Developing the Technical Basis for Selection of Appropriate Return Period for Dams in Active Regions Status of the DRP Project

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Approaches to Design GM for Dams

- Currently use deterministic approach
- Issues for changing to a probabilistic approach
  - What return period should be used?
  - Two Approaches (both used by NRC for NPP)
    - Consistency with current design GM values
      - Find the return period of the ground motion that gives the same design values as deterministic approach
      - Dams currently considered “safe” set the equivalent return period
    - Risk-informed approach
      - Select return period that leads to an acceptably low risk of a severe consequence

Consistency with Current Design GM Values

- Advantage
  - Short-term regulatory stability
  - Easy to compute
    - Just need hazard curves and design GM
- Disadvantage
  - Not stable over long term
    - If hazard is updated, then the equivalent return periods would also change.
  - Somewhat defeats the purpose of moving to a PSHA approach
    - If tying to keep the same design values as deterministic, then why change?

Risk-Informed Approach

- Assess the performance of dams
  - e.g. If we design for a 1,000 year return period ground motion, then what is the return period of dam failure?
- Advantage
  - The return period of dam failure is known.
- Disadvantage
  - Large project to determine technical basis is required.

Work Plan

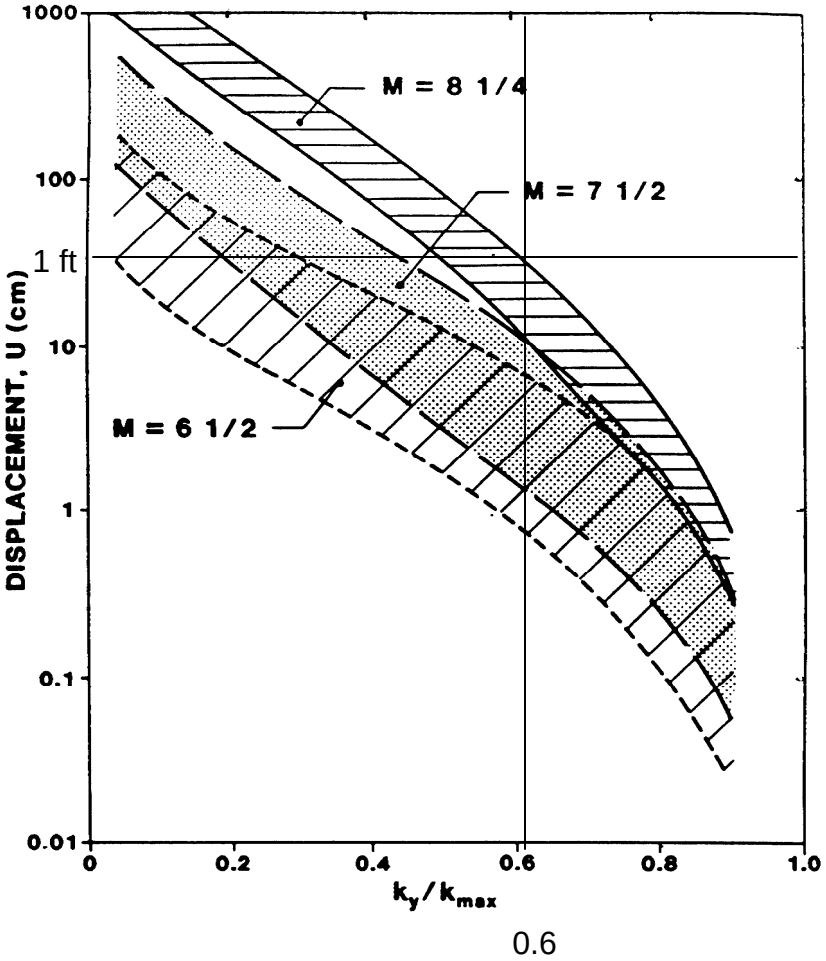
- Conduct PSHA studies for dams in active regions.
- Select representative dams
- Determine the return period of the design ground motion for a suite of dams.
- Develop fragility curves for representative dams for the probability of Uncontrolled Rapid Release of Water (URRW)
- Calculate the rate of URRW for these dams.
- Calculate the Hazard to Risk Ratio.
- Recommend an appropriate return period for design of dams based on Hazard to Risk Ratio.

