cfs* for the case of *Greater than 175,000* at the bottom of the *Release Schedule* table for the *Oroville Flood Control Diagram* shown in this figure.
- k. Figure 6-9 in the STID is the 1971 Flood Control Diagram. It is recommended that the modified Flood Control Diagram referred to in Section 6.2.9 as providing *enhanced flood space* be included in addition to the 1971 diagram.

- I. Section 10 of the STID should be updated to include correspondence with FERC and DSOD since the 2018 update and correspondences since 2017 that concern the Ninth Board's review of DWR's response to recommendations by the Ninth Board.

R-39 is a Priority Level 3 recommendation.

## **Bidwell Bar Canyon Saddle Dam (BBCSD) 10<sup>th</sup> Part 12D Report Recommendations**

There are no Priority Level 1 recommendations for BBCSD. There are eight Priority Level 2 recommendations and six Priority Level 3 recommendations for BBCSD. Priority levels were assigned to the recommendations only considering BBCSD, and not taking into account the entire State Water Project (SWP) portfolio of dams.

### **Recommendations Regarding the Suitability of the Project for Continued Safe and Reliable Operation**

There are no new recommendations to enhance the suitability of BBCSD for continued safe and reliable operation. BBCSD is suitable for continued safe and reliable operation.

### **Recommendations Regarding the Project Description**

In general, the project description in the November 2018 STID for BBCSD is adequate. The Board has identified some improvements to the description as listed in Recommendation R-14.

### **Recommendations Regarding the Level 2 Risk Analysis Report**

Recommendations related to PFMs identified in the L2RA Report are listed below.

- R-1.** The Board recommends that DWR perform a stochastic flood event modeling study to improve the estimates of flood hazard with uncertainty bounds and consideration of inputs from regional precipitation analysis and paleohydrology, as appropriate, for use in future risk assessments. R-1 is a Priority Level 2 recommendation.
- R-2.** The Board recommends that DWR assess the potential for erosion of the BBCSD foundation during a breach of either embankment, which would lead to a greater release of the reservoir than that associated with erosion of the embankment alone. R-2 is a Priority Level 2 recommendation.
- R-3.** The Board recommends that DWR evaluate the potential and likelihood for reactivation of landslides identified in the reservoir rim landslide inventory, and the initiation of new failures in areas of weak weathered bedrock underlying steep slopes, to generate a surge of water that could overtop BBCSD (either as a landslide-generated impulse wave or the release of water temporarily impounded by a landslide debris dam blocking a reservoir arm) or to block the reservoir channel causing a rise in reservoir level that could overtop BBCSD. R-3 is a Priority Level 3 recommendation.
- R-4.** The Board recommends that the scopes, urgency and priority of all investigations and studies, including improved life-loss estimation, and, as appropriate, other types of consequences estimation, should be developed using risk insights and should provide outcomes in a form that will be useful to support future quantitative risk analysis (e.g. considering a range of loading conditions and uncertainty in key parameters). This recommendation would be best implemented if DWR developed a framework for a range of levels of risk analysis including,

where appropriate, application of quantitative risk analysis, with consideration given to uncertainties, as a tool for a) understanding and evaluating the risk associated with potential failure modes for the Oroville Dam Complex, including system interactions considerations, and b) evaluating the effectiveness and justification for risk reduction alternatives to develop a comprehensive risk reduction plan. R-4 is a Priority Level 3 recommendation.

- R-5.** The Board recommends that within the unified framework for condition assessment, risk management, and strategic planning of capital investments, which DWR is adopting for SWP infrastructure (DWR Strategic Plan), the implementation of the corresponding process for the Oroville Dam Complex, provide for appropriately considering “non-breach damage PFMs”, non-life loss PFMs, not-estimated PFMs and other cases listed in Section 3.2.1.1.4a in addition to “breach/life-loss” PFMs. This will require developing methods for weighing life-loss as well as non-life loss consequences, and in the case of not-estimated PFMs, developing methods for assigning urgency and priority to investigations and studies that will provide initial estimates for their risk to better inform DWR’s decision making for prioritizing and justifying risk reduction associated with these types of PFMs. R-5 is a Priority Level 3 recommendation.

