Approach for Developing Design and Evaluation Ground Motions

Faiz Makdisi and Robert Youngs
AMEC Geomatrix

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Overview

- Study conducted for Southern California Edison
- Object to characterize ground motion hazard for assessment of seismic safety of existing dams
- Provide a probabilistic framework for assessment of potential for uncontrolled water release

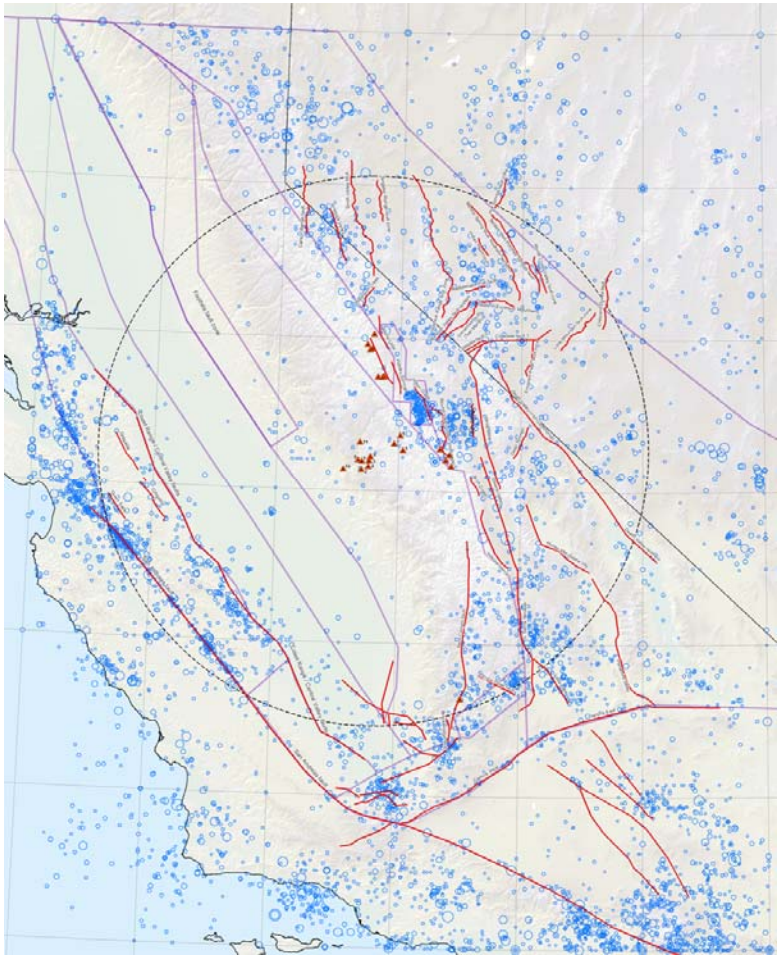
Approach

- Develop a probabilistic seismic hazard model for the study region
- Perform PSHA calculations for each dam site
- Deaggregate PSHA results to identify scenario earthquakes contributing to site hazard
- Develop representative acceleration time histories for scenario earthquakes for analysis of dam performance

Seismic Hazard Study

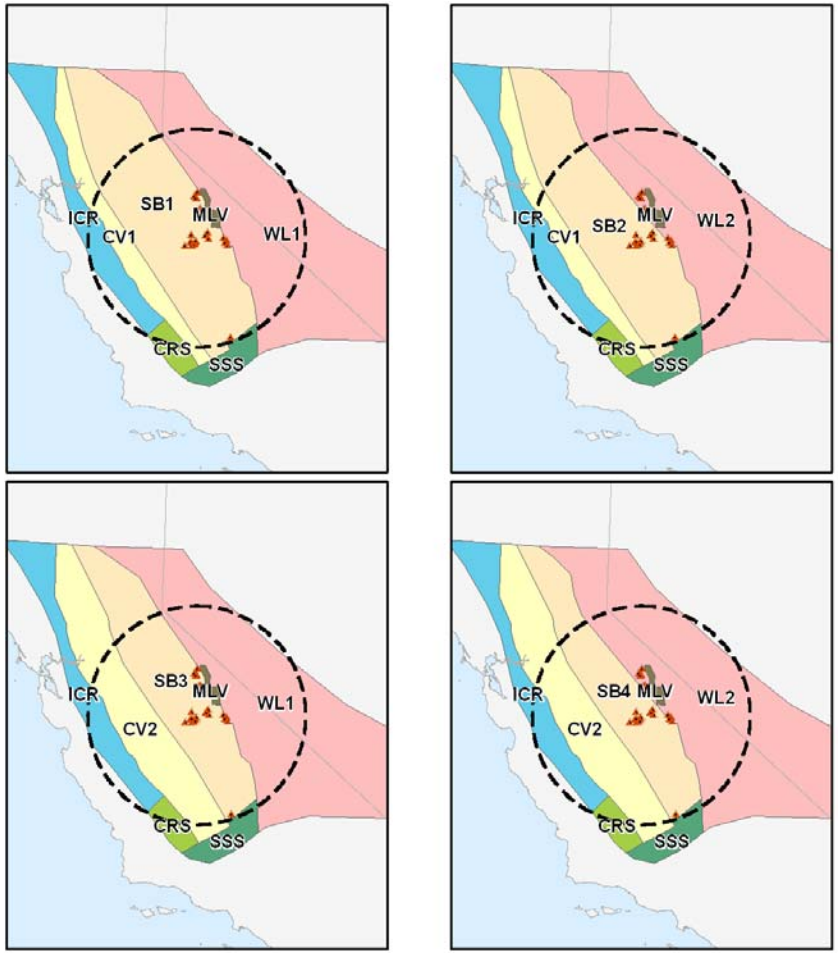
- Develop seismic hazard model for region
  - Compile earthquake catalog
  - Compile information on faulting
    - Location, Activity (slip) rate, maximum magnitudes
  - Assess seismic zonation and earthquake occurrence rates

Study Regions and Fault Sources



- Compile fault data from
  - USGS National Hazard Mapping
  - CGS
  - WG2002
  - Bureau of Reclamation
  - Specific studies for Isabella Dam

Seismic Source Zonation

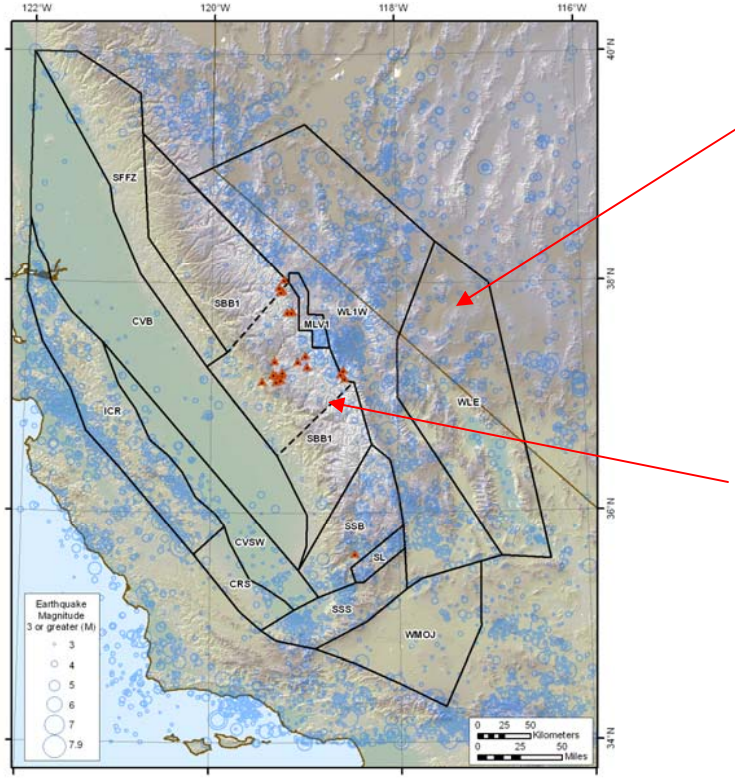


- Defined based on seismo-tectonic blocks
- Consider alternatives for eastern and western boundaries of the Sierra Nevada block and Mono Lakes

