Probabilistic Risk Analysis for Dams

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Workshop on
Probabilistic Flood Hazard Assessment (PFHA)

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U.S. NRC Headquarters Auditorium
11555 Rockville Pike, Rockville, MD 20852

Risk Analysis for Dam Systems

- In comparison to the nuclear industry, the state of PRA for dams is relatively new; maturing.
- In the nuclear business we are arguably in the second major generation of PRAs for all NPP.
- The nuclear industry has risk-informed regulation, a standard for PRAs, a PRA peer review process and regulatory oversight.

Risk Analysis for Dam Systems (cont.)

- With respect to external hazards (specifically seismic)
  - Evaluation of aleatory and epistemic uncertainties is a requirement; evaluation of epistemic uncertainty is at the forefront, not an afterthought
  - A SSHAC Level 3 or 4 is required

- In the dams business risk analysis is not as mature and not yet integrated into dam safety management and regulation; though as we heard it is getting there.

Risk-Informed

- Work is going one now with a number of hydropower utilities and the FERC to develop risk-informed methods for the evaluation of dam systems.

- The process is:
  - Risk-informed (though risk analysis of a project may not be needed),
  - Systems-based, and
  - Incorporates consideration of aleatory and epistemic uncertainties.

- The process is based on the assumption that the FERC is will have a tolerable risk criterion that must be satisfied.

- The process must be pragmatic, since all dams will not be required to do a PRA.

Systems-Based

- Dam systems are a comprised of:
  - Structures (natural and man-made)
  - Systems (control systems to operate gates, low level outlets, etc.),
  - Mechanical & electrical components, and
  - Operators

- While dams are not as complex as nuclear power plants, there are numerous opportunities (combinations of events) that can lead to uncontrolled release.

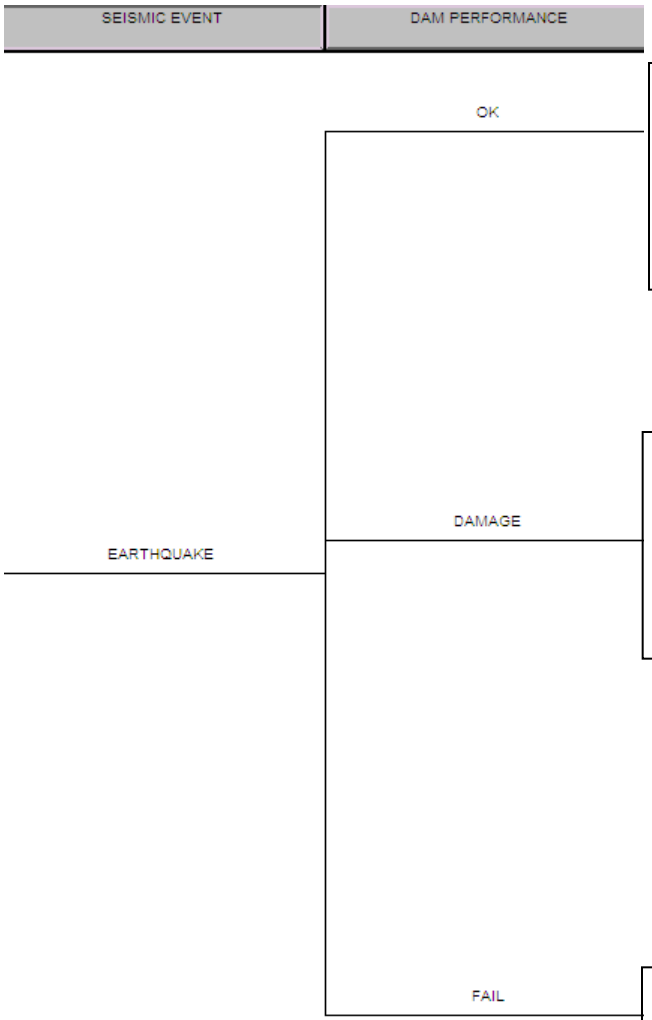
- An objective of the seismic evaluation process is for the licensee to develop an understanding of:
  - Seismic integrity/vulnerability of the structures, systems and components
  - Accident sequences that may occur, and
  - System performance that supports risk-informed operator training, emergency action planning, and post-event operations.

Systems Based (cont.)

- Consider the following scenario for a hydro project:
  - Earthquake occurs; dam survives but may be damaged
  - The reservoir is maintained at a level above the spillway crest
  - Gates have failed closed, offsite power and station power is lost
  - The reservoir pool must be lowered to prevent failure, overtopping of the project embankments – at current (normal) inflows overtopping occurs in 12 hours
- Outflow capacity must be maintained in all cases, otherwise embankment overtopping will occur
- Potential modes of failure:
  - Piping through the damaged embankment
  - Overtopping the damaged or intact embankment


Embankment
Embankment

Systems Based (cont.)

