IMPLEMENTATION OF FEDERAL ENERGY REGULATORY COMMISSION RISK INFORMED DECISION-MAKING PROCESS

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ABSTRACT

Hydropower owners in the United States have invested considerable resources in performing Potential Failure Mode Analyses (PFMA) for their dams, to meet Federal Energy Regulatory Commission (FERC) requirements for dam surveillance and monitoring. However, PFMAs stop short of providing a good portrayal of the true portfolio risk profile. Risk, by definition, includes both likelihood and consequences of failure. The current FERC PFMA process does not allow for consideration of the consequences of failure or provide adequate methodology for assessing likelihood. In addition, the use of the current FERC categories does not provide an appropriate portrayal of the overall portfolio risk. Because of this, FERC has released Draft Risk-Informed Decision Making (RIDM) Guidelines for use by licensees to supplement their Dam Safety Program.

This paper presents the results of one owner's Portfolio Screening, Semi-Quantitative, and Quantitative Risk Analyses and the challenges associated with implementation of the Draft RIDM Guidelines. Semi-Quantitative Risk Analyses (SQRA) were performed to identify potential failure modes (PFMs) that drive the total risk and Quantitative Risk Analyses (QRA) were performed to support decisions regarding modification of the dam. The key steps that were taken to implement the Draft RIDM Guidelines are described, including how requirements for Portfolio Screening Risk Analyses were satisfied and relevant field investigations and analyses performed leading up to and following the SQRA, including the probabilistic hydrologic and seismic studies and consequence studies. The results of the QRA are presented, including a discussion of the mitigation measures that were contemplated and how they were evaluated in the context of risk reduction. A discussion of some of the challenges that licensees are expected to encounter through full implementation of the RIDM Guidelines is also presented.

1. INTRODUCTION

Implementation of the Draft RIDM Guidelines has been slow due to uncertainty of the benefits and costs on the part of licensees and lack of experience with risk analysis among consultants. Because of this, FERC has endorsed licensees to conduct pilot project risk analyses in specific cases, utilizing the methodologies presented in the Draft RIDM Guidelines. Several licensees have opted to perform pilot projects utilizing the Draft RIDM Guidelines.

Southern California Edison (SCE) owns and operates 23 high and significant hazard dams in the eastern and northern Sierra Nevada Mountains of California that are currently regulated by the FERC. In accordance with the FERC requirements, they completed Potential Failure Modes Analyses (PFMA) on the entire portfolio. As part of the FERC process, potential failure modes were developed and categorized into one of four categories, considering the likelihood of failure. In this process the consequences of failure are not considered explicitly. While some of the more important potential failure modes and associated actions are identified, the categories are too general to provide a good portrayal of the risk profile associated with SCE's inventory of dams. This has been the result with most of the FERCs licensees.

2. CURRENT PFMA PROCESS

Under the current PFMA process, all available background material for each dam is collected and thoroughly reviewed by a core team of dam safety specialists. Based on this review, potential vulnerabilities and associated potential failure modes are identified and thoroughly described. Factors making each potential failure mode more or less likely are also identified and key factors are noted. Potential consequences associated with each potential failure mode are typically described based on an inundation zone and qualitative information relating to the population residing in that zone. Based on the descriptions and factors the potential failure modes are characterized using the four categories briefly described below.

Category I – Highlighted PFM Those potential failure modes of greatest significance considering need for awareness, potential for occurrence, magnitude of consequence, and likelihood of adverse response (physical possibility is evident, fundamental flaw or weakness is identified and conditions and events leading to failure seemed reasonable and credible) are highlighted.

Category II – PFM Considered, but not Highlighted. These are judged to be of lesser significance and likelihood. Note that even though these potential failure modes are considered less significant than Category I they are all also described and included with reasons for and against the potential occurrence of the failure mode. The reason for the lesser significance is noted and summarized in the documentation report or notes.