Testing of Source Zonation

- “Classic” PSHA source zones assume uniform spatial distribution
- Model can be tested statistically using observed catalog and simulation (Musson, 2000)
- If tests “fail”, then remedies
  - Spatial smoothing
  - Define subzones/alternative zonation

Adjustments to Source Zones

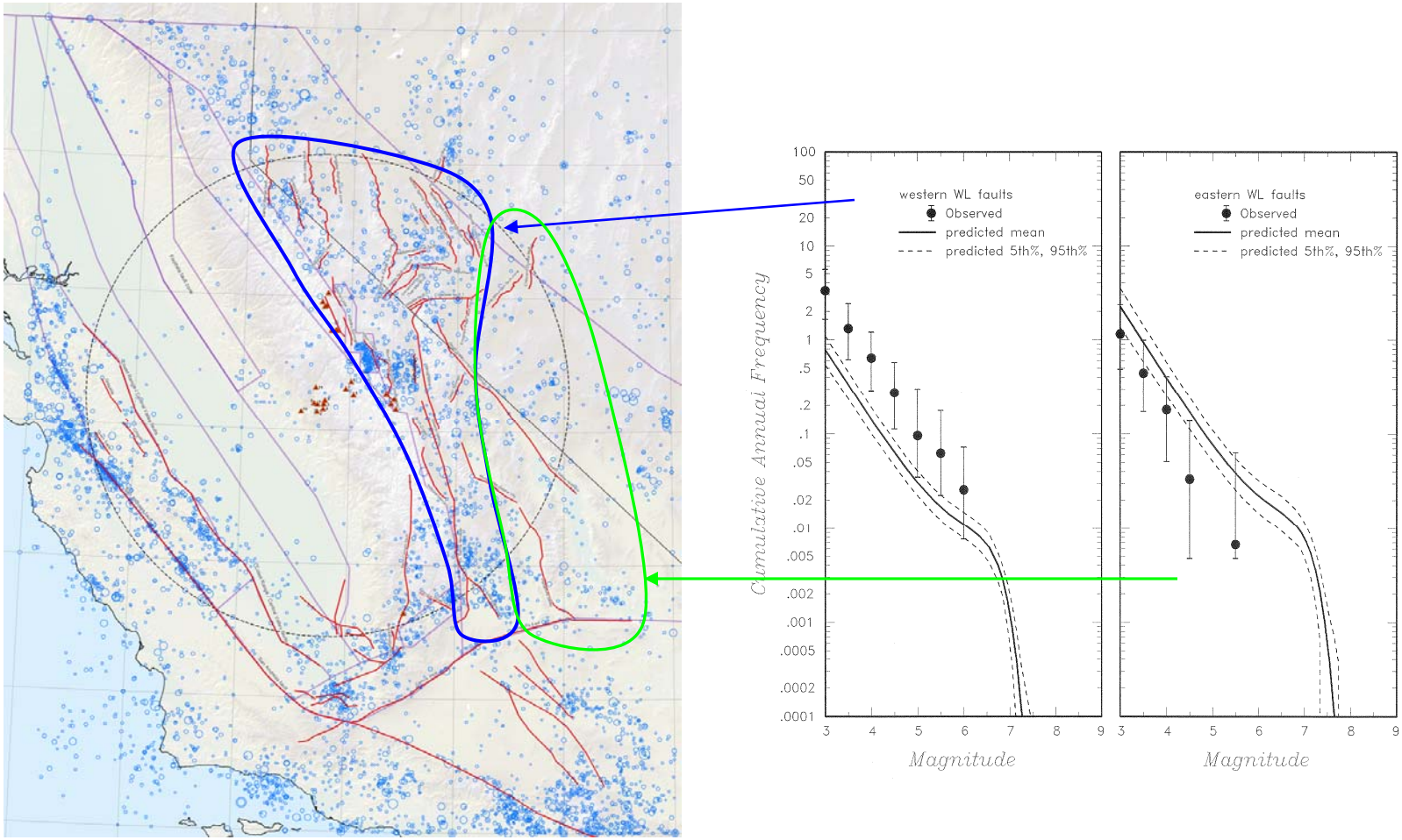


- Subdivision of Walker Lane in eastern California-western Nevada
- Central Sierra Nevada subzone with somewhat higher seismicity rate

Testing of Earthquake Frequency Prediction

- Do geologic based models for earthquake occurrence on faults adequately predict observed seismicity in vicinity of faults?
  - If yes, remove earthquakes in vicinity of faults from computation of earthquake rates for source zones
  - If no, include all earthquakes in calculation of rates for source zones

