

OROVILLE COMPREHENSIVE NEEDS ASSESSMENT

Independent Review Board Memorandum

DATE: July 12, 2019

TO: Mr. Sergio Escobar, Project Manager
Oroville Comprehensive Needs Assessment
California Department of Water Resources

FROM: Independent Review Board for
Oroville Comprehensive Needs Assessment

SUBJECT: Report No. 5

On Thursday July 11, 2019, the Independent Review Board (IRB) met at the Department of Water Resources (DWR) Oroville Field Division Office Main Conference Room at 8:00 am for briefings regarding progress on the Comprehensive Needs Assessment (CNA). The IRB met with representatives from the DWR Division of Engineering (DOE), DWR Division of Operations and Maintenance (DOM), Division of Safety of Dams (DSOD), the Federal Energy Regulatory Commission (FERC), and industry consultants working on the CNA for updates on:

- Progress on the Existing Conditions Screening Assessment for Tasks 1, 3, 4 and 5.
- The CNA Screening Process,
- The Embankment Piezometer Installation Early Implementation Project,
- Task 1 initial conceptual measures for risk reduction,
- Progress on the CNA report,
- Comparison of the CNA Existing Condition Assessment with the FERC Level 2 Risk Assessment (L2RA),
- The status of the IRB Comment Log, and
- Open discussion of the CNA study.

During the morning of Friday July 12, 2019, the IRB deliberated and prepared a draft of this report. Comments made on the individual presentations and the IRB's responses to

DWR questions for the IRB are included in this report. A reading of the IRB's draft report was made to representatives from DWR, DOE, DOM, DSOD, FERC, and industry consultants working on the project at 12:00 pm. The meeting was adjourned following the reading of the report.

All IRB members were present on both days including (Elizabeth) Betty Andrews, Lelio Mejia, Bruce Muller, Dan Wade and Paul Schweiger. A list of meeting participants for both days is attached.

QUESTIONS FOR THE IRB

- 1. Does the IRB have any recommendations or comments on the Task Team's Existing Conditions Assessment presentations?**

Response:

The CNA Team's presentations were well prepared and helpful. The IRB appreciates each Task Leader's summary of the status of their team's progress and findings as they relate to the Existing Conditions Assessment. The work completed since the last IRB meeting in March is remarkable and the IRB is pleased with the Team's progress. Based on the presentations and the materials provided for review, the IRB believes the CNA Team is on track to successfully complete this study. Below are some general IRB comments on the Existing Conditions Assessment as well as specific comments on Tasks 1, 3, 4 and 5.

General Comments:

The IRB concurs with the CNA Team's extension of the DWR Asset Management Risk Matrix from 7 to 11 consequence categories, and from 7 to 10 likelihood groupings to adequately differentiate the consequences and probabilities necessary for assessing risks associated with dam safety. The refinements to the matrix are appropriate given the wide range and scale of potential consequences and the low likelihood of many of the potential failure modes (PFMs). The refined matrix will help decision makers understand the risks and consequences of each PFM and the relative risk difference between PFMs.

To date, the CNA Team has considered a total of 372 PFMs, of which 127 were determined to be unique, credible, and worthy of additional effort to specifically estimate likelihoods and consequences. These 127 PFMs were fully developed into 407 scenarios with 2,035 consequence estimates. The 407 scenarios include lesser loading conditions in addition to the ultimate load, such as the probable maximum flood. Consequence estimates are being made for public safety and

potential for loss of life, regulatory compliance, flexibility and reliability of water delivery, flexibility and reliability of other State Water Project (SWP) purposes, and financial impact. The IRB believes that this effort ranks among the most significant and in-depth assessments of PFMs ever considered and developed for a dam project and the greatest range of consequences considered.

The IRB concurs with the overall PFM screening approach and the method used by each Task Team to reduce the 372 PFMs considered down to 127 PFMs that are being evaluated. The IRB was pleased to learn about the participation of senior members of the Project Integration Team in the review and acceptance of this important screening step to make sure that no PFMs considered were inadvertently omitted from being evaluated. **The IRB recommends that a record be kept of the 245 PFMs that were not carried forward along with an explanation of why each PFM was ruled out.** Similarly, the IRB encourages the Project Integration Team to maintain records of their reviews for future reference.

When determining consequences, the CNA Team is currently making a distinction between “direct” and “indirect” financial impacts as defined in the current DWR SWP Asset Management Approach (See discussion under Question 8 for comments on this aspect of the Existing Conditions Assessment).