Category III – More Information or Analyses are Needed to Categorize.These potential failure modes to some degree lacked information to allow a confident judgment of significance and thus a dam safety investigative action or analyses can be recommended. Because action is required before resolution the need for this action may also be highlighted.

Category IV – PFM Ruled Out. Potential failure modes may be ruled out because the physical possibility does not exist, information came to light which eliminated the concern that had generated the development of the potential for the failure mode, or the failure mode is clearly so remote as to be non-credible or not reasonable to postulate.

Not only are the category descriptions of limited value relating to consequences, they also do not allow for broad enough assessment of the probability of failure. Because of these limitations the PFMA process does not allow FERC licensees to properly identify the risk-driver PFMs, nor does it allow for prioritization of projects within the portfolio.

3. DRAFT RIDM GUIDELINES

FERC has developed draft RIDM Policy Guidance Documents for use in working on FERC RIDM Pilot Projects. In general, the FERC follows risk methodologies developed jointly between US Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers (USACE) and documented in Best Practices in Dam and Levee Safety Risk Analyses. The FERC draft guidelines used for the Rockfill project were issued in March 2016 and consist of the following chapters:

- Chapter 1 – Introduction to Risk Informed Decision Making
- Chapter 2 – Risk Analysis
- Chapter 3 – Risk Assessment
- Chapter 4 – Risk Management

Chapter 2 of the draft guidelines was most applicable to the pilot risk analysis project for Rockfill Dam. Chapter 2 covers the definition of risk as well as discussion on likelihood of failure and consequences. The levels of dam safety risk analysis are included in Chapter 2, and are as follows:

- Level 1 – Screening Level Risk Analyses
- Level 2 – Periodic Risk Analyses
- Level 3 – Semi-Quantitative Risk Analyses (SQRA)
- Level 4 – Quantitative Risk Analyses (QRA)

The guideline also provides information on the composition and qualifications of the “Risk Team” needed to complete a dam safety risk analysis.

4. IMPLENTATION OF RIDM GUIDELINES

4.1 Southern California Edison Portfolio Screening and Level 2 Risk Analysis Process

Prior to release of the FERC Draft RIDM Guidelines SCE made the decision to move their dam safety program forward with the implementation of a risk analysis process. With assistance from individuals from the Reclamation they opted to perform portfolio risk screening of all 23 FERC regulated dams in their portfolio. Prior work related to understanding risks at all 23 regulated dams in the portfolio included Potential Failure Modes Analyses (PFMA), performed as part of the periodic Part 12D inspections and a Semi-Quantitative Portfolio Risk Assessment performed in 2009.

The PFMA study performed for Rockfill Dam in 2007 was conducted by a ten-member team, with representatives from SCE Operations, SCE Dam Safety, FERC, and Division of Safety of Dams of California (DSOD), as well as the Part 12D Independent Consultant. The team identified four candidate Potential Failure Modes (PFMs). Two PFMs were classified as Category I, one as Category III and one as Category IV. No Category II PFMs were identified. A PFMA review session was held as part of the 2013 Part 12D safety review. One Category III PFM was re-categorized as Category I and two additional Category III PFMs were identified.

Table 1 : Rockfill Dam Potential Failure Mode Categories

Category	Description	Last Revision
I	PFM-1 Spillway plugging during flood leading to overtopping erosion	2007
	PFM-2 Flood flow around right side of parapet causes erosion	2007
	PFM-3 Flood overtopping erosion of the embankment	2013
III	PFM-4 Slope failure under flood load leading to loss of crest and overtopping	2013
	PFM-5 Slope failure under seismic load leading to loss of crest and overtopping	2013
IV	PFM-6 Slope failure under normal load leading to loss of crest and overtopping	2007

Semi-Quantitative Portfolio Risk Analyses were performed in 2009 and a Semi-Quantitative Risk Analysis of Rockfill Dam was performed in 2015. Based on the results of work that was completed in 2007, 2009, 2013, and 2015 the FERC considered the Level 1 Risk Analysis (L1RA) and Level 2 Risk Analysis (L2RA), respectively, to be completed at Rockfill Dam. During these analyses, risk for each PFM was characterized by Likelihood of occurrence and Consequences of the failure described by the PFM.