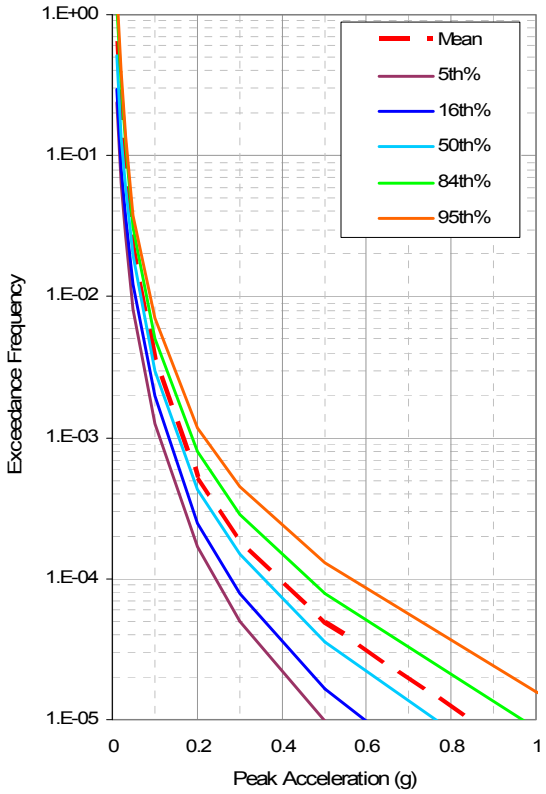
Examples from Walker Lane

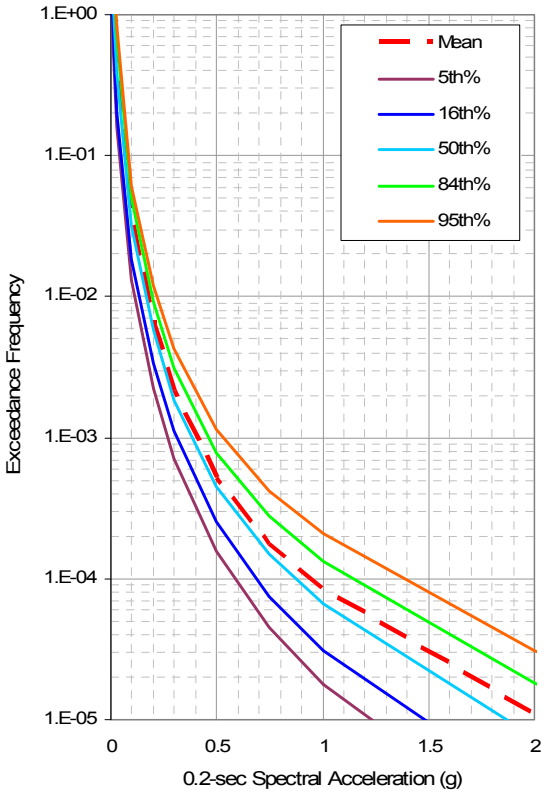


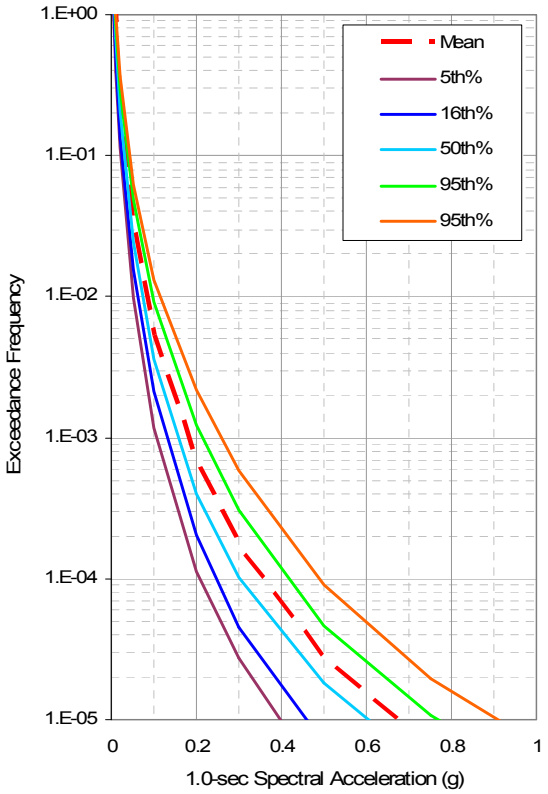
Ground Motion Models

- Used PEER NGA ground motion models
  - 5 for rock sites
  - 4 for soil site
- Included epistemic uncertainty in median for each model based on statistical uncertainty in regression fits ($\sigma_\mu = 0.15$)
- Used nominal V_{S30} values suggested in the past by California DSOS
  - May update using site-specific measurements when available

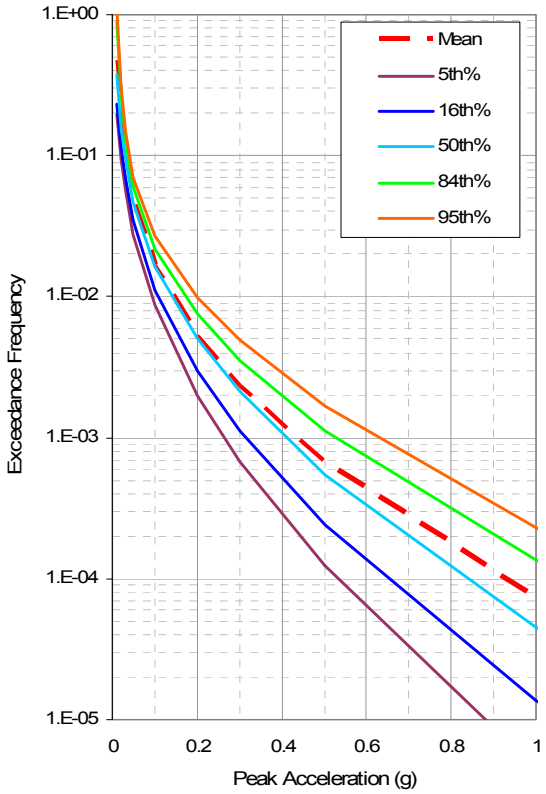
Example PSHA Results
Central Sierra Nevada Site

