

OROVILLE RISK ANALYSIS

OVERVIEW OF PROCESS AND 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. In the case of the Oroville Dam complex, 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, consistent with FERC's risk informed decision-making guidelines. The results of the Level 2 Risk Analysis was then to be used in conducting the five-year Part 12D Safety Inspection of Oroville Dam. Contemporaneously to the Level 2 Risk Analysis and the Part 12D Safety Inspection, DWR embarked on the Oroville Dam Safety Comprehensive Needs Assessment (CNA) that incorporated a similar approach to identify and estimate risks. The CNA incorporated the additional step of identifying potential measures to reduce specific risks. All three of these efforts concluded in 2020.

LEVEL 2 RISK ANALYSIS (2018-2020)

- Mandated by Federal legislation
- Led by independent team nominated by USSD
- Independent team approved by FERC
- Followed FERC draft Level 2 Risk Informed Decision Making Guidelines

OUTCOMES

- Independent identification and analysis of potential failure modes (risk)
- Informs DWR, FERC, and DSOD of "risk drivers"
- Advanced state of practice for non-federal dams

PART 12D SAFETY INSPECTION AND REPORT (2018-2020)

- Required of all FERC licensed dams on 5-year cycle
- Performed by Independent Consultants
- Provides an independent inspection of facilities and review of project documentation
- Informed by Level 2 Risk Analysis

OUTCOMES

- Provides independent conclusions in regards to the safety of facilities and suitability for continued operation
- Incorporates Level 2 Risk Analysis results in formulating their conclusions and recommendations
- Report contains recommendations for DWR's consideration to enhance the safety of the facilities and dam safety practices and procedures relative to the facilities
- Part 12D regulations require DWR to provide FERC with a plan and schedule to address recommendations

OROVILLE DAM SAFETY COMPREHENSIVE NEEDS ASSESSMENT (2017-2020)

- A DWR assessment to identify and assess dam safety risks
- Initiated in advance of the Level 2 Risk Analysis
- Includes development of potential measures to reduce risk
- Included Independent Review Board
- Included Ad Hoc Group to provide stakeholder input and communication

OUTCOMES

- Baseline assessment of risk agrees well with Level 2 Risk Analysis providing confidence in the results from both efforts
- Report contains planning-level measures and estimates of the risk reduction that could be achieved for each measure
- Report contains Plans (combinations of measures) for DWR's consideration to reduce overall risk
- Early Implementation projects identified, endorsed by IRB, and initiated by DWR

The Level 2 Risk Analysis represents a new type of assessment under FERC's Risk Informed Decision-Making initiative. The risk-based approach has many benefits including a greatly improved understanding of the safety of the dam and identifying dam safety vulnerabilities that have not been identified using standards-based evaluation techniques. The independent consulting team provided the results to DWR at the end of March 2020. DWR is reviewing the report in order to remove sensitive security information prior to making the report publicly available. In the meantime, DWR has developed this overview document as well as a more in-depth summary of the process available on the DWR Oroville Facilities (P-2100) [webpage](#).

A Level 2 Risk Analysis is a semi-quantitative assessment intended to identify and prioritize what risk management actions should be taken and what additional information is needed to inform future decisions. One significant change to the usual FERC process was expanding the scope to include issues that could have serious consequences but were not historically defined as a 'failure' (e.g., dam component or appurtenant structure malfunction, or considering consequences downstream even when the dam performs as designed).

Specifically, the purpose of conducting a Level 2 Risk Analysis is to:

- Evaluate potential failure modes and the estimated life loss for each potential failure mode;
- Identify areas where more information is needed to improve decision making and additional studies;
- Inform operations and maintenance, inspections, monitoring, emergency action plans, and training; and
- Prioritize flood risk management decisions at the dam and in the watershed.

PROCESS

Level 2 Risk Analysis includes brainstorming and describing as many unique potential failure modes as possible. For each potential failure mode, the independent team assigns a likelihood of that potential failure occurring and an estimate of the likely consequences. The potential failure modes are plotted on a matrix according to annual likelihood and consequence category. For example, if a particular potential failure mode occurred, there could be significant consequences (estimated loss of life of 1,000) however if the likelihood of that event occurring is very low (estimated one in a million chance per year) plotting that result on the matrix helps contextualize that potential failure mode. Plotting the potential failure modes on a common matrix provides a visual tool to inform the prioritization of measures to reduce risk.

FERC provides the following Failure Likelihood and Consequence guidance for Level 2 risk analyses. In this way, FERC and dam owners can compare risks across dams and ensure consistency in definitions across risk assessment teams. Please note there are two factors: annual likelihood of failure and estimate of incremental life loss.