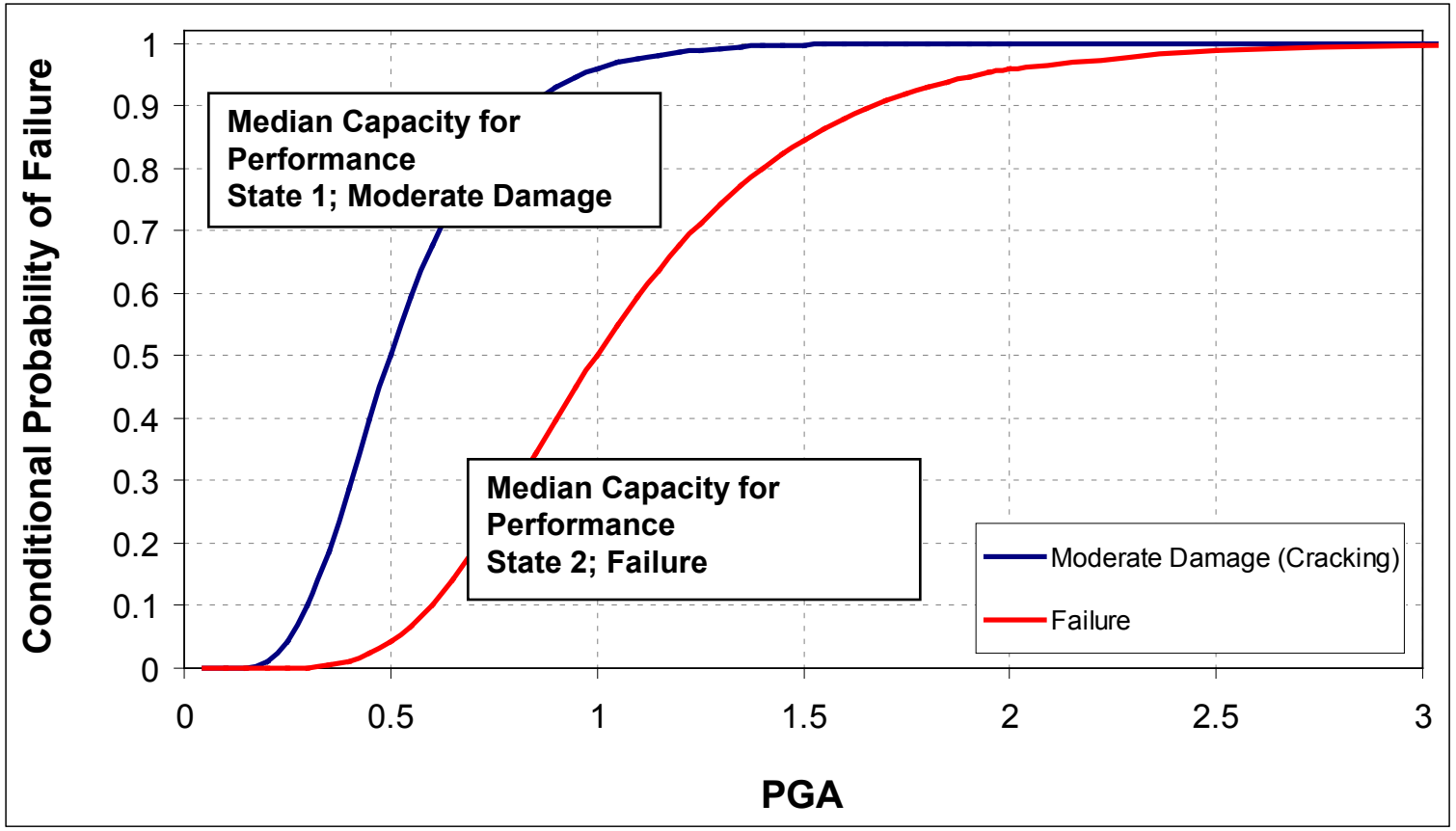


Reservoir retention structures are OK, but hydraulic control systems must operable to maintain outflows, otherwise embankment overtopping occurs leading to uncontrolled release of the reservoir.