In performing the risk analysis, the CNA Team made note of the level of uncertainty associated with the estimated probabilities of PFM occurrence and the estimated consequences. Uncertainty implies that potential risk levels may be greater or smaller than the estimated results. In at least some cases, the greater potential range of risks could drive different decisions in selecting candidate risk reduction measures. Therefore, **the IRB recommends that the CNA Study Team develop a process to incorporate consideration of uncertainty in the selection of risk reduction measures.**

The IRB concurs with reporting the estimated consequences for each PFM as incremental consequences (incremental consequences from failure versus consequences from flooding without failure). For clarity, the IRB suggests that the CNA Team consider also including and discussing the actual flood consequences with and without failure in the final presentation of results.

Task 1 – Emergency Spillway:

Out of 34 PFMs associated with the Emergency Spillway, 9 were fully developed. The activation frequency for the Emergency Spillway is reported to be a 350-year

flood event. Flood protection is provided by the dam with a maximum release of approximately 150,000 cfs before the downstream levees are overtopped. The operation of the flood control outlet (FCO) spillway above the 150,000 cfs up to the activation of the Emergency Spillway should follow the procedures in the U.S. Army Corps of Engineers Flood Control Manual established for the project, and this should be documented in the CNA report. The IRB notes that there are several PFMs associated with the FCO headworks that would cause the Emergency Spillway to operate at a higher frequency.

Preliminary analyses show that many of the risks associated with the Emergency Spillway were resolved or reduced with the 2017-2018 emergency remediation work that included buttressing the ogee gravity monoliths to improve their stability and constructing a downstream RCC apron and secant pile wall to reduce the risk of downstream erosion and headcutting under the Emergency Spillway control monoliths. The remaining primary residual risk appears to be the consequences associated with the deposition of eroded material from the Emergency Spillway into the Diversion Pool and the impact that it has on the Hyatt Power Plant. The analyses show that the risk is greatest for a lesser flood loading than the probable maximum flood. The ongoing scour analyses being performed to evaluate this PFM and lesser flows are important. The IRB suggests that the CNA Study Team calibrate or validate the erosion model using the experience from the 2017 spillway incident as well as consider simulation of plausible concentrated flow scenarios. The IRB would appreciate a presentation on this work at a future progress meeting.

Task 3 – FCO Headworks and Spillway:

The team lead for Task 3 provided an update on the team's effort to identify and assess PFMs for the FCO headworks and spillway. The complexity of the headworks structure required broad consideration by many disciplines and resulted in a significant number of failure modes to be considered. The presentation addressed several examples of failure modes that have associated risks which would suggest consideration of actions to reduce risk. To test the knowledge related to failure modes not addressed, the IRB explored the failure mode addressing backup power for the operation of the flood control outlet. The IRB was pleased to learn that there are multiple methods of delivering backup power to the spillway gates.

The IRB understands that a state-of-the-art dynamic non-linear seismic analysis of the FCO headworks structure is underway. Given the complexity of such analyses and the need for timely results for the CNA report, the IRB suggests a

high-level comparison to the new gated spillway structure at Folsom Dam which was designed based on the FCO headworks concept (as implemented at Oroville Dam) using state-of-the-art ground motions and analysis codes. This would provide a preliminary indication of the potential importance of the detailed analysis results to the overall CNA Study. In addition, **the IRB recommends that the non-linear model for the FCO headworks structure be used to also assess the stresses and strains for both balanced and unbalanced loads associated with the probable maximum flood.**

The IRB understands and considers appropriate that the Project Integration Team will consider a number of failure modes associated with the headworks which could increase the probability of discharge through the Emergency Spillway above the probabilities used in Task 1.

Task 4 – Low-Level Outlets:

The presentation on the existing conditions assessment for CNA Task 4 - Low Level Outlets, was comprehensive and very helpful to facilitate the IRB's understanding of the Task 4 Team's extensive work since the last meeting. The Task 4 Team considered three levels of failure: (1) an uncontrolled release of the reservoir, (2) inability to deliver water to the SWP, and (3) the systems not functioning as designed. A total of 86 PFMs that were identified from previous Part 12 workshops, L2RA workshops, and brainstorming by the Task 4 Team were organized into four systems including the Hyatt Intake and Conveyance, the Hyatt Powerplant, the River Valve Outlet System, and the Palermo Tunnel. Of these, 31 PFMs were selected as key failure modes for detailed development.

The four examples provided in the presentation facilitated the IRB's understanding of how the Task 4 Team approached the assignment of nodal likelihood to event trees by developing consensus among a diverse group of team members with expertise in many engineering and science disciplines including: civil, geotechnical, geology, seismic, tunneling, structural, hydraulic, mechanical and electrical. Although the Team acknowledged areas of challenge and uncertainty that need further development and refinement, the IRB views that this consensus-based approach among a diverse set of subject matter experts strengthens the validity of the preliminary results of the assessment, and notes that the preliminary assessment produced results that are in general alignment with the L2RA results for similar PFMs and loading conditions. The IRB looks forward to viewing the final results of the Existing Condition Assessment and the development and assessment of measures to reduce risk.