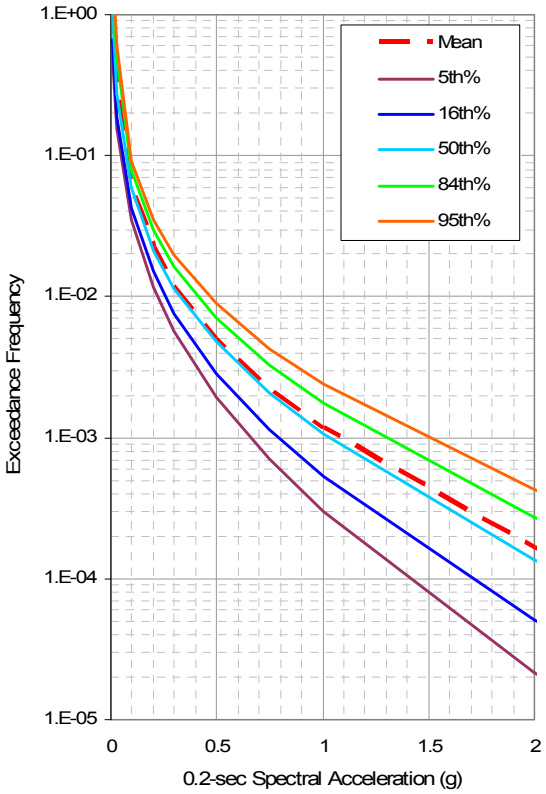


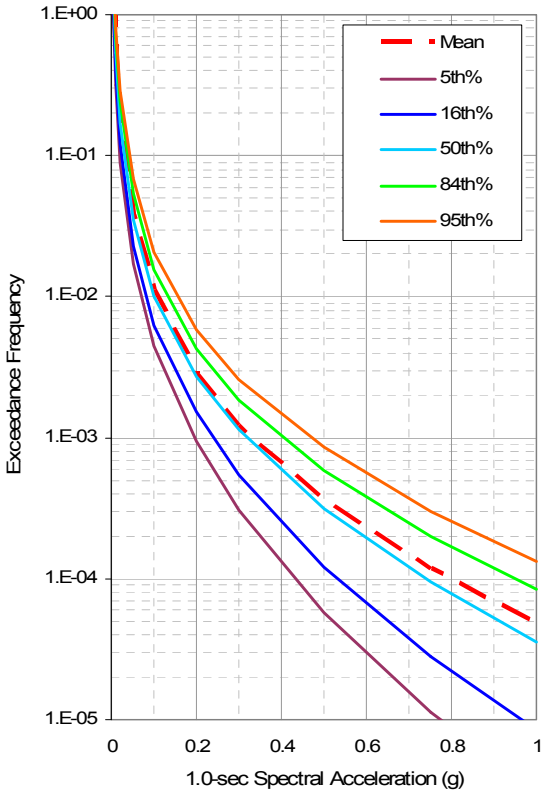




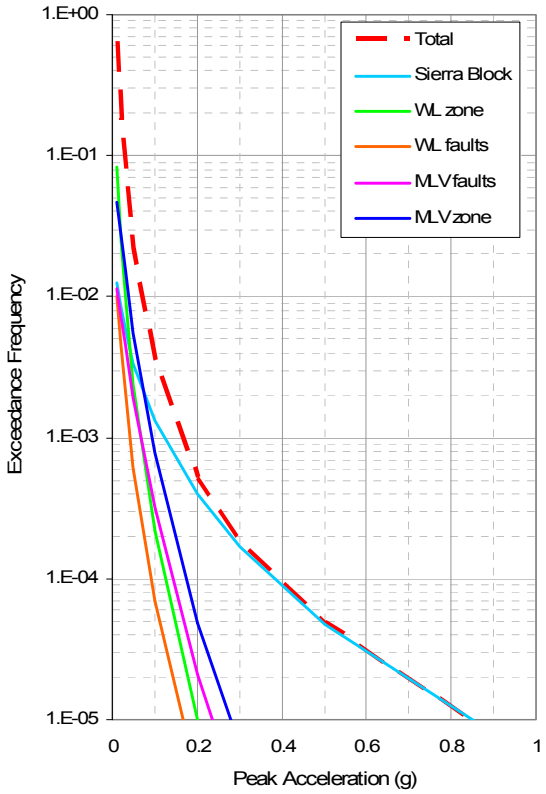
Example PSHA Results
Eastern Sierra Nevada Site

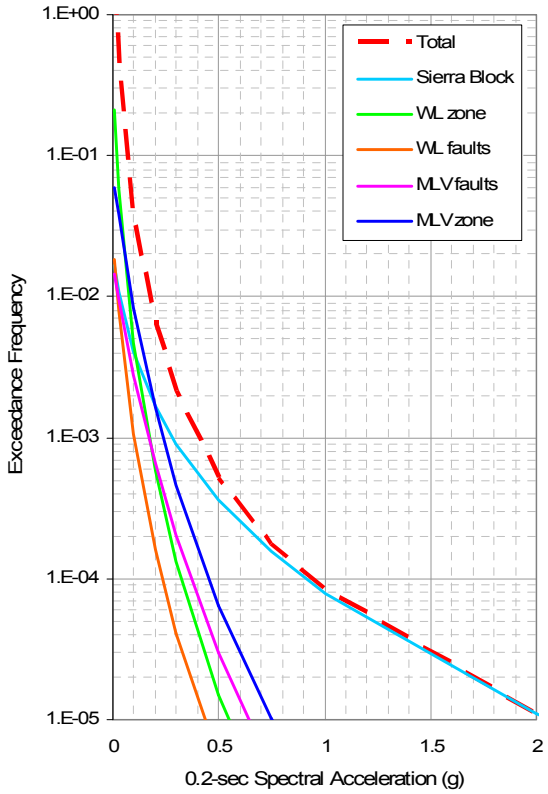


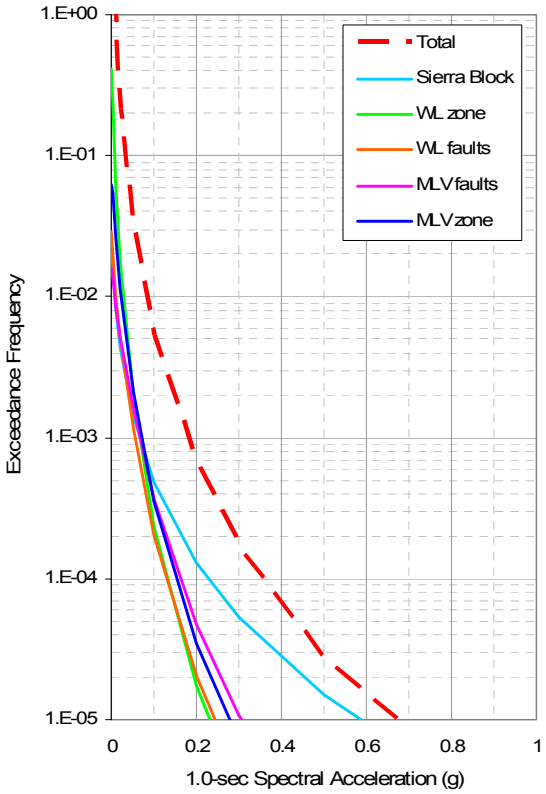




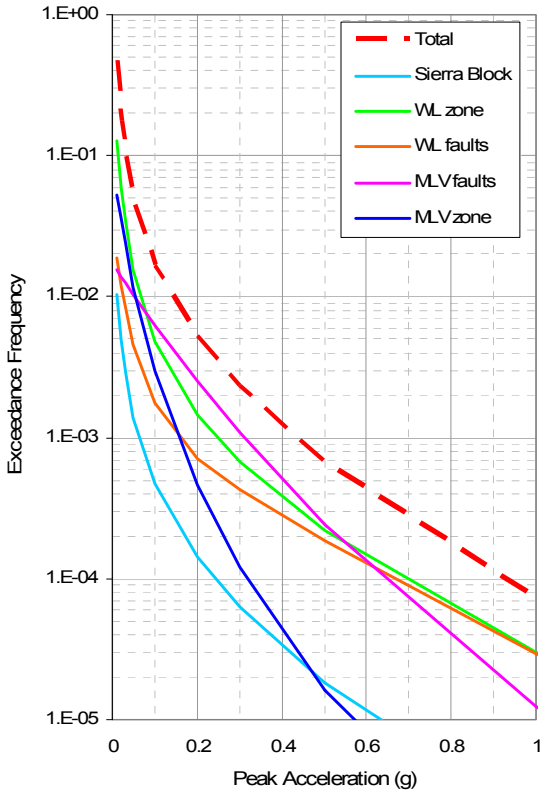
Source Contributions
Central Sierra Nevada Site

