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Oroville Dam Probable Maximum Floods and Spillway Design Floods

July 29, 2022, ***extensively updated 7/7/2023***

Summary: The purpose of this memo is to describe what is known about Oroville Dam Probable Maximum Flood (PMF) estimates and related matters. PMFs are runoff model estimates generated from a hypothetical near Noachian Deluge developed by the National Weather Service called the Probable Maximum Precipitation event (PMP). The PMF is used to ensure that dam spillways are sufficiently sized and capable to handle any potential dam outflows. The Spillway Design Flood is the maximum inflow/outflow flood hydrograph that the spillways can accommodate within design freeboard, the latter the elevation differences (usually displayed in feet above sea level) between the "still water" surface of the reservoir and the top of the dam or spillway training wall(s). To telegraph the conclusion of this short memo, the 2017 (and apparently current) Oroville Dam PMF is modeled to encroach on 40% (two feet) of the dam and auxiliary spillway's nominal five-foot design freeboard during the Spillway Design Flood. In 2022, the Federal Energy Regulatory Commission (FERC) asked the owner of the Oroville Dam Complex, the California Department of Water Resources (DWR or Department), for an expeditious report and schedule for determining the safe capacity of the auxiliary spillway and spillway adequacy of DWR's Oroville Dam. Typically, FERC orders its licensees to make modifications to their dams or spillways to safely accommodate new assessments of PMFs. DWR has argued and likely is arguing that it should not have to meet this requirement from its federal regulator. The Oroville Dam FERC docket does not appear to contain any response to FERC's request.

Baseline PMFs and Spillway Design Floods: The 1970 U.S. Army Corps of Engineers (Corps) Oroville Dam "Flood Control Manual" provides the design baseline capabilities of the Oroville Dam spillways.

The Spillway Design Flood for Oroville Dam has a peak inflow of 720,000 cfs and a 72-hour runoff value of 2,510,000 acre-feet.[1] The 1968 "Spillway Design Flood Routing" curves show a peak inflow of 718,000 cfs and a peak outflow of 623,200 cfs.[2] The Probable Maximum Flood (PMF) is described to be the basis of the Spillway Design Flood.[3] The maximum storage attained in the PMF routing is 3,817,000 acre-feet,[4] corresponding to a reservoir elevation of 917.2 feet.[5] The nominal design elevation of the dam crest is 922 feet,[6] providing for a nominal design-freeboard (dam and spillway training wall elevation minus the still-water PMF peak reservoir elevation) of five feet.[7] In addition to factors of safety, freeboard helps to contain wind and wave runup and allows for safer operation of the dam and related facilities.

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[1] Oroville Dam and Reservoir, Feather River, California, *Report on Reservoir Regulation for Flood Control*, August 1970, Department of the Army, Sacramento District, Corps of Engineers, Sacramento, California, p. 13. (Oroville Flood Control Manual) Access to reservoir regulation manuals are restricted Critical Energy Infrastructure Information. Only redacted versions are presently available from the Corps.

[2] Id., Chart 33.

[3] Id., p. 13.

[4] Id., Chart 33.

[5] Id., Page 12 of Chart 16. Rounding off, the *Oroville Flood Control Manual* alternatively reports that "Maximum storage during the spillway design flood is 3,814,000 acre-feet at 917.0 feet, p. 18.

[6] Id., The dam's gross pool is 3,538,000 acre-feet. This is at elevation 900 feet, p. 18.

[7] As constructed, DWR recently determined that the spillway design flood has at least six feet of freeboard, at least at for most of the dam. DWR told FERC that "[d]ue to the placement of a significant camber during original construction, the crest of the dam is generally at least 2 feet higher at elevation 924 feet or more for almost its entire length…However, the right end of the dam crest is below elevation 924 feet for only a relatively short distance: on the order of 300–400 feet. In this limited area, the crest appears to be on the order of elevation 923 feet or higher, not the elevation 922-foot nominally assumed." However, "LiDAR surveys presented in Figure 2 show that the crest of the dam drops down to elevation 922 feet only on the non-overflow monoliths of the FCO [service spillway] Headworks Structure and at the abutments of the embankment dam. (Letter from Gwen Knittweis, Chief, Hydropower License Planning and Compliance Office, Executive Division, Department of Water Resources, to Mr. Frank L. Blackett, P.E., Regional Engineer, Federal Energy Regulatory Commission, March 22, 2021, p. 3.) (FERC e-library no. 20210322-5282) (DWR March 22, 2021, letter) https://www.friendsoftheriver.org/wp-content/uploads/2022/07/20210322-5282_20210322_DWR-FERC_P2100_OERS_Response_PMF_Study.pdf. The letter does not provide information on the as-built elevation status of the auxiliary spillway training wall or auxiliary spillway crest. From previous statement, it would appear that as-built portions of the service spillway supporting structure are at elevation 922. This is consistent with DWR Bulletin 200: "The top of the 570-foot-long headworks is coincident with the top of the Dam (elevation 922 feet). The gated outlet passages are placed in an excavated channel depressed from the emergency spillway approach channel." California *State Water Project, Volume III, Storage Facilities, Bulletin Number 200* November 1974, State of California, The Resources Agency, Department of Water Resources, p. 93. (DWR Bulletin 200)

The maximum Oroville Dam main service spillway (FCO) PMF release capacity is 296,000 cfs.[8] Additional flows from the service spillway are likely constrained by the gate support structures.[9] The auxiliary spillway and its surrounding lands are not similarly constrained. For PMF peak outflow, assuming no river valve outlet system (RVOS) or powerplant releases,[10] by subtraction from the design peak outflow, this would mean a 327,200 cfs release at the auxiliary[11] spillway during the Spillway Design

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[8] Id., p. 19.