Task 5 – Embankment:

The IRB appreciated the project team's thorough presentation on the existing conditions assessment for the Oroville Dam Complex embankments, namely Oroville Dam, Bidwell Bar Canyon Saddle Dam (BBCSD), and Parish Camp Saddle Dam (PCSD). As in the case of other tasks, the process used to identify, develop, and evaluate PFMs for the embankments, and to assess corresponding consequences, seems thorough and methodic. The process resulted in the identification and development of a large number of PFMs for the three embankments. The IRB considers the presented methodology for development of PFMs and for evaluation of their likelihood, as illustrated by the project team through a few examples, to be reasonable and appropriate.

As is the case for many embankment dams, the potential for internal erosion, overtopping, and instability were identified as the main risk drivers. For many PFMs involving the same progression mechanism, those PFMs associated with moderate consequences were estimated to be higher risk than those leading to a full dam breach. One of the highest risk PFMs evaluated is that associated with potential overtopping of the PCSD.

Internal erosion mechanisms were generally estimated to be lower risk, most likely in recognition of the robust design of the dams. In this regard, the IRB notes that although the likelihood estimates for PFMs associated with these mechanisms seem reasonable, the assessment of the potential for internal erosion is generally subject to large uncertainty. This is likely to be the case for the project embankments in view of the standards at the time for filter compatibility used in their design and the broadly graded nature of the materials used in their construction. In addition, for these types of PFMs the load has a high probability of occurrence as it is generally sustained over the life of the dam. Thus, these types of PFMs are often associated with higher estimated risks for embankment dams. The IRB suggests that the Task Team consider how to address uncertainty in the assessment of internal erosion in the identification and development of remedial measures.

2. Does the IRB have any recommendations or comments on the CNA Screening Processes?

Response:

Members of the Project Integration Team presented the procedures used to: (1) develop PFMs and screen them to identify those that would be developed to sufficiently understand the associated risks, and (2) develop measures to be considered and developed to a point of feasibility for inclusion in the final report. The screening process for PFMs appropriately allows for consideration of previously identified failure modes and new failure modes identified by both the CNA task teams and the L2RA effort. It also allows for consolidation of duplicate and/or similar failure modes.

There is a review process in place to review task team decisions made to not fully develop failure modes with extremely low probabilities. The screening process for measures to reduce risk allows for brainstorming of actions that could be taken to address significant risks. These “initial conceptual measures” will then be evaluated to identify any fatal flaws. The “candidate measures” will then be evaluated to determine their effectiveness in meeting the objectives set forth by the task teams; those that pass this test will be deemed “feasible measures”. The IRB believes this process will be effective and appropriate to identify feasible measures for consideration.

3. Does the IRB have any recommendations or comments on the embankment piezometer installation?

Response:

The IRB is pleased with DWR’s intention to implement early risk reduction measures that are practical and readily identifiable, an approach which the IRB endorsed in one of its prior reports. One of those early implementation projects is the installation of new piezometers in the downstream shell and foundation of Oroville Dam. The installation is planned for two phases. The proposed Phase 1 consists of installing six piezometers in the area of the downstream seepage barrier, drilled from the ground surface upstream and downstream of the barrier, and to the sides beyond the ends of the barrier. Phase 2 consists of installing 5 piezometers drilled from the core block galleries into the foundation and the embankment downstream shell, and from the grouting gallery into the abutments. The CNA Team’s rationale for the piezometer installation seems reasonable and

the IRB agrees with the overall concept, although we note that additional redundancy in the downstream piezometer installation would be desirable. Thus, **the IRB recommends that DWR consider installing two (as a pair) additional piezometers some tens of feet to the right of proposed piezometers P-200A and P-200B, along the road at elevation 350 and within the footprint of the river channel, to measure water levels below Zone 5A upstream of the seepage barrier.**

4. Does the IRB have any recommendations or comments on Task 1 – Preliminary Measures?

Response:

Preliminary measures to reduce risk associated with erosion of material into the Diversion Pool, backwater flooding the Hyatt Power Plant, environmental impacts, cultural resource impacts, and head-cutting under the Emergency Spillway monolith were presented to the IRB. Each Task Team is similarly developing a master list of “initial conceptual measures” that will be screened down to “candidate measures” and ultimately reduced to “feasible measures”. The IRB commends the Task 1 Team for developing a wide range of creative initial conceptual measures, including variations of a measure that incrementally reduce risk. The IRB believes that the primary focus should be to develop as many conceptual measures as possible in a “brain storming” approach to ensure that all opportunities are being considered, but not to develop them in too much detail. It is understood that many of the risk reduction opportunities identified in the “initial conceptual measures” phase may have fatal flaws. To expedite the screening process from the initial conceptual measures to candidate measures, the IRB suggests that the CNA Team develop an efficient and consistent approach.