The qualitative descriptions for Likelihood and Consequence were taken from Reclamation Best Practices Guidelines. Split classifications were also used (e.g. “Moderate/High”, “Level 2/3”). Additionally, the Confidence in each categorization of Likelihood and Consequence were described as High, Moderate, and Low. A summary of the 2015 risk workshop is provided below.

The 2009 portfolio risk analysis (L1RA) of dams in Bishop and Mono Basin areas (Eastern Hydro Division Dams) included Rockfill Dam. A key component of the Risk Analysis was a facilitated team workshop held in 2009. The core team consisted of twelve members, including SCE representatives from Dam Safety, Operations, and Compliance, Peer Reviewers from FERC and PG&E, and independent consultants. During the workshop, the team reviewed all identified PFMs for eleven dams, assigning Likelihood and Consequence categories (and Confidence for each categorization).

In 2015, SCE performed the L2RA focusing specifically on Rockfill Dam. During the workshop twenty-eight participants reviewed the Phase I Likelihood and Consequence classifications of key PFMs for Rockfill Dam. SCE participants included representatives from Dam & Public Safety, Operations, Licensing, Law, and Enterprise Risk Management. External participants included representatives from FERC, DSOD, and consultants. New information was considered, including field investigations, monitoring data, updated seismic analyses and revised consequence evaluation based on 2-D flood modeling with high-resolution elevation data from a LiDAR survey and the 2015 USBR Interim Guidelines for Estimating Life Loss for Dam Safety Risk Analysis.

During the L2RA Workshop, the Likelihood and Consequence categories of several PFMs were revised based on the newly obtained information. Through this process, SCE reached the following key conclusions regarding risk at Rockfill Dam:

- Overtopping failure due to a flood event is the primary contributor to risk.
- The potential for blockage of the spillway during a flood event substantially increases the risk.
- The consequences are almost entirely associated with downstream campgrounds, which are heavily occupied in July and August, but are essentially unpopulated November through March.
- Potential loss of life for a sunny-day failure is nearly zero regardless of with or without warning, even during the peak season for the campgrounds.
- The consequences of a flooding-related failure can be reduced by an order of magnitude or more with effective warning. In a flood event, there will likely be a window of several hours in which to deliver warning.

4.2 Previous studies and analyses prior to the L3RA

Six supplemental studies were completed prior to and in support of the L3RA performed on Rockfill Dam in 2017. The results from these studies were used to inform the L3RA. The studies are listed below with brief descriptions of the intent. Details of these studies are not part of this paper. It is important to note however, the studies were performed specifically to provide more quantitative information that could be used to better estimate the likelihood and consequences of failure resulting from development of the PFMs that were identified previously.

- Evaluation of right abutment crest elevation relating to PFM-2. PFM-2 focuses specifically on potential for overtopping at the end of the parapet wall where observations in the field questioned whether a low area existed beyond the right end of the parapet wall.
- Evaluation of embankment stability relating to PFMs 4, 5, and 6. PFMs 4, 5, and 6 all relate to embankment stability and the significant lack of information on the material properties of the embankment.
- Analysis of the probable maximum flood relating to the potential for overtopping (PFMs 1, 2, and 3) as well as providing additional information relating to the consequences of failure.

- Preliminary probabilistic flood analysis was performed to better estimate the likelihood of flood loading (spillway crest, dam crest, and parapet crest) at specific frequencies. This information was used in the evaluation of PFMs 1, 2, and 3.
- Dam failure analysis and inundation mapping. Failure analysis and inundation mapping were performed for the watershed comprising Rockfill Dam and two others owned and operated by SCE. The study provides inundation mapping that was used for the analysis of consequences associated with breach of Rockfill Dam.
- Seismic hazard evaluations were updated, and the seismic hazard report was adapted from the report "NGA-West2 Seismic Hazard Evaluation for Lee Vining Creek, Rush Creek, and Mill Creek Dams", prepared previously by Southern California Edison. Since release of that report, SCE has been conducting follow-up investigations into the amplification factors used for soil and soft rock sites.