[9] "The headworks structure (Figure 77) has eight outlet bays controlled by *top-seal* radial gates, 17 feet - 7 inches wide by 33 feet high." (DWR Bulletin 200, p. 92) Emphasis added.

[10] Operation of the powerhouse and RVOS is not likely during a PMF. During the 2017 spillway incident, among other reasons, high water stages at the powerhouse/RVOS from downstream hillside deposition partially damming the channel required a shutdown of both systems. Extensive use of the auxiliary spillway would also mobilize hillside deposition into the channel. Also, high stages at the powerhouse/RVOS outlet could also be expected to result from a PMF release even in the absence of hillside deposition.

[11] DWR refers to the ungated spillway as the "emergency" spillway, a spillway category where more damage can be associated with their use under FERC's *Engineering Guidelines*. In 2022, FERC told DWR to classify the spillway differently: "The emergency spillway should be reclassified as an auxiliary spillway since it is a secondary spillway in the project's current configuration and is being relied upon to pass more flow than the primary spillway (flood control outlet (FCO)) during a PMF event." (Letter to Mr. Ted Craddock, Oroville Emergency Recovery - Spillways, California Department of Water Resources, from Frank L. Blackett, P.E., Regional Engineer, San Francisco Office, Federal Energy Regulatory Commission, October 25, 2018, p. 3.) (FERC e-library no. 20181025-3103) (FERC October 25, 2018, letter). https://www.friendsoftheriver.org/wp-content/uploads/2018/10/20181025-310333211845-FERC-on-spillway-damage-and-auxiliary-spillway.pdf. There are FERC *Engineering Guidelines* consistency and potential regulatory consequences to such a determination. As described in the *Engineering Guidelines*, "Auxiliary spillways are usually designed for infrequent use, and it is acceptable to sustain limited damage during passage of the IDF" [inflow-design-flood, the PMF in this case]. Emergency spillways are different. "Because of their infrequent use it is acceptable for them to sustain significant damage when used and they may be designed with lower structural standards than used for auxiliary spillways." Nevertheless, there are still constraints on even emergency spillway design: "Large conservation storage volumes should not be lost as a result of degradation of crest during operation" and "the effects of a downstream flood resulting from uncontrolled release of reservoir storage should not be greater than the flood caused by the IDF without the dam." (FERC *Engineering Guidelines*, October 1993, pp. 2-11 & 2-19) DWR objected to FERC's reclassification of the spillway arguing that "DWR believes there is no immediate reason to rename the spillway. DWR believes maintaining the original name that appears on all past and present official documents and reports would be prudent to avoid confusion, both for our respective organizations and the general public."(DWR March 22, 2021, letter, p. 4) FERC's response was the following: "While we continue to hold to our previous comment regarding the classification of the emergency spillway, we have no objection to DWR continuing to use the current name for continuity, as proposed." (Letter from Frank Blackett, Regional Engineer, FERC Office of Energy Projects, Division of Dam Safety and Inspections, to Mr. Jeremiah McNeil, Acting Manager Hydropower License Planning and Compliance Office, California Department of Water Resources, July 14, 2022, p. 2.) (FERC e-library no. 20220714-3063) (FERC July 14, 2022, letter)

Flood. If RVOS and powerhouse outlets were assumed to be used at their design capacities, the design auxiliary spillway release would be closer to 300,000 cfs. Alternatively, in Chart 19, at elevation 917 feet, the combined rating curves of the two spillways achieve a maximum release of 650,000 cfs.[12] Under this understanding, the arithmetic for the auxiliary spillway PMF flow at the design freeboard would then be approximately 354,000 cfs.

Varying PMF estimates have been made over the years. Some were compiled in the December 15, 2014, "Oroville Dam Part 12D Report " prepared as part of the Federal Energy Commission's (FERC) Office of Energy Projects, Division of Safety of Dams and Inspections'[13] periodic reviews. They were presented in tabular form as adapted here, in which I have also added data from recent FERC/DWR correspondence:

Study Identifier	Author/date	PMP Basis	Initial reservoir elevation	Inflow/outflow in cfs	Peak reservoir elevation
PMF-58	USACE 1958	HMR 36	900 ft.	718,000/ 624,000	917 ft.
The preceding document includes an analysis of the Standard Project Flood and includes estimates of the PMF and freeboard requirements for Oroville Reservoir. The precipitation depth used to develop the hydrology for the PMF was developed by the Hydrometeorological Section of the U.S. Weather Bureau using HMR 36.					
FR-58	USACE 1958	HMR 36	900 ft.	718,000/ 624,000	917 ft.
The preceding flood routing (FR) report utilizes PMF-58 to develop the flood control operation requirements that were used to assist in the project design. Operation criteria included rules both for the use of regular flood control space and for the operation of spillway gates during extreme flood emergencies. Reservoir release limitations, flood control storage, and emergency spillway release diagrams were also included in this report.					
FR-70	USACE 1970	HMR 36	900 ft.	960,000 (likely inflow, the table is not clear.)	NA
The preceding "Feather River Basin, California, Probable Maximum Flood For Lake Oroville", October 1980 is an update and addendum to PMF-58. This update included the development of a HEC-1 model and model calibration to the December 1964 flood. Inputs were generally carried over from PMF-58, except that the PMP was revised to 28.9 inches from 21.1 inches, an additional 4.5 inches to the PMP from snowmelt was calculated, and overtopping flows from Butt Valley Dam (assumed failed) and Bucks Lake Dam were included.					
FR-81	Leps 1981	HMR 36	—	—	—

https://www.friendsoftheriver.org/wp-content/uploads/2023/06/20220714-3063_P-2100-000-Oroville-PMF-Nos.-4-5-6-Responses-2021.pdf. We use FERC's preferred classification in this memo.