The IRB recognizes that the conceptual measures presented are works in progress and intended for initial consideration. The IRB suggests that the Task 1 Team specify that the channel alignment for conceptual measures that involve improving the conveyance of flows from the existing Emergency Spillway to the Diversion Pool be as straight as possible since these flows would be expected to be supercritical. The IRB believes that an understanding of the bedrock jointing will be important in the evaluation of some of the conceptual measures being considered.

5. Does the IRB have any recommendations or comments on the final and task-level report outlines?

Response:

The IRB commends the early effort to further develop the final and task-level report outlines. The task-level report outline that was previously presented in IRB Meeting #4 has now been further developed into a detailed template for task teams to begin using immediately. The IRB views that this up-front work to develop the detailed template and commitment to provide periodic reviews of all task reports under development will greatly help facilitate clear, efficient and effective report writing in a consistent manner across task teams.

The IRB appreciates the use of text boxes in the report margins to summarize and highlight key information. The IRB concurs with keeping the individual Task Team reports separate from the main report.

6. Does the IRB have any recommendations or comments on the CNA comparison with the L2RA?

Response:

The concurrent CNA and L2RA efforts to better understand project risks presented an opportunity for comparing the results of each process. While the processes for each study do not have identical objectives, they intersect when considering extreme events to which the dam could be subjected as well as the life safety consequences. The vast majority of PFM cases compared show general agreement with respect to the PFMs carried forward for evaluation and their likelihood for occurrence. In those cases where there are noticeable differences, the CNA Task teams are reviewing the basis for their estimates. The comparisons of results were reviewed to look for any unusual patterns, and it was determined that the differences appear to be randomly distributed with no indication of one group of evaluators being more or less conservative with respect to the other evaluators.

The general agreement between the results was encouraging given that the L2RA team is largely comprised of industry experts with significant knowledge of dams throughout the nation and world, while the CNA Task teams largely relied on staff intimately familiar with the details and history of Oroville Dam. The IRB believes this comparison has served as a unique and effective quality assurance process for identifying the PFMs with risk levels that warrant consideration of risk reduction

measures. The IRB concurs with extending this analysis to the facilities that have yet to be evaluated by the L2RA Team once this information becomes available.

7. Does the IRB have any recommendations or comments on the IRB Comments Log?

Response:

The IRB reviewed the Comments Log and entered the status of each recommendation based upon the information provided in presentations to date. The IRB Comments Log is up to date.

8. Does the IRB have any other recommendations or comments?

Response:

The IRB recommends that the definitions of “direct” and “indirect” costs used for CNA purposes be revisited. It is possible that the definitions applied in the SWP Asset Management Framework are appropriate for general SWP Operations, Maintenance, Repair, Replacement, and Rehabilitation purposes, but may not best serve the needs of a water resources planning study. For example, definitions of direct and indirect costs in accounting principles are driven by costs that would accrue to the budgeting entity only. These may not be appropriate definitions for purposes of examining financial impacts for a project measure under the CNA.

The IRB looks forward to hearing about the following topics at the next IRB meeting:

- Results from the completed CNA Existing Conditions Assessment (semi-quantitative risk analysis (SQRA)) and the L2RA
- Progress reports for CNA Tasks, including: identification of measures for risk reduction, identification of any measures screened out from further consideration, and progress in completing the task reports providing process and background information.

Concluding Remark:

The IRB appreciates the continued enthusiasm demonstrated by the CNA Team and the progress that has been made. The IRB looks forward to seeing the results from each team's assessment of risk reduction measures for the identified risks.

IRB RECOMMENDATIONS SUMMARY

- M5-1 The IRB recommends that a record be kept of the 245 PFMs that were not carried forward along with an explanation of why each PFM was ruled out.
- M5-2 The IRB recommends that the CNA Study Team develop a process to incorporate consideration of uncertainty in the selection of risk reduction measures.
- M5-3 The IRB recommends that the non-linear model for the FCO headworks structure be used to also assess the stresses and strains for both balanced and unbalanced loads associated with the probable maximum flood.
- M5-4 The IRB recommends that DWR consider installing two (as a pair) additional piezometers some tens of feet to the right of proposed piezometers P-200A and P-200B, along the road at elevation 350 and within the footprint of the river channel, to measure water levels below Zone 5A upstream of the seepage barrier.
- M5-5 The IRB recommends that the definitions of “direct” and “indirect” costs used for CNA purposes be revisited.

Respectfully submitted,


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