4.3 Level 3 Semi-Quantitative Risk Analysis

The PFMs that were identified either during previous PFMA workshops, combined PFMs from previous workshops, or created during the 2017 SQRA workshop and carried forward through the SQRA process are briefly discussed below.

- **Overtopping of Parapet leads to Erosion Failure during a Flood.**

Potential failure mode is described as a breach of the embankment due to overtopping of the parapet during a hydrologic event. The overtopping in this scenario can initiate due to either plugging of the spillway with debris or reservoir rise during a hydrologic event. In either case, overtopping of the parapet initiates erosion of the embankment which undercuts the concrete lining on the upstream face of the dam, resulting in the structural failure of the unsupported concrete lining and ultimately a breach and failure of the embankment section.

- **Abutment/Embankment Failure due to Erosion caused by Flanking the Parapet on the Right Abutment during Hydrologic Event.**

Potential failure mode develops due to flood flows discharging around the right side of the parapet extension. The failure occurs due to downcutting erosion which undercuts the parapet along the right abutment. This scenario involves plugging of the spillway, decreasing discharge capacity, and reservoir rise above the height of the parapet extension along the right abutment. Flows discharge around the parapet edge and exceed the erodibility threshold of the abutment material. Downcutting ensues and undermines the parapet extension. Erosion continues into the reservoir and results in an uncontrolled release from the reservoir through the eroded channel.

- **Embankment Failure due to Slope Instability during Normal Operations.**

PFM assumes the reservoir is at normal operating level. A slope failure initiates along the downstream slope and extends through the crest of the upstream slope. The upstream face and parapet fail, and freeboard is lost. The dam overtops, and flow erodes the embankment leading to the uncontrolled release of the reservoir.

- **Embankment Failure due to Slope Instability caused by Hydrologic Event.**

The PFM occurs during a hydrologic event. Debris from the watershed blocks the spillway and increases the rate at which the reservoir level rises. The reservoir level rises to the top of the parapet. Overtopping occurs over the parapet increasing the seepage pressures in the rockfill. The overtopping and seepage increase the phreatic level and slope failure occurs on the downstream slope. The slope failure extends through the crest and into the upstream slope. The upstream face and parapet fail into the slope failure. Freeboard is lost, and the dam is overtopped. Flow erodes the embankment and leads to the uncontrolled release of the reservoir.

- **Embankment Deformation during a Seismic Event Results in Overtopping**

PFM is initiated by a seismic event resulting in deformation of the embankment. The deformation of the upstream face and parapet is greater than the freeboard. The embankment and parapet are overtopped, and flow erodes through the embankment resulting in an uncontrolled release from the reservoir.

- **Slope Movement during Earthquake Loading Results in Seepage and Failure of Dam.**

PFM is initiated with a seismic event which results in slope movement of the embankment and cracking or displacement of a joint in the upstream concrete face. Seepage occurs through the cracked face and causes a rise in the phreatic surface of the embankment. The increased phreatic surface leads to slope instability and the downstream slope fails. The failure exposes the backside of the upstream concrete face leaving it unsupported. The unsupported concrete slab structurally fails resulting in a breach and uncontrolled release from the reservoir.

- **Spillway Failure due to Rock Scour/Erosion caused by Flows during Hydrologic Event.**

PFM is a failure of the spillway due to erosion. This scenario occurs during a hydrologic event with high flows in the spillway. The bedrock erosion threshold is exceeded and head cutting progresses back to the spillway sill. The sill becomes undermined and fails. Downcutting continues through the sill and into the bedrock below. An uncontrolled release occurs along the failed spillway.