[12] Oroville Flood Control Manual. Graphical interpretation of Chart 19.

[13] FERC is the Oroville Dam Complex's federal regulator. The state regulator dam safety regulator is the California Department of Water Resources Division of Safety of Dams (DSOD).

The preceding flood routing (FR-81) memorandum was developed to address the reasonableness of the use of substantially lower initial Oroville Lake elevation before routing the PMF-80 flood. It was determined that El 855.0 was an acceptable and logical initial reservoir elevation before the occurrence of a PMF, assuming that the flood control discharge rules that are outlined in the FR-70 study are followed. The FR-81 study also provides a table that includes results from a hydrologic analysis for several storm events. The table provides the initial reservoir elevation, peak inflow, maximum reservoir elevation, and resulting peak outflow for each scenario.					
FR-83	DWR 1983	HMR 36	855 ft.	1,167,000/ 798,000	921.41 ft.
The preceding report provides an analysis of a hypothetical dam break at Butt Valley Dam to evaluate the effects of the resulting flood wave upstream and through Oroville Reservoir during a PMF event. The computer program DAMBRK was used to calculate the flood wave discharge, depth, and velocity. The FR-83 report also provides a wind-wave analysis to evaluate overtopping potential due to wave run-up.					
PMF-03	DWR 2003	HMR 59	900 ft.	725,000/ 675,000	917.5
The preceding study (PMF-03) is considered an update and addendum to the PMF-80 report. This report uses HMR 59 to estimate the PMP and the resulting PMF at Lake Oroville. This report also includes the conversion of the basin model from the original HEC-1 model to the newer HEC-HMS model. The change to HMR 59 from HMR 36 resulted in a 17 percent decrease in peak flow through the reservoir. This study also eliminated overtopping failure of the Butt Valley Dam from the PMF inflow and it is unclear whether snowmelt impacts were considered in the results.					
FR-06	DWR 2006	HMR 59	901 ft.	725,000/ 675,00	917.5
The preceding memorandum (FR-06) includes routing of the PMF-03 that was developed in the 2003 study through the spillway at Oroville Reservoir under various conditions. A review of Oroville Dam in 1999 by the Director's Safety Review Board (Sixth Part 12D Board) advised that for the development of an updated PMF, routing should consider full operation of the spillway gates and the effect of non-operation of one and two spillway gates. As a result, this study utilized PMF-03 for each modeling scenario, and only the initial reservoir elevation and spillway discharge curves were adjusted to evaluate the peak discharge and resulting reservoir water surface elevation.					
	DWR 2017	HMR-59 NOAH Atlas 14		743,800/ 716,000	919.2 ft.
The preceding information was gathered from FERC/DWR correspondence from 2018 to 2022 because, apparently, estimates of hypothetical “Noachian” deluges (PMFs) are regarded as Critical Energy Infrastructure Information and are not currently available to the public.					

The Most Recent PMF: The California Department of Water Resources (DWR or Department) public version of the 2020 Oroville Dam *Comprehensive Needs Assessment*[14] (CNA) did not provide any quantitative information on Oroville Dam PMFs or acknowledge any recent revisions to the PMF or any discussions on the implications to

[14] The public version of the CNA can be found here: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/State-Water-Project/Oroville-CNA/Files/20201030_Oroville_CNA_Project_Report_Summary_Final_Accessibility-Check-FINAL.pdf.

the adequacy and capacity of the dam's auxiliary spillway,[15] although the apparent deficiency in the public draft and scope of the CNA was repeatedly raised by this member of the Department of Water Resources' CNA *Ad Hoc*.[16] The *Ad Hoc* was not provided any estimates of the PMF, the recent PMF changes, or their implications for spillway capacity and other improvements at the auxiliary spillway.

What is known about these questions is what can be gleaned from the publically available correspondence between FERC's Office of Energy Projects, Division of Dam Safety and Inspections, and the Department. There isn't much, but what there is appears to be meaningful.

First, although the 2017–2018 reconstruction and additions increased the likely resistence of the auxiliary spillway to backstepping erosion resulting in an uncontrolled release from the reservoir,[17] the geometric capacity of the spillway — determined by the

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[15] The CNA public draft did recommend a three-foot dam raise of the Parish Camp Saddle Dam as an Interim Implementation Project, to be completed in the near term. "While DWR is considering long-term risk-reduction measures for the entire SWP as part of its overall asset management approach, including potential risk-reduction plans at the Oroville Dam Complex, the CNA recommends several interim risk-reduction actions for the Oroville Dam Complex be completed in the near term (considered to be within approximately five years) (p. 11). The CNA noted that the PMF would not *overtop* the saddle dam (or other dams) (p. 7), but the Parish Camp Saddle Dam work was justified for potential events more rare than the PMF because the low cost of the raise (p. 78). The CNA did not discuss PMF *freeboard* encroachments or regulatory reluctance to allow freeboard encroachments. The only other CNA mention of the PMF was in the definition section (p. 94).