#### **Recommendations Regarding the Surveillance and Monitoring Plan**

- R-6.** The Board recommends that DWR field-check the locations of all the survey benchmarks at the dam to confirm they are founded on suitable material not subject to movement due to moisture change or other types of disturbance. Benchmarks founded on materials subject to potential movement or disturbance should be relocated or modified and rebuilt to be founded on rock not susceptible to movement. R-6 is a Priority Level 2 recommendation.
- R-7.** The Board recommends that in addition to monitoring seepage flows, as recommended by the Ninth Board, DWR test the observed reverse seepage flows in the new weir to be installed at the Main Dam for turbidity, solids content, and water chemistry and that DWR perform additional analyses to assess the pathway for the seepage and explain the seepage quantities observed. After installation of the weir, the DSSMP should be updated accordingly. R-7 is a Priority Level 2 recommendation.
- R-8.** The Board recommends DWR evaluate the need and implementation options for a monitoring system or procedure to detect a breach or overtopping of the West Dam, which would not be reflected in a rise of the currently monitored Miners Ranch Reservoir (MRR) level. R-8 is a Priority Level 2 recommendation.
- R-9.** The Board recommends that DWR evaluate the options to reduce the detection and response time in the event of overtopping or breach of either BBCSD embankment (associated with all identified PFMs), such as infrared cameras or increased surveillance by DWR staff of the area downstream of BBCSD. R-9 is a Priority Level 3 recommendation.
- R-10.** The Board recommends that DWR perform a high-density three-dimensional (3D) survey of the embankments and abutments using laser scanning and/or photogrammetry methods, of a sufficient resolution and precision for comparisons with future 3D surveys to allow detection of overall changes in the embankment geometry. An initial survey should be performed to

establish an appropriate baseline. Subsequent surveys should be performed as needed and after significant events, such as earthquakes or floods. R-10 is a Priority Level 3 recommendation.

#### **Recommendations Regarding the Field Inspection**

- R-11.** The Board recommends that the parking area at the left abutment of the Main Dam be surveyed, and if found to be lower in elevation than the design dam crest elevation, that it be regraded to an elevation equal to or higher than the design dam crest elevation. R-11 is a Priority Level 2 recommendation.

#### **Recommendations Regarding the Operation and Maintenance Programs**

- R-12.** The Board recommends that an in-depth briefing on the outcomes of the L2RA process be conducted for senior DWR decision-makers to enhance their technical insights for decision making relevant to potential issues associated with the performance of the dam. R-12 is a Priority Level 2 recommendation.

#### **Recommendations Regarding the Supporting Technical Information Document**

- R-13.** The Board recommends that DWR perform an evaluation focused on the Cleveland Hill Fault in the vicinity of BBCSD that is supplemental to the DWR Phase 1 evaluation of the fault in 2015. The supplemental evaluation should include review and incorporation of geologic information related to Miners Ranch Dam and Kelly Ridge Tunnel contained in the archives of South Feather Water and Power Agency (SFWPA) and DSOD. The document review should include dam safety reports, construction documents, and inspection records for these facilities. High-resolution topographic data should be interpreted for an updated lineament analysis to evaluate possible surface expression along the trend of shear zones mapped in the foundations of Miners Ranch Dam and both BBCSD embankments. In addition, the location(s) and orientation(s) of shear zones noted on the geologic log of the Kelly Ridge Tunnel should be spatially plotted with respect to the shear zones mapped in the foundation of the West Dam, along with lineament analysis to evaluate possible surface expression of the shear zones between the tunnel and the West Dam. The Board also recommends that DWR evaluate the potential impact of surface fault displacement on the West Dam. R-13 is a Priority Level 2 recommendation.
- R-14.** The Board recommends the following updates to the STID:
- a. Chapters of the L2RA Report pertaining to BBCSD should be included in Section 1 of the STID for documentation purposes.
  - b. The conflicting statements in the DSSMP on the reservoir elevation at which the inspection frequency increases from monthly to weekly should be resolved.
  - c. Section 2 of the STID should be expanded to provide available information on the embankment materials related to permeability, relative compaction, and gradation curves of the as-placed material.

- d. The summary in Section 3 of the STID should be expanded to include information on construction practices (e.g., underwater placement of portions of the Main Dam), material shortages, and design changes.
- e. Include the *Miners Ranch Dam and Dike Preliminary Design Analysis* and the *Miners Ranch Dike Foundation Grouting Summary*<sup>6</sup> reports in Section 3 of the STID.
- f. The project chronology in Section 3 of the STID should be expanded to include when construction of BBCSD was completed and to include the appropriate project-safety-related modifications and/or repairs as listed in Section 2.4 of this report.
- g. Reflect new information from recent studies that is pertinent to the description of the dam and its materials, construction specifications, geologic and seismic hazard studies, hydrology and hydraulic studies, and other pertinent documents.
- h. Figure 6-9 in the STID should be corrected by changing *Lesser of maximum inflow or 15,000 cfs* to *Lesser of maximum inflow or 150,000 cfs* for the case of *Greater than 175,000* at the bottom of the Release Schedule table for the Oroville Flood Control Diagram shown in this figure
- i. Figure 6-9 is the 1971 Flood Control Diagram. It is recommended that the modified Flood Control Diagram referred to in Section 6.2.9 as providing *enhanced flood space* be included in addition to the 1971 diagram.
- j. Section 10 of the STID should be updated to include correspondence with FERC and DSOD since the 2018 update and correspondences since 2017 that concern the Ninth Board's review, and FERC acceptance, of DWR's response to recommendations by the Ninth Board.