The Level 3 Semi Quantitative Risk Analysis (L3RA) was conducted over a 3-day period and was performed in general accordance with the FERC Draft RIDM Guidelines. Each PFM was fully developed by the team and factors making the PFM more and less likely were discussed. To determine the likelihood and consequence levels, the group provided their best estimate of the likelihood and consequence for each PFM. All participants were allowed to estimate on each PFM. The estimate provided by the appropriate technical SME for any given failure mode was given additional consideration by the team during discussion. Confidence estimates were provided after the discussion to assess the level of uncertainty in the data and the adequacy of information needed to fully characterize the risk associated with each PFM.

Results were displayed on f-N charts to visualize the likelihood and consequence as well as the uncertainty of each PFM. FERC Draft RIDM Guidelines indicate that PFMs that are at or above the Line of Tolerable Risk, defined as the Average Annual Life Loss (AALL) of greater than 1E-3 lives per year (likelihood of event x PLL), are considered unacceptable except in extraordinary circumstances and risk should be reduced to below the line of tolerable risk regardless of cost. PFMs falling between the Line of Equal Risk, as defined as the AALL of 1E-5 lives per year, and the Line of Tolerable Risk will be considered intolerable unless as low as reasonably practicable (ALARP) considerations are satisfied. PFMs falling below the Line of Equal Risk will be considered tolerable provided ALARP considerations are addressed to evaluate potential risk reduction opportunities to further reduce risk.

Figure 1 below presents a summary of the 2017 PFM SQRA. Of these PFMs, 1 PFM was found to plot along the Line of Tolerable Risk and the other 6 PFMs were determined to fall at or below the Line of Equal Risk. PFM 1 was carried forward for evaluation in the L4RA (Quantitative Risk Analysis).