[16] For descriptions of the *Ad Hoc* see the CNA p. 4, and DWR's CNA web page: https://water.ca.gov/Programs/State-Water-Project/SWP-Facilities/Oroville/Oroville-Dam-Safety-Comprehensive-Needs-Assessment.

[17] The hilltop downstream of the auxiliary spillway was armored with concrete and a terminal cutoff wall. However, the hillside below remains susceptible to erosional mobilization and deposition of large volumes of earth and rock into the downstream channel if significant water is discharged over this spillway. This should be planned for — and not just for PMF operations. The Reservoir Design Flood is a hypothetical flood used to characterize the *flood-control performance* of the project. The Reservoir Design Flood is a smaller flood than the Spillway Design Flood, the latter which is used to determine *dam and auxiliary features-safety* performance. According to the still-in-force 1970 Corps Oroville Dam Flood Control manual, 9.7 feet of auxiliary spillway *surcharge* (above the auxiliary spillway lip) operations would be needed to confine combined outflows to the Reservoir Design Flood objective release of 150,000 cfs. At the peak of such operations, ~130,000 cfs would be discharged onto the hillside below the auxiliary spillway. (Oroville Flood Control Operations Manual, charts 16 and 32) This is ten times the 2017 peak discharge. In contrast, in the 2017–2018 and 2018–2019 flood seasons, the latter operation going forward, DWR's *interim* operations plan increases the flood-season flood reservation (and decreases top-of-conservation) to avoid use of the auxiliary spillway during the Reservoir Design Flood, but these are discretionary operations plans by DWR, although developed with concurrence from the Army Corps of Engineers and FERC, and may change in the future. "The Plan does not deviate from our Manual or

height difference between the lip of the spillway crest (at 901 feet) and the elevation of the dam and spillway training walls (at 922 feet) minus freeboard and multiplied by the length of the spillway[18] — remained unaltered.[19] The same cannot be said about the PMF. The 2017 PMF inflow determination resulted in a new hydrograph[20] with a peak inflow of 743,800 cfs and a 72-hour volume of 3,092,000 acre-feet[21] (compared with the original peak inflow of 718,000 cfs and a 72-hour runoff volume of 2,510,000 acre-feet[22]). Perhaps more meaningfully, the PMF outflow for the auxiliary spillway is now referred

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existing agreements. Therefore, relative to our regulatory role and associated policies, it does not require our approval or concurrence." (Letter to Mr. Joel Ledesma, State Water Project Deputy Director, from Colonel David G. Ray, Commander, Sacramento District, U.S. Army Corps of Engineers, January 3, 2018.) https://www.friendsoftheriver.org/wp-content/uploads/2023/06/Sacramento-District-Oroville-interim-ops-approval-2018-ocr.pdf. DWR developed its first interim plan for the 2017–2018 operating season. (FERC e-library no. 20171017-5033)
https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/FOTR/for_13.pdf
https://water.ca.gov/News/News-Releases/2017/Oct-17/DWR-Releases-2017-18-Lake-Oroville-Flood-Season-Operations-Plan.
DWR has subsequently been submitting yearly notifications to the Corps of Engineers (and filed with FERC e-library nos. 20191001-5257, 20201013-5335, 2021124-5180, & 20221209-5004) confirming their intention to follow their published 2018/2019 "final" Oroville Flood Operations Plan (Plan). This plan is available from DWR:
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/State-Water-Project/Oroville/Misc/Lake_Oroville_2018-2019_FloodOps_Plan_011819_ay_19.pdf.

[18] The length of the Oroville Dam spillway is 1,730 feet. (Oroville Flood Control Manual, p. 19, DWR Bulletin 200, p. 92)

[19] "At the conclusion of the current spillway modifications, the original design capacity of the flood control outlet (FCO) will be restored;" (FERC October 25, 2018, letter, p. 2)

[20] This is not the only relevant performance standard that may (should) change. The Oroville Dam Reservoir Design Flood was the Standard Project Flood at the time of design. (Reservoir Regulation Manual, p 16.) Standard Project Flood (SPF) estimates are based on a methodologies developed by the Corps to establish a reasonable "worst-case" flood-magnitude estimate the purposes of sizing a floodwater-management project for an urbanized area. *(ACE Engineering Manual, 1110-2-141, SPF Determination, SPF Methodologies*, 1 March 1965) SPFs are often scaled from PMFs as it appears to be here. (An interesting contrary view, perhaps supported by the Oroville Dam Part 12D Report table earlier in this memo, was taken by DWR John Leahigh, Water Operations Executive Manager, in answer to a question posed by this writer during the CNA *Ad Hoc* — Mr. Leahigh replied that the SPF was first derived from HMR 36, and then the PMF was scaled from the SPF.) Regardless, if there is a scaled relationship, when PMFs are updated, so should SPFs — although SPF revisions have not found well-exercised regulatory settings, in contrast to PMFs. Perhaps consequently, DWR did not discuss in the interim operations plan or Comprehensive Needs Assessment any upward revising of the SPF and consequent need to revise the Reservoir Design Flood in response to the 2017 PMF revision.