R-14 is a Priority Level 3 recommendation.

---

<sup>6</sup> *Miners Ranch Dam and Dike Preliminary Design Analysis* and the *Miners Ranch Dike Foundation Grouting The Summary Reports* contain Critical Energy Infrastructure Information and are not publicly available.



## Parish Camp Saddle Dam (PCSD) 10<sup>th</sup> Part 12D Report Recommendations

There are no Priority Level 1 recommendations for PCSD. There are five Priority Level 2 recommendations and seven Priority Level 3 recommendations for PCSD. Priority levels were assigned to the recommendations only considering PCSD, and not taking into account the entire State Water Project (SWP) portfolio of dams.

### Recommendations Regarding the Suitability of the Project for Continued Safe and Reliable Operation

There are no new recommendations to enhance the suitability of PCSD for continued safe and reliable operation. PCSD is suitable for continued safe and reliable operation.

### Recommendations Regarding the Project Description

In general, the project description in the existing PCSD STID is adequate. The Board has identified some improvements to the description as listed in Recommendation R-12.

### Recommendations Regarding the Level 2 Risk Analysis Report

Recommendations related to PFMs identified in the L2RA Report are listed below.

- R-1.** The Board recommends that DWR assess the potential for erosion of the PCSD foundation and area immediately downstream of the dam during a dam breach event that erodes the embankment, which would lead to a greater release of the reservoir than that associated with erosion of the embankment alone. R-1 is a Priority Level 2 recommendation.
- R-2.** The Board recommends that DWR perform a stochastic flood event modeling study to improve the estimates of flood hazard with uncertainty bounds and consideration of inputs from regional precipitation analysis and paleohydrology, as appropriate, for use in future risk assessments. R-2 is a Priority Level 2 recommendation.
- R-3.** The Board recommends that DWR evaluate the potential and likelihood for reactivation of landslides identified in the reservoir rim landslide inventory, and the initiation of new failures in areas of weak weathered bedrock underlying steep slopes, to generate a surge of water that could overtop PCSD (either as a landslide-generated impulse wave or the release of water temporarily impounded by a landslide debris dam blocking a reservoir arm) or to block the reservoir channel causing a rise in reservoir level that could overtop PCSD. R-3 is a Priority Level 3 recommendation.
- R-4.** The Board recommends that the scopes, urgency and priority of all investigations and studies, including improved life-loss estimation, and, as appropriate, other types of consequences estimation, should be developed using risk insights and should provide outcomes in a form that will be useful to support future quantitative risk analysis (e.g. considering a range of loading conditions and uncertainty in key parameters). This recommendation would be best implemented if DWR developed a framework for a range of levels of risk analysis including, where appropriate, application of quantitative risk analysis, with consideration given to

uncertainties, as a tool for a) understanding and evaluating the risk associated with potential failure modes for the Oroville Dam Complex, including system interactions considerations, and b) evaluating the effectiveness and justification for risk reduction alternatives to develop a comprehensive risk reduction plan. R-4 is a Priority Level 3 recommendation.

**R-5.** The Board recommends that within the unified framework for condition assessment, risk management, and strategic planning of capital investments, which DWR is adopting for SWP infrastructure (DWR Strategic Plan), the implementation of the corresponding process for the Oroville Dam Complex provide for appropriately considering “non-breach damage PFMs”, non-life loss PFMs, not-estimated PFMs and other cases listed in Section 3.2.1.1.4a in addition to “breach/life-loss” PFMs. This will require developing methods for weighing life-loss as well as non-life loss consequences, and in the case of not-estimated PFMs, developing methods for assigning urgency and priority to investigations and studies that will provide initial estimates for their risk to better inform DWR’s decision making for prioritizing and justifying risk reduction associated with these types of PFMs. R-5 is a Priority Level 3 recommendation.

Recommendations Regarding the Surveillance and Monitoring Plan

**R-6.** The Board recommends evaluating the suitability of LS 10 and LS 20 to act as reference monuments for horizontal movement considering site conditions, current monument conditions, behavior trends, and susceptibility to movement. R-6 is a Priority Level 2 recommendation.