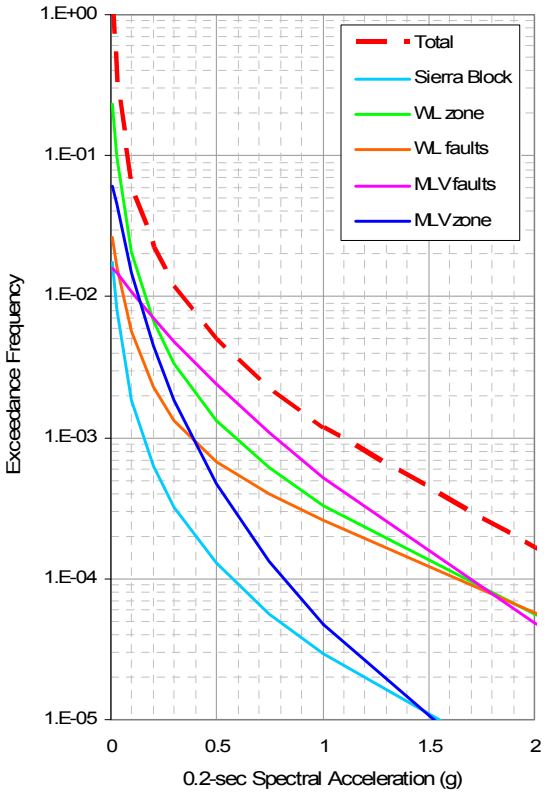


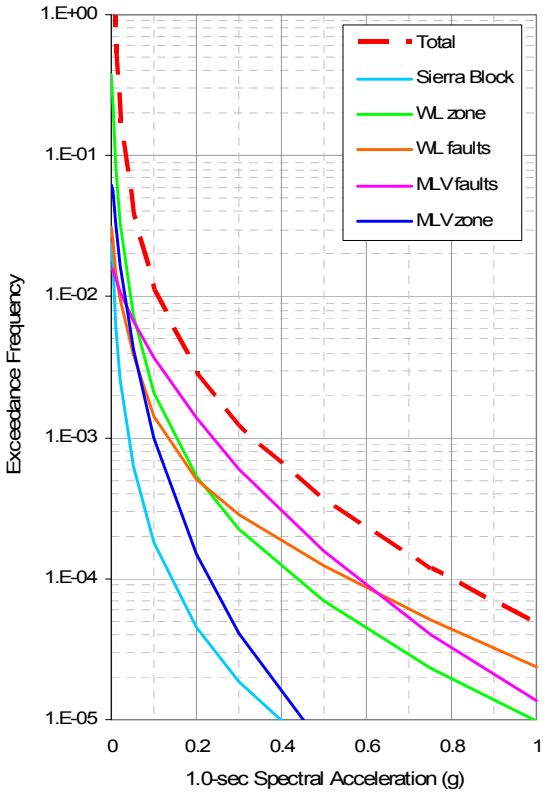




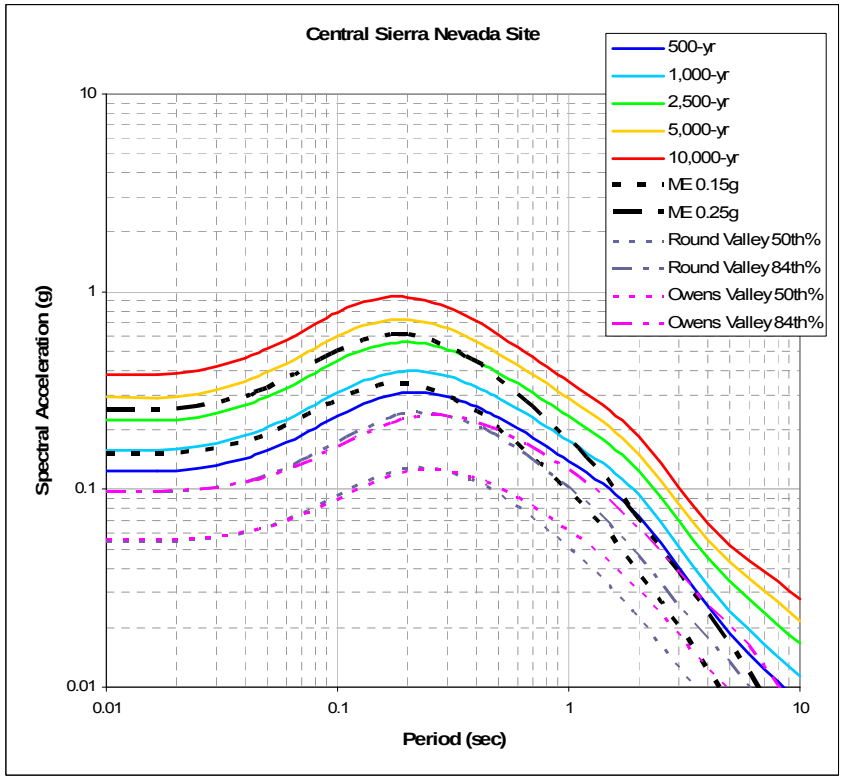
Source Contributions
Eastern Sierra Nevada Site

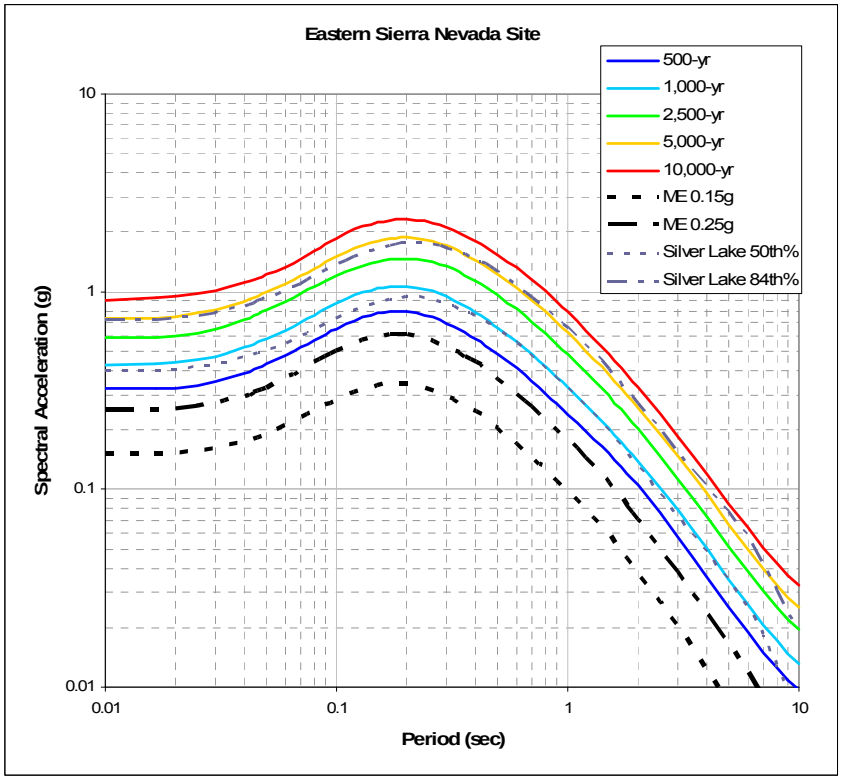






Example Uniform Hazard Response Spectra

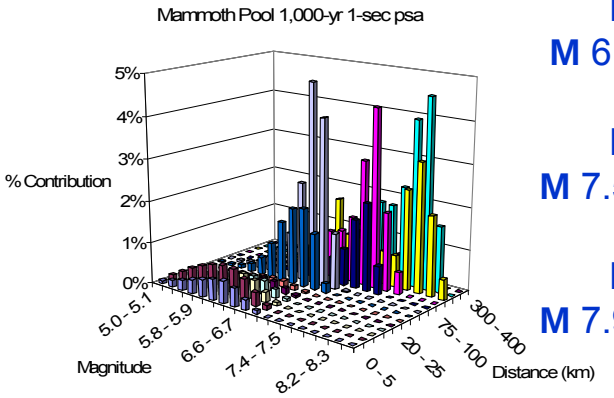




Development of Ground Motions for Seismic Analysis

- Identify scenario earthquakes from deaggregation of PSHA for spectral frequency of dam
- Construct appropriate response spectral shapes for scenario earthquakes
- Select strong motion recordings that have response spectra consistent with scenario earthquake spectra
- Scale time histories to match UHRS in frequency range of interest