[21] FERC October 25, 2018, letter, p. 1.

[22] Oroville Flood Control Manual, p. 13.

to as 420,000 cfs, roughly 70,000 to 100,000[23] cfs or more than the design spillway capacity at the design freeboard.[24] The 2017 PMF peak reservoir elevation is 919.2 ft.[25] Thus, the peak still-water[26] reservoir elevation stage for the 2017 encroaches on 40% of the nominal five feet of design freeboard.[27]

Setting aside the question of wave runup, the new PMF analysis does demonstrate that the new PMF can be routed over the spillways without spilling over the dam — something that DWR provides assurances to the public.[28] However, DWR has not so far

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[23] Confusingly, apparently conflating spillway capacity and engineering resilience, FERC had also written to DWR the following: "however, the design capacity of the emergency spillway is on the order of 100,000 cfs to 300,000 cfs lower than the maximum PMF discharge through the emergency spillway." (FERC October 25, 2018, letter, p. 2.) We are unaware of any recent PMF estimates that would result in an excess PMF discharge of more than 120,000 cfs over the auxiliary spillway, but since PMF studies and estimates apparently are no longer public information, we cannot confirm this. Subsequent correspondence, may have clarified this: "DWR identified an interim maximum combined spillway design flow of approximately 400,000 cubic feet per second (cfs) at the conclusion of construction in 2018 pending further evaluations of the integrity of the Emergency Spillway (ES). One hundred thousand cfs flow was the portion that would pass over the ES. The 100,000 cfs is the flow of unlimited duration that could be safely passed over the end of the roller compacted concrete (RCC) apron without inducing significant damage to either the secant pile wall or the RCC apron." (DWR March 22, 2021, letter p. 1) This is not necessarily reassuring.

[24] "The hydraulic capacity of the ES [emergency spillway] is approximately 420,000 cfs at the peak stage of the PMF at elevation 919.2 feet." (DWR March 22, 2021, letter, p. 2.) "As it stands, the hydraulic capacity of the emergency spillway is 420,000 cubic feet per second (cfs) during the probable maximum flood." (DWR Director Karla Nemeth email to Ronald Stork, July 28, 2022.) (Director Nemeth email, July 28, 2022)

[25] DWR March 22, 2021 letter, p. 2.

[26] Reservoirs during windy conditions can have wave runup. This is one of the reasons for design freeboard. In correspondence with DWR, FERC noted that "the wind wave setup and runup study showed that 3.8 feet of overtopping of the Main Dam is possible at the peak of the new PMF determination." (FERC October 25, 2018, letter, p. 2) The Department responded with a "Critical Energy Information Infrastructure" (CEII) analysis that wave runup would be no more than 0.8 feet below the design elevation of the dam and that the majority of the dam reached an elevation higher than 922 ft. (DWR March 22, 2021, letter, p. 3) CEII materials are not available for public review.

[27] As noted earlier, the as-built freeboard in most, but not all, reaches of the dam, exceeds the design freeboard by more than one foot — although no public information exists for the auxiliary spillway training walls.

[28] "This flow through the emergency spillway coupled with additional flow that would occur through the flood control outlet [FCO, the main service spillway] is adequate to pass the probable maximum flood without overtopping Oroville Dam." (Director Nemeth email, July 28, 2022) "[A]ll three embankment dams can safely retain flood waters associated with a probable maximum flood (PMF), the largest flood loading generally required by dam safety regulatory agencies to be safely retained by a dam." (CNA, p. 7)

discussed that it does so by encroaching on 40% of the design freeboard of the auxiliary spillway, which it apparently regards as an acceptable condition.[29]

DWR's 2020 Comprehensive Needs Assessment approaches Oroville Dam facility modifications on what it describes as Risk Analysis Methodology.[30] This methodology does not approach PMF issues in the context of standards by regulators that licensees are required to meet, although conceding that FERC generally requires that its licensed dams meet that standard.[31] It does not discuss that the Spillway Design Flood when handling a PMF may have a design freeboard.[32] Rather, it asserts that the PMF is so rare that under risk-informed decision-making no spillway or dam elevation measures are required.[33]

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[29] The slide deck of DWR's July 29, 2022, presentation to its Oroville Citizen's Advisory Committee meeting (https://resources.ca.gov/-/media/CNRA-Website/Files/Initiatives/Oroville/20220729-oro-slidedeck.pdf) displays the Department's relatively low priority assigned by DWR in addressing spillway capacity deficiencies:

> Between 2018–2020, DWR conducted two parallel risk assessments, the Comprehensive Needs Assessment, and the Level 2 Risk Analysis, the latter of which followed FERC's risk processes.
> Both studies found that risks associated with the Emergency Spillway were less than the risks associated with other areas we have been working and reporting on.
> DWR responded to FERC comments on the Probable Maximum Flood study on March 22, 2021. DWR indicated further studies evaluating the erodibility/performance of the Emergency Spillway would be implemented after studies for higher risks identified by the CNA and 10th Part 12D Independent Consultants.

[30] "The risk-informed methodologies and standards used by the CNA project team were informed by risk-informed decision-making (RIDM) guidelines published by FERC, and by other federal agencies such as the United States Army Corps of Engineers, and the United States Bureau of Reclamation." (CNA, p. 16.