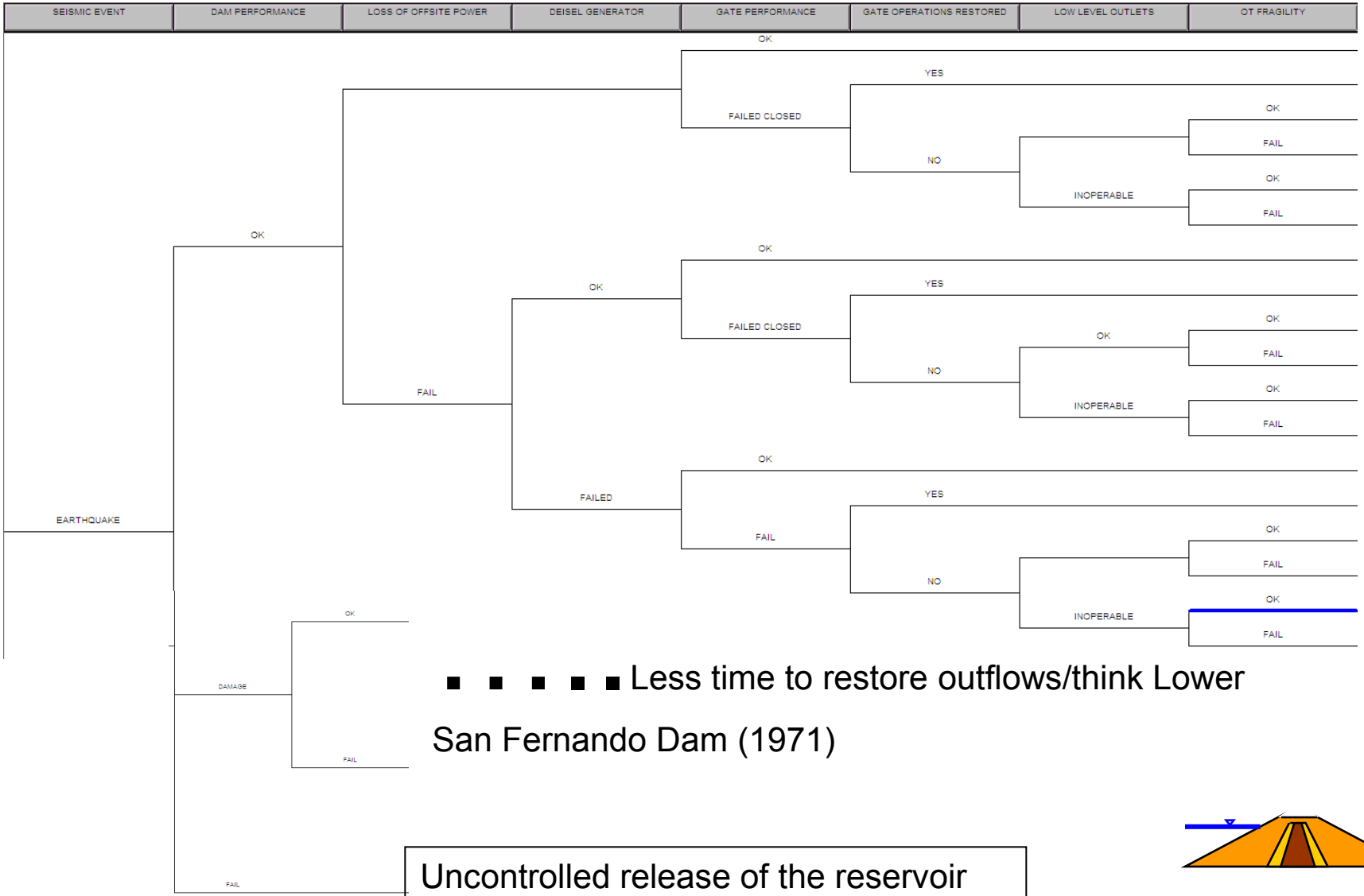
Reservoir retention structures are damaged. Failure may occur unless the reservoir can be lower considerably (i.e., Lower San Fernando Dam). Hydraulic control systems must operable.

Uncontrolled release of the reservoir

Systems Based (cont.)



Systems Based (cont.)



■ ■ ■ ■ ■ Less time to restore outflows/think Lower San Fernando Dam (1971)

Uncontrolled release of the reservoir

Consideration of Uncertainties

Taxonomy / Partitioning of Uncertainties

Element	Epistemic	Aleatory
Modeling	Uncertainty about a model and the degree to which it can predict events. Model, epistemic uncertainty addresses the possibility that a model may systematically (but not necessarily predictably), over- or under-predict events/results of interest (i.e., deformations).	Aleatory modeling variability is the variation not explained by a model. For instance, it is variability that is attributed to elements of the physical process that are not modeled and, therefore, represents variability (random differences) between model predictions and observations.
Parametric	Parametric epistemic uncertainty is associated with the estimate of model parameters given available data, indirect measurements, etc.	This uncertainty is similar to aleatory modeling uncertainty. However, this is variability that may be due to factors that are random, but ave a systematic effect on model results.

Summary

- The seismic evaluation process is being prototype on a number of projects.

- Once this work is completed, final documentation of the methodology and implementation guidance will be prepared.