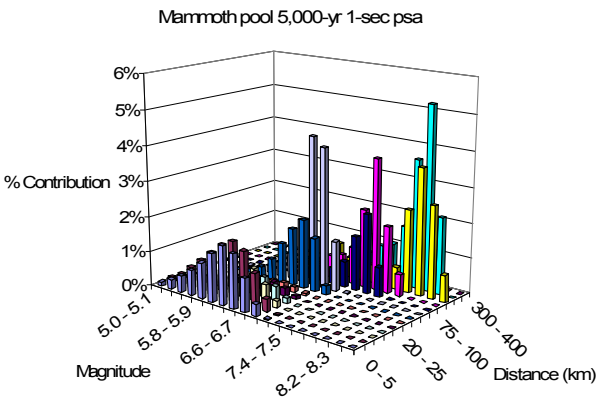
Example Scenario Earthquakes for Low Frequency Dam (~ 1 Hz)

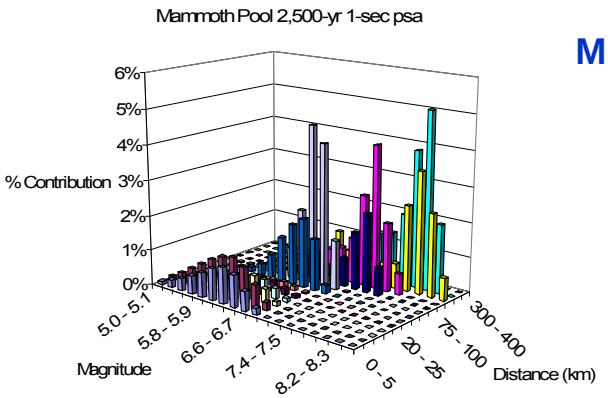


Event 1
M 6.6 at 60 km

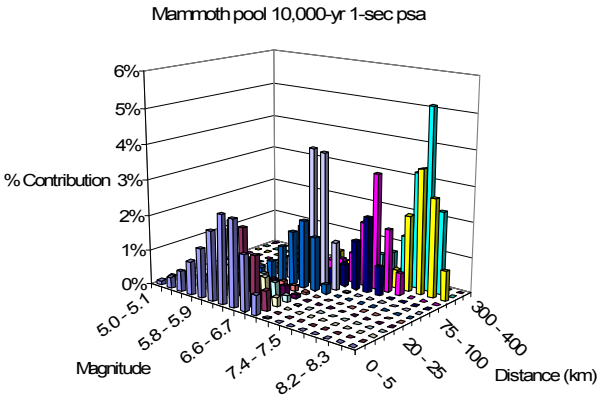
Event 2
M 7.5 at 100 km

Event 3
M 7.9 at 200 km

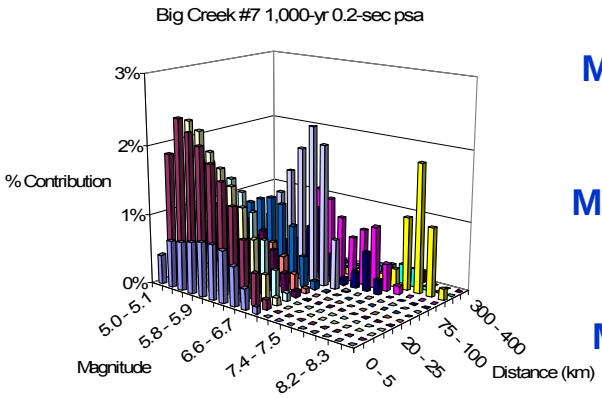




Event 4
M 6 at 7 km



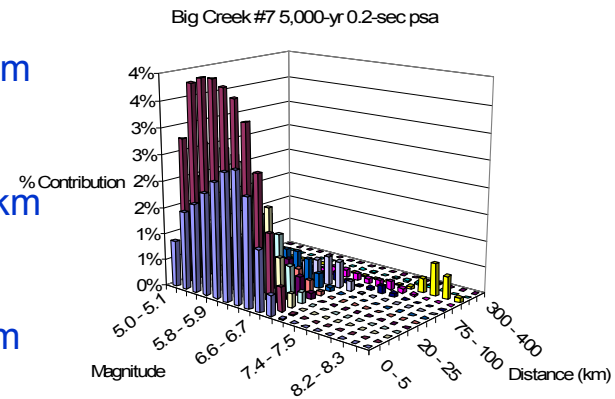
Example Scenario Earthquakes for High Frequency Dam (~ 5 Hz)