[31] "[P]robable maximum flood (PMF), the largest flood loading generally required by dam safety regulatory agencies to be safely retained by a dam." (CNA, p. 7)

[32] DWR's extensive history of the design and construction of Oroville Dam states that auxiliary spillway was sized to operate with freeboard during a PMF: "The emergency spillway, in conjunction with the flood control outlet, has the capacity to pass the maximum probable flood release of 624,000cfs for the drainage area (peak inflow 720,000 cfs) while maintaining a freeboard of 5 feet on the embankment." (DWR Bulletin 200, p. 92–93) However, some subtle distinctions regarding this matter may be in dispute. A senior DWR staff member communicated with this writer that there is no "design freeboard" at Oroville Dam, that such a concept does not exist at FERC. (Personal communication with John Yarbrough, PE, DWR Assistant Deputy Director, State Water Project)

[33] CNA, p. 74, although this low-probability theme is carried through much of the CNA. This theme goes back to the original design of the auxiliary spillway. "Except for a narrow strip immediately

The CNA does not discuss the FERC October 25, 2018, letter to DWR that the auxiliary spillway itself may sustain moderate to severe damage during the spillway design flood or the new PMF,[34] even apart from the mobilization of portions of the hillside within the FERC project boundaries being swept into the downstream. In 2021, after the completion of the CNA, DWR responded to FERC's 2018 letter. DWR said that it had evaluated the damage that might occur to the auxiliary spillway and any associated breeching of the spillway during extreme events.[35] It also noted that such an event was rare[36] and that "emergency" spillways can be expected to sustain damage during extreme events.[37] DWR also noted that auxiliary spillway potential failure modes (PFMs) do not or very rarely are expected to involve loss of life.[38]

In the same reply letter, DWR also responded to FERC's 2018 direction that "[t]he emergency spillway should be reclassified as an auxiliary spillway."[39] Here, DWR argued that the "emergency" spillway classification be retained to ensure consistency with documents using the previous appellation.[40] DWR also began but did not complete a concession that the expected engineering performance of an auxiliary spillway in

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downstream of the weir, the terrain below the weir was not cleared of trees and other natural growth because emergency spillway use will be infrequent." (DWR Bulletin 200, p. 200) The susceptibility of this slope to erosion was not appreciated by DWR decision makers, something documented Independent Forensics Team Report, Oroville Spillways Incident, January 5, 2018, see especially pp. 38–41, 53–56, and portions of Appendix C. (2018 IFT Report)

[34] "At the conclusion of the current spillway modifications, the original design capacity of the flood control outlet (FCO) will be restored; however, the design capacity of the emergency spillway is on the order of 100,000 cfs to 300,000 cfs lower than the maximum PMF discharge through the emergency spillway. The emergency spillway and natural discharge channel would likely sustain substantial headcutting erosion downstream of the secant pile wall when passing the expected full peak flow of approximately 420,000 cfs. In addition, it is likely the roller compacted concrete (RCC) apron section would experience moderate to severe damage from flows of this magnitude as well. A more robust and resilient design of the emergency spillway may be required to prevent the possibility of moderate to severe damage to the emergency spillway structure for the expected full peak flow of approximately 420,000 cfs. Further hydraulic and erodibility analyses of the emergency spillway structure should be performed to determine if it can safely pass PMF outflows." (FERC October 25, 2018 letter p. 2)

[35] DWR March 22, 2021, letter p. 2

[36] Id., p. 2.

[37] Ibid.

[38] Id., p. 2.

[39] "DWR believes there is no immediate reason to rename the spillway. DWR believes maintaining the original name that appears on all past and present official documents and reports would be prudent to avoid confusion, both for our respective organizations and the general public." (FERC October 25, 2018, letter, p. 3)

[40] DWR March 22, 2021, letter, p. 6.

comparison to an emergency spillway in FERC's *Engineering Guidelines* differed. DWR did not repeat its CNA's concession that use of the auxiliary spillway could cause serious damage to other Oroville Dam Complex project works and cause multi-year operational disruptions to energy production and deliveries to the State Water Project[41] — a description probably not consistent with either spillway classification or FERC's interest in its licensees having project facilities that are "adequate to fulfill their stated functions."

In general, DWR's focus in the CNA and in its correspondence with the FERC Office of Energy Projects, Division of Dam Safety and Inspections was on traditional dam safety issues, although broader in scope than previous analyses.[42] In neither case did DWR focus on the broader relicensing applicant's duty under FERC's 18 C.F.R. 4.51(g)(3) to furnish information "to demonstrate that existing and proposed structures are safe and *adequate to fulfill their stated functions*," the latter a somewhat broader responsibility.[43] The CNA does concede that the use of the auxiliary spillway during "moderate to large flood events" could cause damage to and create major operational difficulties for the project.[44]

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[41] CNA p. 74.