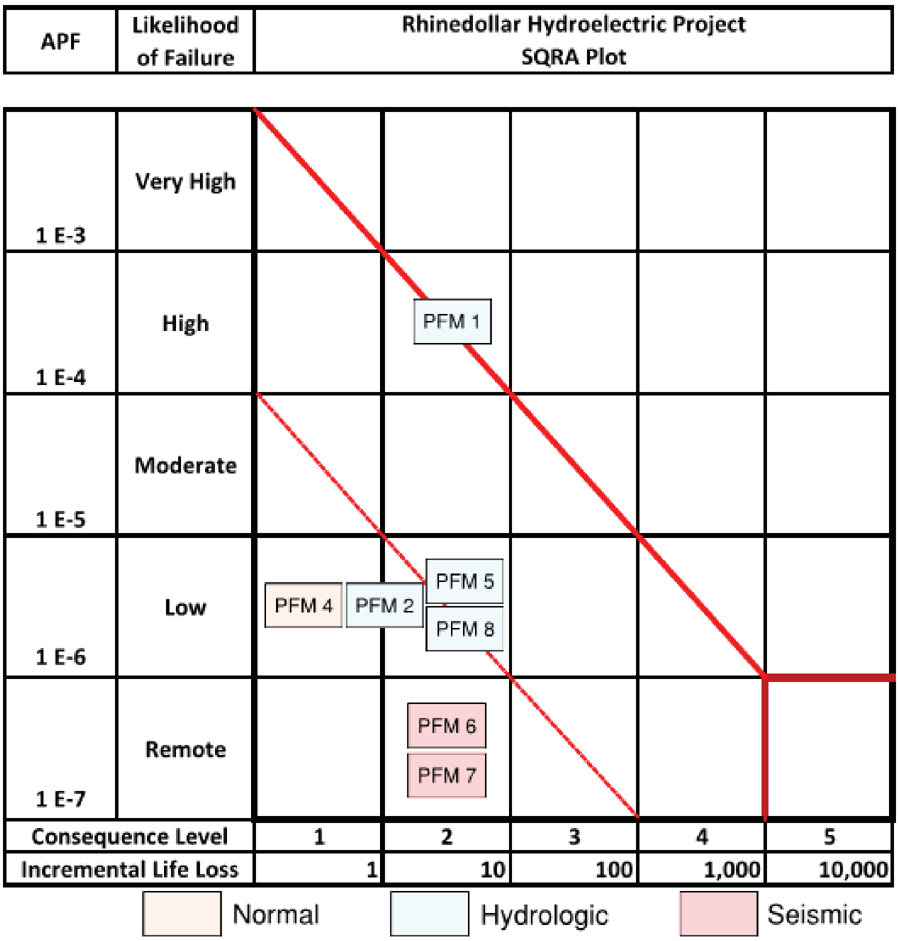

Figure 1 : Results of L3RA

4.4 Level 4 Quantitative Risk Analysis

Using the information gained during the L3RA, a Level 4 Risk Analysis (L4RA) was conducted for the Rockfill Dam. The L4RA is considered a quantitative risk analysis, and as such had a more rigorous level of detail than the L3RA. Based on the results of the L3RA it was determined that only PFM 1 "Overtopping of Parapet leads to Erosion Failure during a Flood" needed to be further analyzed in the L4RA.

Additional engineering analyses specific to PFM 1 were conducted prior to the L4RA to inform the L4RA workshop and achieve a defensible risk estimate for risk management decision making. A summary of the analyses performed specifically to support the L4RA workshop are listed below.

- Stochastic Event Flood Model (SEFM) – This was a probabilistic hydrologic hazard analysis for the Rockfill Dam which provided information on the probability of the flood loading intervals.
- Overtopping Erosion Analysis – Both deterministic and probabilistic evaluations of erosion or scour of the Rockfill Dam embankment during overtopping were conducted. This provided estimates of erosion initiation for various depths of overtopping at the dam.
- Concrete Slab Structural Analysis – A structural analysis of the Rockfill Dam upstream slab was conducted to determine the depth of scour that would result in loss of support and failure of the concrete slab. Probabilistic methods were used to develop a relationship between overtopping depth and height of scour that results in failure.
- Slope Stability Analysis – Geotechnical analysis was performed to evaluate the factor of safety against slope failure under the case of overtopping and complete saturation of the Rockfill Dam.

The L4RA workshop was held in 2019 at the SCE headquarters in Rosemead, CA and included SCE engineers, subject matter experts, FERC, a risk review board, and the risk workshop facilitators. The workshop focused on PFM 1, and a detailed failure mode event tree was developed by the group. Working from loading and initiation to ultimate failure of the dam, the likelihood for each node of the failure mode was estimated. Likelihood estimates were made by the SMEs, but only the SMEs that had specific expertise in the topic being evaluated contributed to the estimate. For example, a node in the failure mode dealing with initiation of erosion in the rockfill would have been estimated by the geotechnical engineers and engineering geologists. For the likelihood estimates, the SMEs provided a best estimate as well as a low and high estimate based on a 90% confidence (5% fall below the low estimate and 5% fall above the high estimate). The estimates for each node were averaged and a probability density function using the average of the low, best, and high were entered in a spreadsheet. Using the @Risk add-in for excel, a Monte Carlo simulation was performed to estimate the expected likelihood of failure as a range based on the likelihood estimates for each node. This was conducted for each leg of the event tree that resulted in dam failure.

In addition to the likelihood of failure, the consequences were estimated using the Reclamation Consequence Estimating Method (RCEM) developed by the Bureau of Reclamation, as was done for the L3RA. However, a probability density function for PLL was developed for the L4RA and entered into the spreadsheet. Using both the likelihood and consequence estimates, the range of expected risk results was plotted as a point cloud on the f-N chart (see Figure 2). The "existing conditions" risk estimates developed in the L4RA were very similar to those found in the L3RA for PFM 1 and support the need to perform some mitigation to reduce the risk associated with failure due to overtopping to an acceptable level.