**R-7.** The Board recommends that DWR evaluate the options to reduce the response time in the event of overtopping or breach of PCSD (associated with the identified PFMs), such as infrared cameras or increased surveillance by DWR staff of the area downstream of PCSD. R-7 is a Priority Level 2 recommendation.

**R-8.** The Board recommends that DWR perform a high-density three-dimensional (3D) survey of the embankment and abutments using laser scanning and/or photogrammetry methods, of a sufficient resolution and precision for comparisons with future 3D surveys to allow detection of overall changes in the embankment geometry. An initial survey should be performed to establish an appropriate baseline. Subsequent surveys should be performed as needed and after significant events, such as earthquakes and floods. R-8 is a Priority Level 3 recommendation.

**R-9.** The Board recommends the following updates and revisions to the DSSMP:

- a. The conflicting statements in the DSSMP on the increased monitoring frequency when the reservoir reaches or exceeds El. 890 ft. should be resolved.
- b. The DSSMP should provide a clear description of the reason that, and the date when, the new area benchmark Parish 3 was established. The date the new benchmark was established should be indicated on the plots of crest settlement time histories in the DSSMP and in future DSSMRs. In addition, to provide appropriate context for the plotted data, the DSSMP and DSSMRs should clearly state which benchmark was used before the change in benchmark.

- c. Prior crest centerline survey data should be included on a profile in the DSSMP and in future DSSMRs. This will allow for understanding of the changes in the PCSD crest elevation and camber over time.
- d. Clarifying text should be added to the DSSMP indicating that the current settlement design-based Threshold Levels are based on 2.5 times the cumulative heave experienced between 1967 and 1985.
- e. The DSSMP should include inspection and removal of debris from the inlet of the existing high flow detection device located immediately downstream of PCSD when the device is activated. R-9 is a Priority Level 3 recommendation.

#### **Recommendations Regarding the Field Inspection**

- R-10.** The Board recommends that DWR locate, visually inspect, and document the current surface conditions of the former mine adit plug, and if feasible, survey the invert elevation of the adit portal. R-10 is a Priority Level 3 recommendation.

#### **Recommendations Regarding the Operation and Maintenance Programs**

- R-11.** The Board recommends that an in-depth briefing on the outcomes of the L2RA process be conducted for senior DWR decision-makers to enhance their technical insights for decision making relevant to potential issues associated with the performance of the dam. R-11 is a Priority Level 2 recommendation.

#### **Recommendations Regarding the Supporting Technical Information Document**

- R-12.** The Board recommends the following updates to the STID:
  - a. A copy of the chapters of the L2RA Report pertaining to PCSD should be inserted into Section 1 of the STID for documentation purposes.
  - b. Section 2 of the STID should be expanded to provide available information on the embankment materials related to permeability, relative compaction, and gradation curves of the as-placed material.
  - c. The STID should provide additional information on the construction history and characteristics of the 100-ft.-wide upstream bench. If the information is not available, statements to that effect should be included in the STID.
  - d. The construction summary in Section 3 of the STID should be expanded to include available information on construction methods, including quality control during construction.
  - e. Section 5.1.4 should be expanded to include available information regarding the limestone deposits mapped in the vicinity of PCSD.
  - f. The STID should be updated to reflect new information from recent studies by HDR that is pertinent to the description of the dam and its materials, construction specifications,

geologic and seismic hazard studies, hydrology and hydraulic studies, and other pertinent documents.

- g. The one-dimensional (1D) and two-dimensional (2D) backwater analyses performed by DWR (Reference [20]) that showed 1-ft. and less than 0.25 in. backwater effects at PCSD, respectively, should be referenced in Section 6.2.7 of the STID.
- h. Figure 6-9 in the STID should be corrected by changing *Lesser of maximum inflow or 15,000 cfs* to *Lesser of maximum inflow or 150,000 cfs* for the case of *Greater than 175,000* at the bottom of the Release Schedule table for the Oroville Flood Control Diagram shown in this figure.
- i. Figure 6-9 is the 1971 Flood Control Diagram. It is recommended that the modified Flood Control Diagram referred to in Section 6.2.9 as providing *enhanced flood space* be included in addition to the 1971 diagram.
- j. Section 10 of the STID should be updated to include correspondence with FERC and DSOD since the 2018 update and correspondences since 2017 that concern the Ninth Board's review of DWR's response to recommendations by the Ninth Board.

R-12 is a Priority Level 3 recommendation.