[42] According to DWR, "The CNA project was performed to identify potential dam safety and operational needs, and what enhancements, if any, are needed for dam safety or facility reliability. The CNA was the most comprehensive risk analysis that DWR has undertaken for any of its facilities and is possibly the most comprehensive such risk analysis for any non-federal dam in California. It is also one of the first such risk analyses to consider failure states other than uncontrolled release of reservoir water, and one of the first to fully consider multiple consequences other than life-loss or financial impacts." (CNA, p. 73)

[43] The DWR Oroville facilities are still undergoing FERC relicensing. This "adequacy" issue was a feature to the intervention of Friends of the River, South Yuba River Citizens League, and Sierra Club. (Motion to Intervene of Friends of the River, Sierra Club, South Yuba River Citizen's League, Project No. 2100-052, filed Oct. 17, 2005) (eLibrary no. 20051017- 5033) (FOR et al. Intervention). DWR's and FERC's response are discussed in the 2018 IFT Report, pp. C-28–C-32. https://damsafety.org/sites/default/files/files/Independent%20Forensic%20Team%20Report%20Final%2001-05-18.pdf

[44] In general, "moderate to large" are not terms usually applied to PMFs — and perhaps not even to SPFs. Here's the CNA language. "The other higher-risk PFM [potential failure mode] was associated with the potential for major erosion on the unlined channel below the secant pile wall on the emergency spillway during future moderate to large flood events. The risk for this latter PFM was not dominated by potential life-loss, but rather associated with financial impacts resulting from the flooding of the Hyatt Powerplant induced by partial blockage and elevation of the diversion pool. These financial impacts include direct impacts associated with the repair of the Hyatt facilities and indirect financial impacts downstream of the dam associated with the disruption of water deliveries. Flooding of the powerplant would be expected to result in an extended outage of at least five years for this powerplant, which serves as the primary water delivery system of reservoir water to the SWP. An extended outage of the

The CNA can be summarized in its own words:

> The CNA's results showed that there are no dam safety issues that exhibit a need for immediate risk-reduction actions.
>
> Though no unacceptable risks were found, and therefore no immediate actions need to be taken, DWR concluded that there were potential vulnerabilities identified that require further consideration and examination to better estimate their actual risk. In addition, the CNA developed potential risk reduction measures for consideration to potentially reduce risks to even lower levels, and recommended implementation of these measures if they are found to be reasonably practicable. To be reasonably practicable, a risk reduction measure must be capable of being implemented and to be cost effective – that is, the cost of implementation must not be disproportionately large compared to the benefits obtained.
>
> The CNA project team recommended the implementation of several of these potential risk-reduction measures, or improvements, to be completed over three phases (early, interim, and long-term). The first phase (early) is already underway and the second phase (interim) would be completed within approximately the next five years. Risk management and implementation of any additional major risk-reduction measures or plans at Oroville over the long-term will depend upon the risks that exist at Oroville relative to those at other SWP dams and facilities. Since there are no unacceptable risks at Oroville, there is not a need for any immediate risk reduction actions. DWR will need to make balanced risk-informed decisions regarding where the highest risks are with the SWP, and to then set priorities to reduce those risks across the entire SWP.[45]

In that context, the CNA identified only three projects recommended for "Interim Risk Reduction Actions." Two might be considered projects of value in extreme runnoff events: 1) the recommended 3-foot raise of the Parish Camp Saddle Dam and 2) the installation of new remote starter and power connections to the service spillway radial gates to improve their reliability in the event of disruptions to dam power. However, consistent with the CNA's Risk Reduction Methodology theme, neither are proposed to meet a traditional regulatory PMF framework. This is particularly noteworthy for the recommended Parish Camp Saddle Dam 3-foot raise, the raise that would restore the existing PMF design freeboard for the 2017 PMF.[46]

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powerplant would result in significant impacts to SWP water deliveries." (CNA, p. 74)

[45] CNA p. x

[46] Id., pp. 78–83.

The CNA also adopted six "Additional Recommended Interim Measures," three of which may have value for PMF and floodwater management operations. Two are notable: 1) complete a *study* to examine the feasibility and risk reduction for adding small and limited crest parapet walls on the Oroville Dam at the left and right abutments and 2) implement flood-influenced-reservoir-operations (FIRO) and coordinated operations with New Bullards Bar Dam.[47] Again, neither is posed as a measure to meet a regulatory standard such as the PMF for the parapet wall study or a operational objective such as managing the existing or potentially revised Reservoir Design Flood.

The CNA also devised four actions on a "Recommended Long-Term Path Forward for Future Consideration of Alternative Risk-Reduction Plans."[48] The first advocated a fleet management approach (rather than a response to regulator requirements) to prioritize addressing risks with a portfolio of all the critical facilities of the State Water Project (SWP). The Oroville Dam Complex would be just one of many potential projects within the SWP, potentially deprioritizing addressing deficiencies in the safety and the adequacy of facilities to fulfil their stated functions at the Complex.

The second recommended long-term action was, *after* completion of the SWP portfolio risk assessment, to consider one of the ten CNA "Alternative Plans Recommended for Future Consideration" for implementation. Some included obvious PMF measures,[49] although cloaked in the language of Risk Reduction Methodology language of the CNA.[50]

Action possible? In effect, DWR's NA contemplates addressing the operational competence, PMF competence, operational constraints, and potential damage to project lands and facilities at the Oroville Dam and appurtenant facilities from contemplated

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[47] Id., p. 84.

[48] Id., p. 85.

[49] CNA chapter five describes alternative plan development. CNA p. 76 describes some of the potential risk-reduction measures within some plans: "Modifications to the upper portion of the Oroville Dam, particularly at the right abutment, and limited raises (e.g., 3 feet) at all three embankments to reduce the risks of internal erosion or flood overtopping breaches at the dams" and "Armoring measures for the unlined portion of the emergency spillway channel to reduce the potential for scour erosion into the Diversion Pool (Feather River) and the threat of flooding of the Hyatt Powerplant." They also include "[m]ajor new facilities such as a new gated concrete spillway to replace the emergency spillway." They do not note that the latter measure may not be possible to license because of a conflict with 16 U.S.C. 1278.