FUTURE LIKELIHOOD DESCRIPTORS

Likelihood Descriptors	Annual Failure Likelihood	Evidence
Certain	More frequent (greater) than 1/10	There is direct evidence or substantial indirect evidence to suggest it certain to nearly certain that failure is eminent or extremely likely in the next few years.
Extreme	1/10 to 1/100	There is direct evidence or substantial indirect evidence to suggest that failure has initiated or is very likely to occur during the life of the structure.
Very High	1/100 to 1/1,000	There is direct evidence or substantial indirect evidence to suggest that failure has initiated or is likely to occur.
High	1/1,000 to 1/10,000	The fundamental condition or defect is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward "more likely" than "less likely."
Moderate	1/10,000 to 1/100,000	The fundamental condition or defect is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward "less likely" than "more likely."
Low	1/100,000 to 1/1,000,000	The possibility cannot be ruled out, the fundamental condition or defect is postulated. Evidence indicates it is very unlikely.
Very Low	1/1,000,000 to 1/10,000,000	The possibility cannot be ruled out, but there is no compelling evidence to suggest it has occurred or that a condition or flaw exists that could lead to initiation.
Remote	More remote (less) than 1/10,000,000	Several events must occur concurrently or in series to cause failure, and most, if not all, have negligible likelihood such that the failure likelihood is negligible.

LIFE SAFETY CONSEQUENCE CATEGORIES

Life Safety Consequence Category	Incremental Life Loss	Description
Level 0	None expected	No significant impacts to the downstream population other than temporary minor flooding of roads or land adjacent to the river.
Level 1	Less than 1	Although life-threatening releases occur, direct loss of life is unlikely due to severity or location of the flooding, or effective detection and evacuation.
Level 2	1 to 10	Some direct loss of life is likely, related primarily to difficulties in warning and evacuating recreationists/travelers and small population centers.
Level 3	10 to 100	Large direct loss of life is likely, related primarily to difficulties in warning and evacuating recreationists/travelers and smaller population centers, or difficulties evacuating large population centers with significant warning time.
Level 4	100 to 1,000	The fundamental condition or defect is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward "less likely" than "more likely."
Level 5	Greater than 1,000	Extremely high direct loss of life can be expected due to limited warning for very large population centers and/or limited evacuation routes.

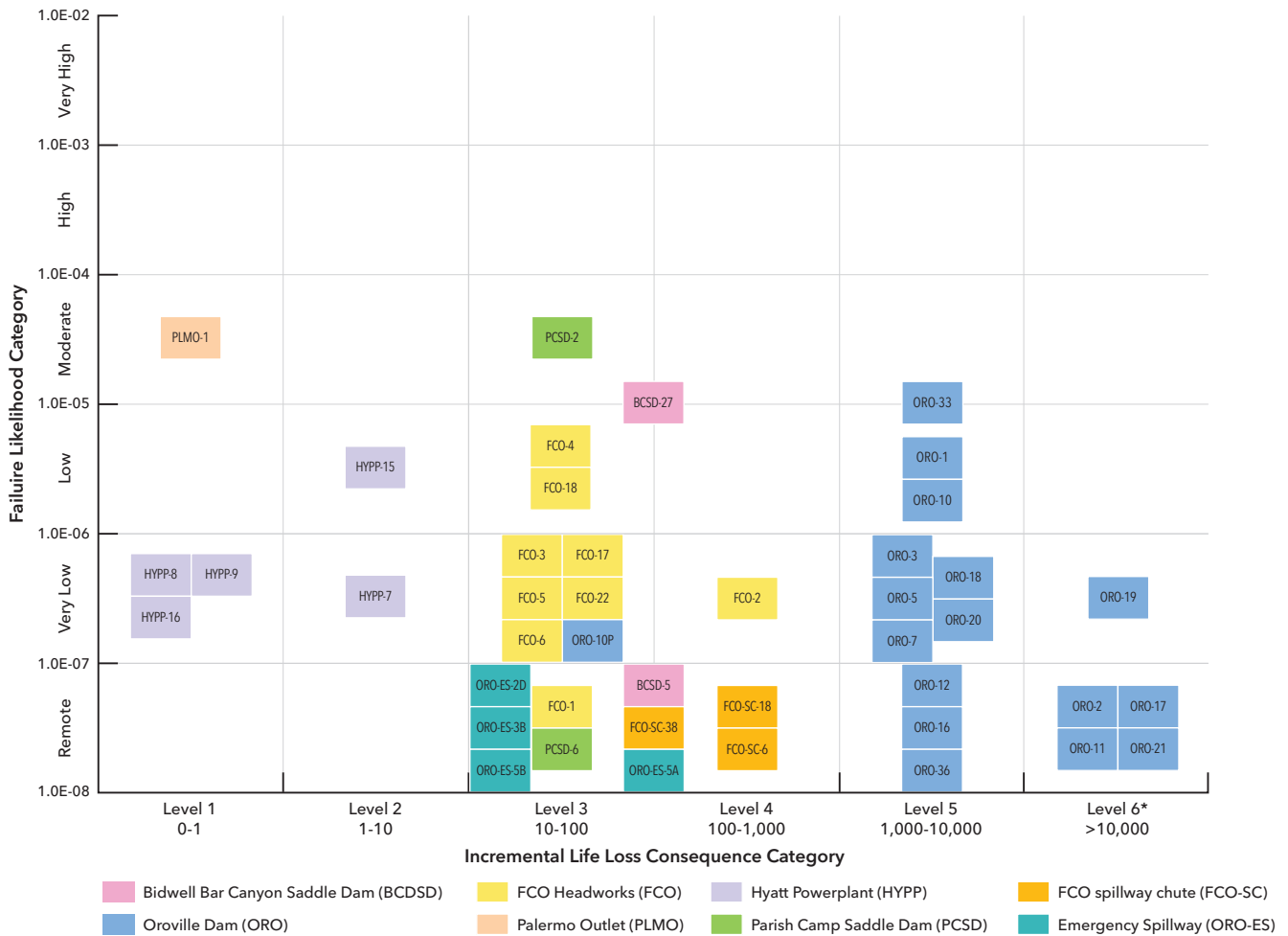
The independent consultant team, using a combination of quantitative guidelines and best professional judgement used the following process to assess and compare potential risks associated with the Oroville Dam complex:

1. Brainstorm every possible problem, no matter how remote. Develop a comprehensive list of potential failure modes (this included brainstorming by the independent study team as well as inclusion of potential failure modes that were developed as part of previous assessments).
2. Narrow this list. Combine duplicates and eliminate extremes (those that are extremely unlikely to occur and those for which there are minimal consequences).
3. Conduct multi-disciplinary process to estimate occurrence and consequences.
 - a. Estimate the likelihood that each potential failure mode would occur.
 - b. Estimate the consequences of each potential failure mode should it occur.
4. Compare. Plot each estimate on a matrix which includes two factors: likelihood of potential failure occurring and estimate of incremental life loss.

Summary of Level 2 Risk Analysis Results

- A total of 630 candidate potential failure modes were proposed, screened, and consolidated to 189 that were carried forward for risk analysis.
- Of the 189 potential failure modes analyzed by the independent team, there were none that were estimated to have a high likelihood of occurring (greater than 1/10,000 annual likelihood).
- The majority of potential failure modes were estimated to be very low or remote (1/1,000,000 annual likelihood or less).
- Sixteen potential failure modes were estimated to have the potential for 1,000 or more incremental loss of life. However, these high impact potential failures were estimated to have low or very low likelihood categories of actually occurring (1/100,000 annual likelihood). These potential failure modes were associated with failure of the Oroville Dam and were related to overtopping due to an extreme flood (greater than the probable maximum flood) or internal erosion. Five of the potential failure modes with the most significant life loss estimates are related to the impacts of a major earthquake.

An important finding from the process was that when large storms occur, there may still be flooding downstream of the dam even when the dam and its appurtenant structures perform and are operated as designed. There is potential that in extreme storms the combination of stormwater runoff in the watershed and releases from the dam would overtop downstream levees, leading to property damage and loss of life.



Notes:

- *FERC draft PL2RA procedures do not include Level 6. Level 6 was added to the matrix to portray PFMs with life loss potential greater than 10,000 people.
- Each PFM is positioned in a matrix cell that represents the best estimate failure likelihood category and life loss consequence level. All PFMs within a matrix cell are considered to have equal best estimate risk; the relative position of PFMs within each cell is arbitrary and is not an indicator of relative risk.
- PFMs positioned to straddle a line between failure likelihood categories or life loss consequence levels represent the best estimate (the order of magnitude) that spans across the category or level.

NEXT STEPS

DWR has submitted the Level 2 Risk Analysis report developed by the independent consulting team to FERC and the California Division of Safety of Dams (DSOD), and the Part 12D Independent Consultants. The Part 12D Independent Consultants reviewed the Level 2 Risk Analysis report and utilized its findings to augment their recommendations to enhance the safety of the Oroville Dam complex.

DWR will use information developed during the Level 2 Risk Analysis to make risk-informed management decisions at the dam (e.g., improvements and upgrades to the dam) and in the watershed (e.g., operations and evacuation effectiveness). DWR will also use improved understanding of potential failure modes to focus future monitoring, investigation, and analysis to better target risk management actions. The results were also used to inform the Oroville Dam Safety Comprehensive Needs Assessment.