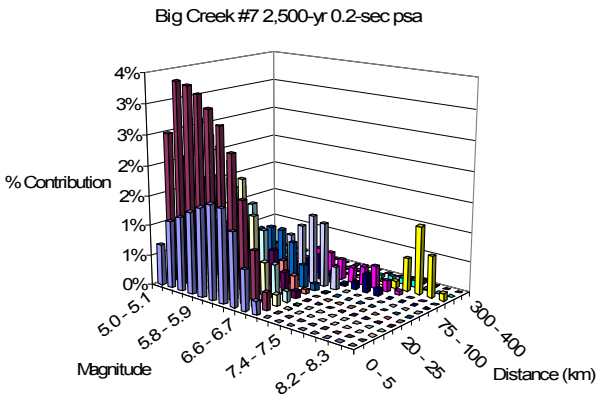


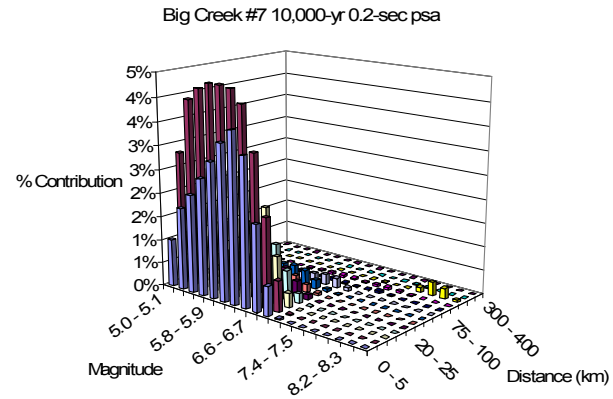
Event 1
M 6.6 at 45 km

Event 2
M 7.9 at 175 km

Event 3
M 5.8 at 7 km





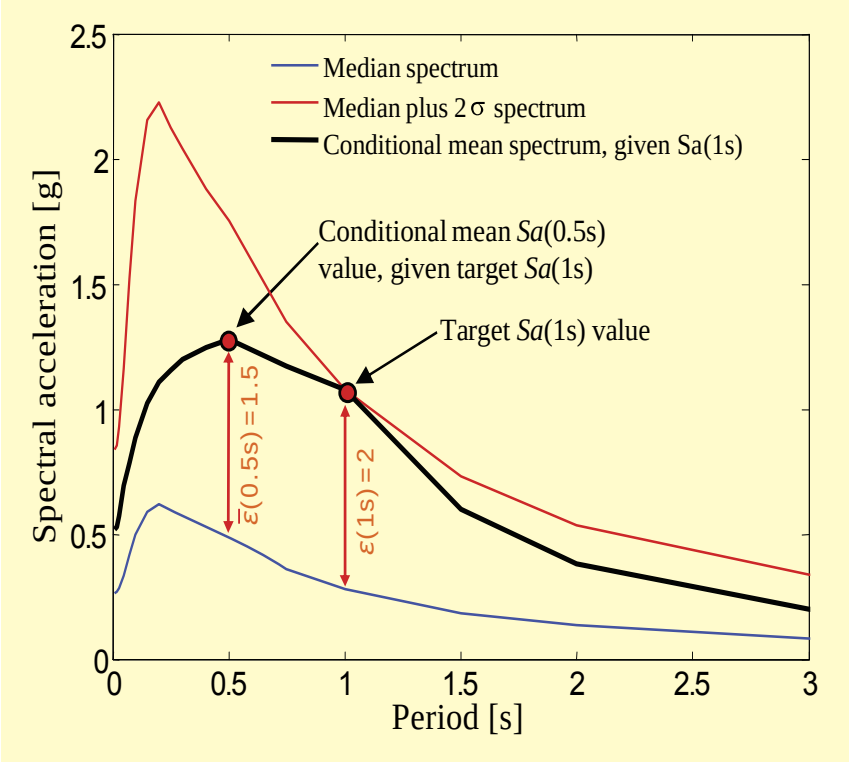


Target Response Spectra

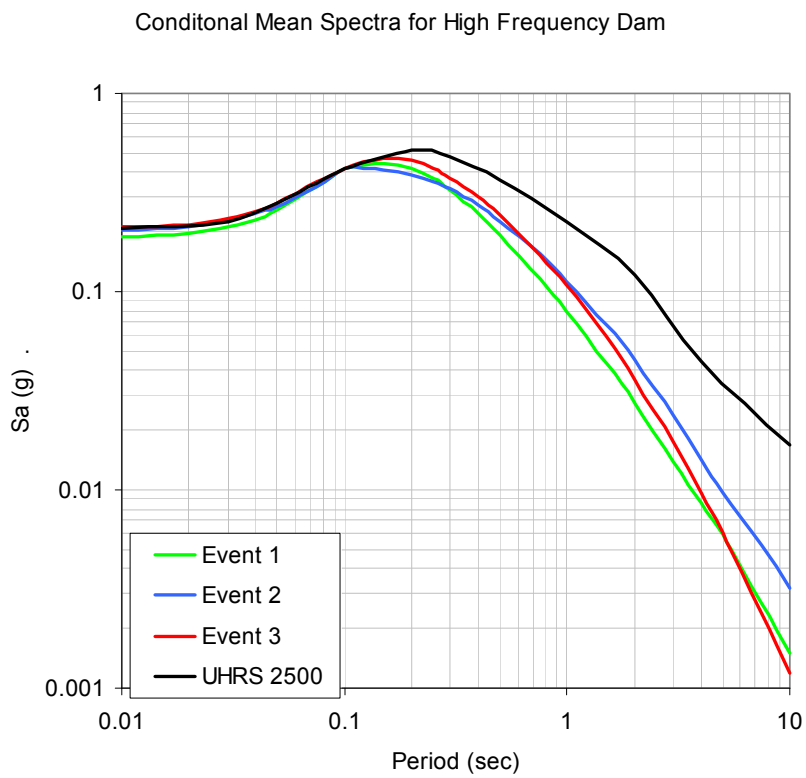
- Using UHRS is a conservative approach in that no single earthquake is likely to produce that level of shaking over a broad frequency range
- Used concept of Conditional Mean Spectra (Baker and Cornell, 2006) to develop response spectra targeted to UHRS value at frequency (or frequencies) of importance to dam response.

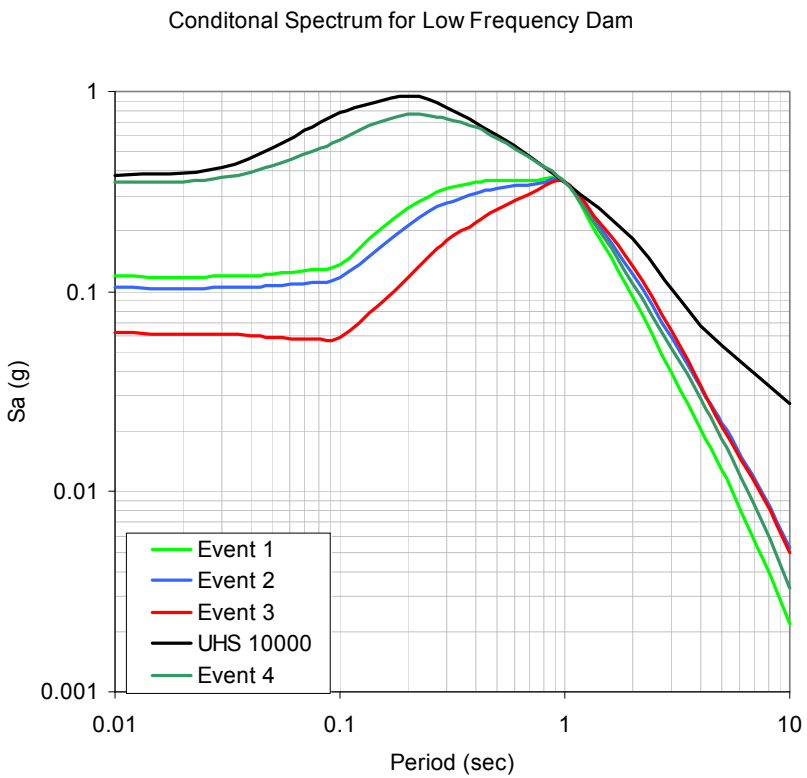
Conditional Mean Spectrum
(Baker and Cornell, 2006)

- Determine target spectral acceleration at target period from UHRS
- Determine number of standard deviations for this value.
- Use model for correlation between spectral periods to determine the expected ground motions at other periods.