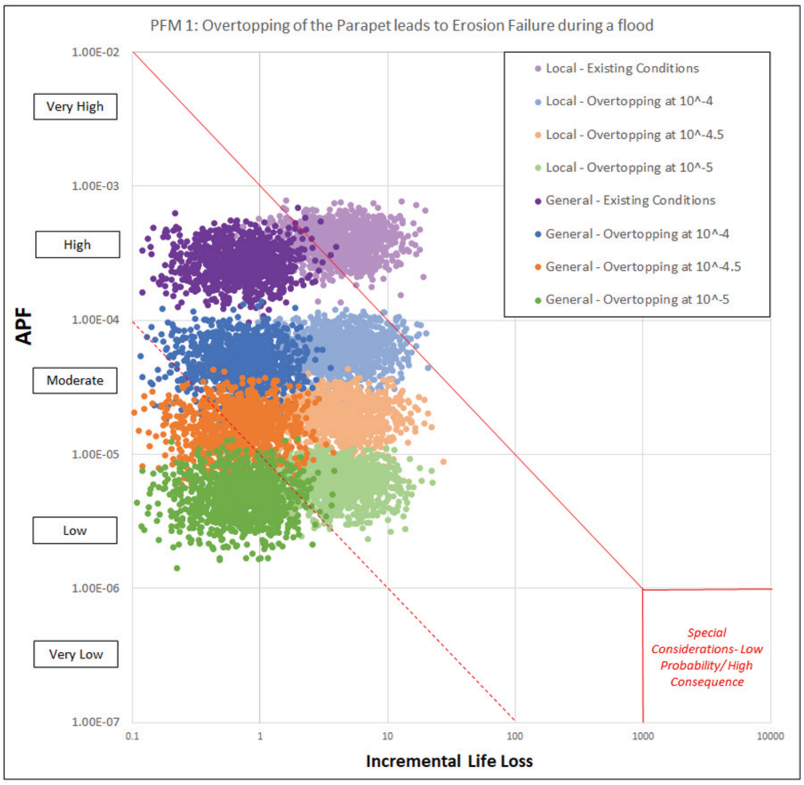

Figure 2 : Results of L4RA

4.5 Mitigation Alternatives

At the end of the workshop, potential alternatives for reducing the risk were discussed. The discussion included both options for reducing the likelihood of failure and options for limiting the consequences. Work had also been done prior to the workshop to evaluate potential risk reduction mitigation alternatives and their estimated costs. The items that were evaluated prior to the workshop are focused on modifying the dam to reduce the likelihood of failure. The primary rehabilitation alternatives and their estimated costs are provided Table 2.

Mitigation alternatives were evaluated by re-estimating the likelihood of overtopping based on the spillway modification considered, which was reflected in the AEP of the first node (depth of overtopping) and by re-estimating the probability of eroding through and failing the embankment under that new depth of overtopping. The structure of the event tree allows for relatively rapid evaluation of alternatives and combinations of alternatives.

Table 2 : Mitigation Alternatives Considered

	Construction Cost	
Rehabilitation Alternative	**Low**	**High**
1. RCC Armoring	$799,000	$1,482,000
2. ACB Armoring	$538,000	$1,025,000
3. Boulder Armoring	$364,000	$767,000
4. Boulder Armoring with Slush-grouting	$492,000	$1,025,000
5. Auxiliary Labyrinth Spillway	$1,003,000	$1,897,000
6. Raised and Lowered Parapet	$296,000	$556,000
7. Labyrinth Principal Spillway	$826,000	$1,448,000
8. 40' Principal Ogee Spillway	$603,000	$1,027,000

5. CHALLENGES ASSOCIATED WITH IMPLEMENTATION OF RIDM GUIDELINES

There were several challenges associated with implementing the RIDM Guidelines for this pilot project. These can be categorized into four general areas described below.