[50] CNA p. 84.

operations to the indefinite future. FERC may be uncomfortable with that approach. On July 14, 2022, the Department received a letter from the FERC's Office of Energy Projects, Division of Dam Safety and Inspections Regional Engineer.[51] He states:

> Regarding the capacity of the emergency spillway, the previously-accepted plan and schedule for resolving this comment was tied to the Comprehensive Needs Assessment (CNA), which was submitted to FERC by letter dated August 28, 2020. We note that the CNA did not definitively resolve this topic nor did it provide a firm schedule going forward. Although the response in the subject letter provided some insight into this comment, the letter provided insufficient documentation of the emergency spillway's ability to safely convey the PMF…. The letter notes that no emergency spillway-focused studies were identified by the 10th Part 12D Independent Consultants. This is because, at DWR's request, the consultants were not required to assess that structure as it was under construction at the time of the Part 12D inspection.
>
> DWR's proposal for risk reduction measures to 'be considered for future implementation', or studied 'after completion of the studies and investigations identified by the CNA' is not acceptable. It is imperative that DWR develop and submit a detailed plan and schedule for determining the safe capacity of the emergency spillway and the spillway adequacy of Oroville Dam.
>
> …Within 60 days from the date of this letter, submit a plan and schedule for addressing the comments.[52]

It is possible that FERC is preparing to take regulatory action to require that DWR not only determine the safe capacity of the auxiliary spillway (such as recovering its design freeboard) but requiring modifications be made to the Oroville Dam Complex in response. FERC certainly routinely requires other FERC licensees to have adequate freeboard on spillways regulated by FERC. DWR may be hoping for less, although shortly after receipt of the letter from FERC they expected to respond:

> Last week FERC responded to an approach that DWR proposed in March 2021 and informed DWR that their view is that a more detailed plan and schedule is needed with additional focused analysis to better inform decisions around

[51] FERC July 14, 2022, letter. FERC e-library no. 20220714-3063. https://www.friendsoftheriver.org/wp-content/uploads/2023/06/20220714-3063_P-2100-000-Oroville-PMF-Nos.-4-5-6-Responses-2021.pdf.

[52] FERC July 14, 2022 letter, pp. 1–2.

> whether additional investments should be made. DWR will be responding to FERC with this plan and schedule within the next 60 days.[53]

I have reviewed the Oroville Dam FERC docket and can see no additional correspondence regarding this matter.

Nevertheless, parties in FERC Oroville Dam relicensing proceedings (yes, these are still ongoing) who raised spillway issues, those who followed the discussions in the CNA *Ad hoc,* or observers of DWR's and FERC's dam-safety and relicensing programs, it will be meaningful if FERC is setting up a decision framework that may lead to action instead of indefinite delay.[54]

Stepping back, FERC's Office of Energy Projects, Division of Dam Safety and Inspections primary focus has historically addressing vulnerabilities that may result in a loss of crest control at a FERC-licensed dam and its spillways. In potential contrast, FERC's Office of Energy Projects, Division of Hydropower Licensing, appears to have the responsibility to license projects that are safe and adequate to fulfil their stated functions. These responsibilities clearly overlap. Moreover, these divisions operate differently. Most of the Division of Dam Safety and Inspections' work is continuous (punctuated by scheduled assessments every five or ten years) and does not involve public participation. The Division of Hydropower Licensing attends to these matters (or does not attend to these matters in deference to the Division of Dam Safety and Inspections) during licensing and relicensing and license amendments, something that can be once in a generation. Its proceedings are largely public. How to marry the work of these two divisions in the FERC Office of Energy Projects has proven difficult.[55] Nevertheless, "adequate to fulfil their stated functions" issues are properly before the FERC, likely under the purview of both Divisions. For example, some of the possible spillway PMF modification actions that may be eventually considered by the Division of Dam Safety and Inspections may also benefit the floodwater management functions of the dam. Such matters that should be of interest to the Division of Hydropower

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[53] Director Nemeth email, July 28, 2022

[54] The CNA advocated a "fleet" maintenance approach to prioritizing dam safety and other projects within the entire State Water Project (SWP). "The actual implementation of any potential risk-reduction plan at Oroville would depend upon the risks that exist at Oroville relative to those at other SWP dams and facilities. Since there are no unacceptable risks at Oroville, DWR will need to make balanced risk-informed decisions regarding where the highest risks are within the SWP, and to then set the priorities to reduce those risks across the entire SWP." (CNA p. 9) Clearly, this approach "is not acceptable" to FERC.

[55] Some of the NGO parties in the relicensing requested clarification and a series of workshops to sort these inter-Divisional matters out. (e-library no. 2017419-5231) There was no response.

Licensing under its Federal Power Act Section 10 responsibilities. These matters should be followed closely.[56]

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[56] Completion of a hillside auxiliary spillway that does not use a bare hillside for spillway discharges or additional low-level outlet facilities useful for forecast-influenced reservoir operations (FIRO) are examples of dam-safety improvements that could improve the floodwater management capabilities of Oroville Dam.