Event Trees

Dam Safety Risk Analysis Best Practices

Last Modified 7/2/2010
Presentation Taken From One Developed for Reclamation Best Practices

• This is an abbreviated version and not meant to be a complete look at the Reclamation Best Practices

• The presentation is to provide an introduction to important concepts that Reclamation has developed over many years
Key Concepts

• An event tree is constructed using a series of nodes and branches
• Each node represents an uncertain event and each branch represents a possible outcome
• A well-defined failure mode is easily “decomposed” into a sequence of necessary events or potential states of nature
• All events in the sequence must take place to allow an uncontrolled reservoir release
• Event trees are very flexible and can be adapted to portray most any potential failure mode
Key Concepts (cont.)

• Event trees are typically constructed from left to right starting with an initiating event, typically a load.
• Loads are partitioned into ranges which cover the full possibility of loading.
• The probability for each outcome at each subsequent node (proceeding to the right) is estimated assuming the previous branch has already occurred.
• The branch probabilities for a given node must sum to 1.0.
• Branch probabilities are multiplied through the tree from left to right.
• End branch probabilities which lead to failure are summed for annual failure probability.
Key Concepts (cont.)

• Consequences are usually included at the end branches which result in failure
• The end-branch probability multiplied by its associated consequence is that branch’s contribution to the annualized probability of that consequence (if life loss, then APLL)
• Contributions from each branch are summed in various ways
• Event trees shown are examples only. It is important to think about site specific conditions and adjust the event trees accordingly
Example Failure Mode Description No.1

- During a period of high reservoir, when the foundation becomes saturated (based on piezometric measurements), seismically-induced liquefaction of a loose and continuous foundation sand layer, identified in borings between Stations 2+50 and 5+50, leads to instability of the downstream slope of the dam, crest deformations greater than the available freeboard, and overtopping erosion breach of the dam.
Example Event Tree No. 1

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Example Failure Mode Description No. 2

- During strong earthquake shaking, the concrete gravity dam cracks completely through upstream to downstream over several monoliths along a lift joint at the change in slope on the downstream face at Elevation 1137. If sufficient earthquake-induced sliding displacements follow, the formed drains in the dam could become severed, increasing the uplift pressures on the cracked plane. Post-earthquake sliding instability of the cracked section results in dam breach and uncontrolled release of the reservoir.
Example Event Tree No. 2

Note: Risks dependent on earthquake level and reservoir level at the time of the earthquake

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Load Ranges

• Threshold loading – below which risk contribution is considered negligible – very important, put some thought and study into it and how you will define what the threshold represents. This may require iterative analyses at smaller loads.

• Select enough load ranges such that changes in conditional response are smoothly captured. Interpolate analysis results if necessary (may require analyses at more than just 10k and 50k ground motions)

• There should not be a wide range in conditional response between the upper and lower end of a load range.
Load Ranges (cont.)

• Be aware that load range probability is dominated by most frequent load when estimating conditional response for the range
• Load range boundaries may be selected to correspond to loads where analysis results are available (consider weighting response estimates toward low end of range)
• Or, place corresponding analysis value within the range (consider placing it closer to the lower end)
Load Ranges (cont.)

- To obtain a mean load range probability, subtract the probability of the lower load from the probability of the upper load.

\[
\begin{align*}
P &= 0.006 \\
P &= 0.033 \\
P &= 0.027 \\
\end{align*}
\]

\[
\begin{array}{c}
\text{Annual Probability of Exceedance} \\
\text{Peak Horizontal Acceleration (g)} \\
\end{array}
\]

\[
\begin{array}{c}
\text{Return Period (yrs)} \\
\end{array}
\]

\[
\begin{array}{c}
\text{Mean} \\
16\text{th Percentile} \\
84\text{th Percentile} \\
\text{Median} \\
\end{array}
\]

\[
\begin{array}{c}
0.10g \\
0.30g \\
\end{array}
\]