Conditional Mean Spectra

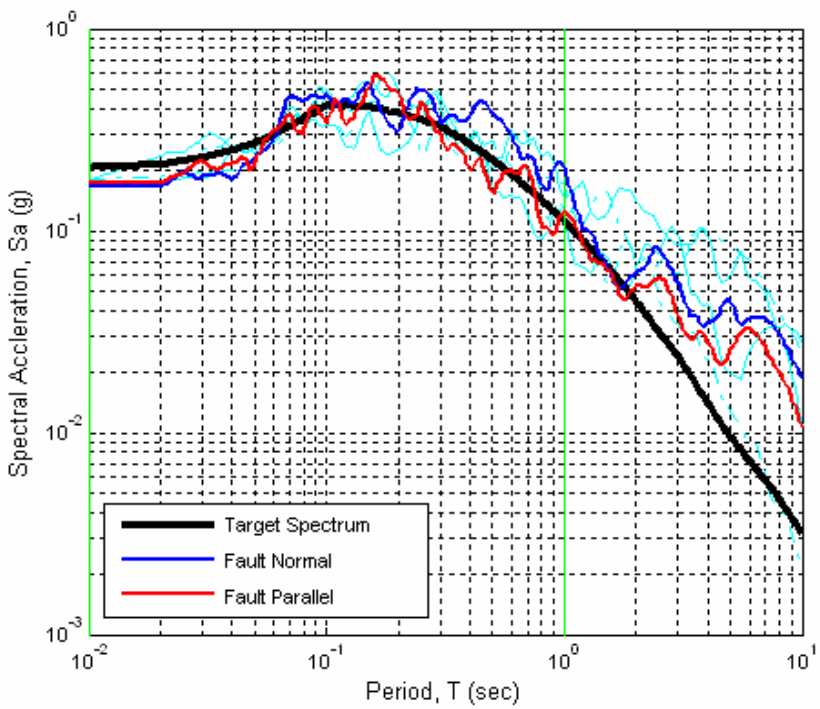


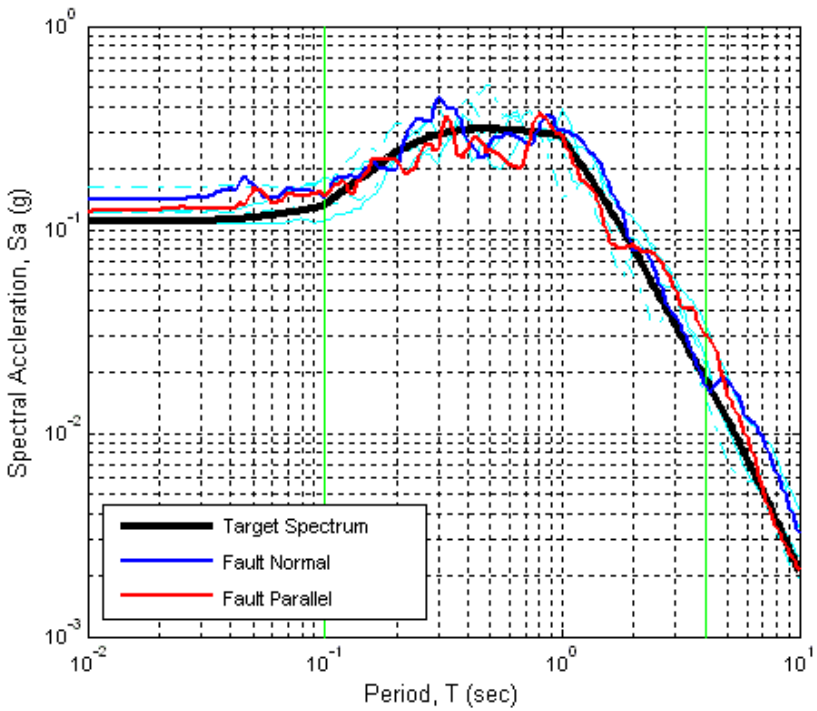


Selection of Time Histories

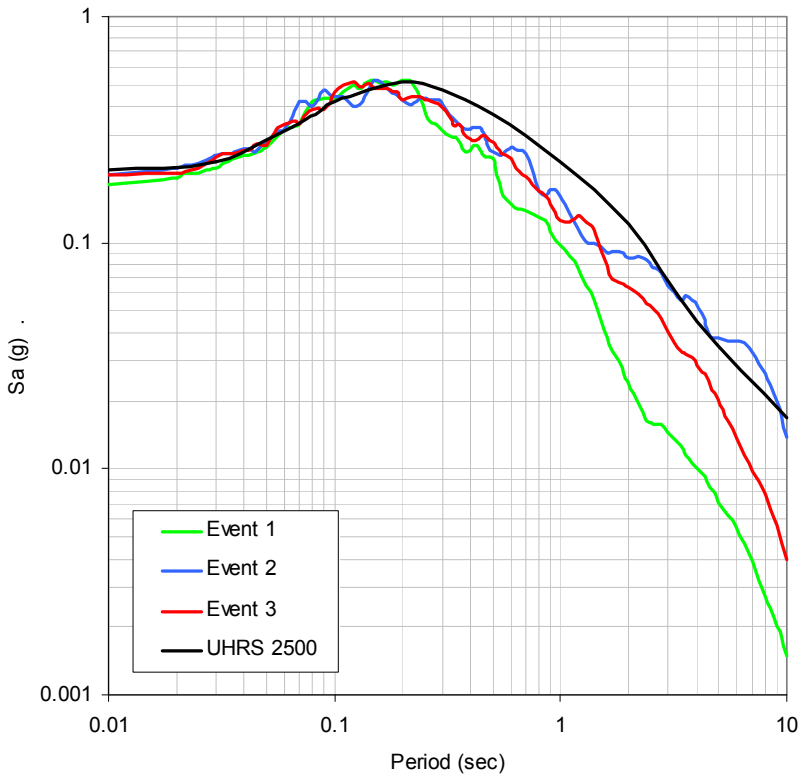
- Use as recorded motions from the PEER-NGA data base
- Select time histories whose spectra (geometric mean of two components) match on average target Conditional Mean Spectra over a broad frequency range (have the same shape)
- Scale time history (linearly) to match UHRS over the period range of interest

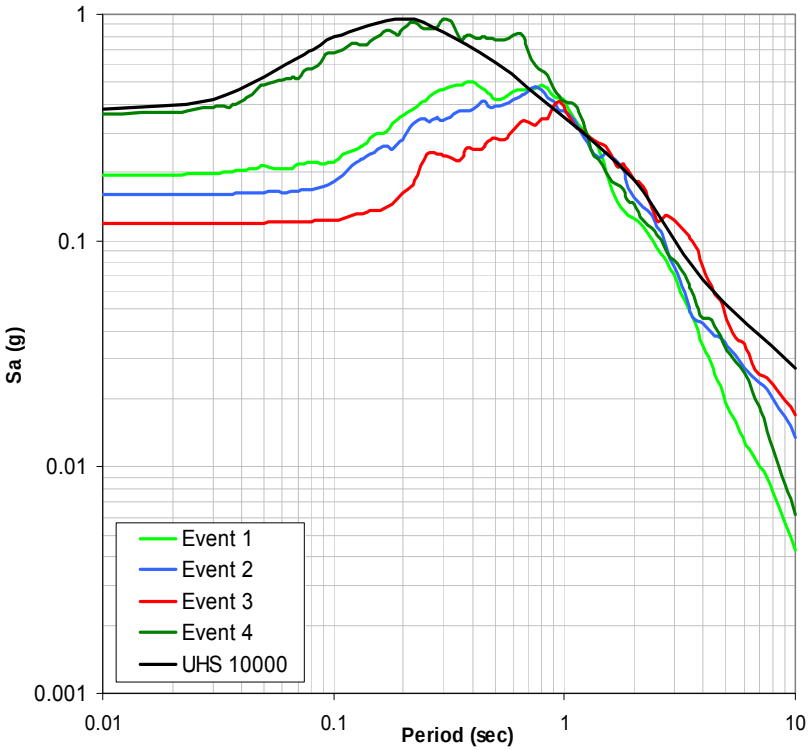
Example Record Selection





Average of Scaled Spectra





Conclusions

- Advantage - Conditional Mean Spectra provide a more realistic representation of individual earthquakes that may affect the dam
- Disadvantage – may require multiple scenario earthquakes to cover the full frequency range of importance to dam response – more analyses may be needed