5.1 Use of Previously Developed Potential Failure Modes

Since the early 2000s licensees, through five-year periodic inspections and associated potential failure modes analyses (PFMA), have developed potential failure modes (PFM) that could form the basis for implementation of RIDM. If formulated correctly these PFMs would be initially evaluated utilizing the Draft RIDM Guidance for evaluating the likelihood and consequences of failure. However, in many cases, the previously developed PFMs are of insufficient detail to accurately portray the initiation, progression, and continuation to failure. Because of this, most licensees have been required to spend excessive amounts of time and money brainstorming, screening, and developing failure modes that had they been properly developed previously would have formed the basis for evaluating risk.

In addition, over the last 20 years, many licensees have been reluctant to thoroughly brainstorm, screen, and develop PFMs and many credible PFMs were overlooked, dismissed as non-credible or ruled out. This has also added to the need for licensees to spend much more time during the implementation of L2RA, brainstorming, screening, and developing PFMs which requires more significant investment to move from the PFMA process to a RIDM process. SCE addressed this issue early on, during the implementation of a thorough portfolio screening process.

5.2 Limited to No Flood Frequency or Probabilistic Seismic Hazard Information

Moving from qualitative risk analysis (PFMA) to semi-quantitative and quantitative risk analysis requires better understanding of probabilistic relationships for flood and seismic events. The FERC PFMA process utilizes deterministic parameters (PMF and MCE) to evaluate PFMs. This clearly provides very limited information for estimating likelihood for events of lesser magnitude and as a result the critical load cases (loads of higher probability that result in similar consequences) would be missed. To properly assess likelihood moving into semi-quantitative and quantitative analyses requires that licensees perform these analyses. SCE addressed this issue by performing probabilistic seismic hazard analysis (PSHA) and stochastic event flood modeling (SEFM) during the semi-quantitative and quantitative analyses.

5.3 Limited Understanding of Consequences of Failure

Because the PFMA process does not specifically require a rigorous assessment of consequences, very little information is typically available beyond inundation mapping and an estimate of population at risk (PAR). While this provides an upper bound for L2RA, it is likely to grossly overestimate the potential life loss which should include assessment of breach location and duration, warning time, depth and velocity, and proximity to safe locations during a failure event. As a result, most licensees will need to perform some form of consequence analysis prior to performing the L2RA. SCE utilized the Reclamation Consequence Evaluation Method (RCEM) to estimate PLL for various failure scenarios.

5.4 Availability of Subject Matter Experts

Because implementation of risk informed decision making has been slow to develop outside of the Federal dam owners in the US, the broader dam engineering community is not well versed in the use of risk analysis methods. As a result, there are limited numbers of experienced engineers to serve as subject matter experts (SME), outside of those with previous USACE and USBR experience where risk analysis has become common place over the last 10 to 20 years.

To help mitigate this problem, SCE utilized several SMEs who may have lacked an extensive risk background but whom were recognized for their strong technical credentials. SCE worked closely with FERC on approvals for these individuals for the pilot project. FERCs level of comfort with this approach stemmed from recognition of their technical credentials, and from the strong collaborative relationship SCE maintains with consultants.

5.5 Coordination and Schedule

Because of the high demand for the relatively small pool of individuals who have the requisite experience, the project was delayed due to scheduling conflicts and lack of availability. It was difficult to coordinate and schedule days long working meetings and workshops for up to fifteen individuals from SCE, FERC, DSOD, and multiple consulting firms. Teleconferencing was used with limited success and the process was pushed out to allow as many of the key individuals as possible to attend in person.

5.6 Simulation/Calculation Results

There was a tendency for SMEs to "anchor" to their estimates which can potentially lead to underestimation of uncertainty. This was discussed during the QRA workshop, particularly relating to erodibility and consequence estimation. During the QRA, the risk review board (RRB) was allowed to voice concerns if they felt this was occurring. The suggested sensitivity analyses be performed and upon discussion it became clear the SMEs had performed adequate sensitivity analyses and properly evaluated "what-if" scenarios.