Example Calculation

- Site along the San Andreas
- Typical embankment dam
  - FS static = 1.5
  - Upstream slope 3:1

Determine the Design Ground Motion Return Period

- Maximum displacement of 1 foot.
- For areas dominated by large magnitude earthquakes (M8) this gives a maximum Ky/Kmax of 0.6.
- Typical Ky value is approximately 0.15.
- Thus, the minimum Kmax is 0.25.



Determine the Design Ground Motion Return Period

- Slide masses that lead to dam failure are likely to be large.
- We assume y/h greater than 0.8.
- Kmax/Umax is approximately 0.4.
- Umax is then 0.625g.

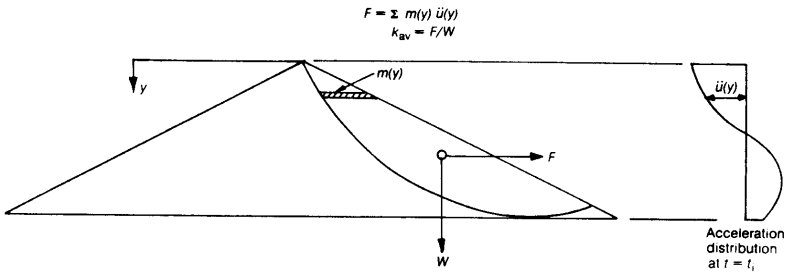


Fig. 18. Determination of effective acceleration for potential slide mass

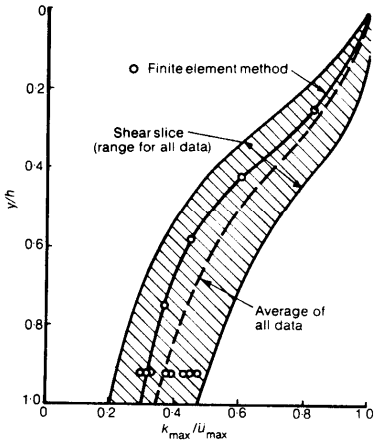
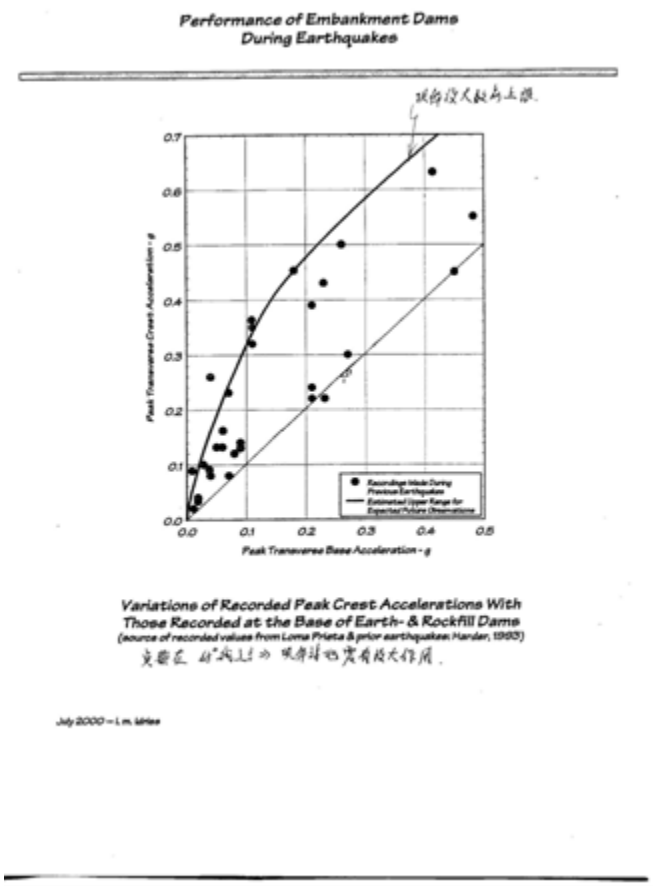


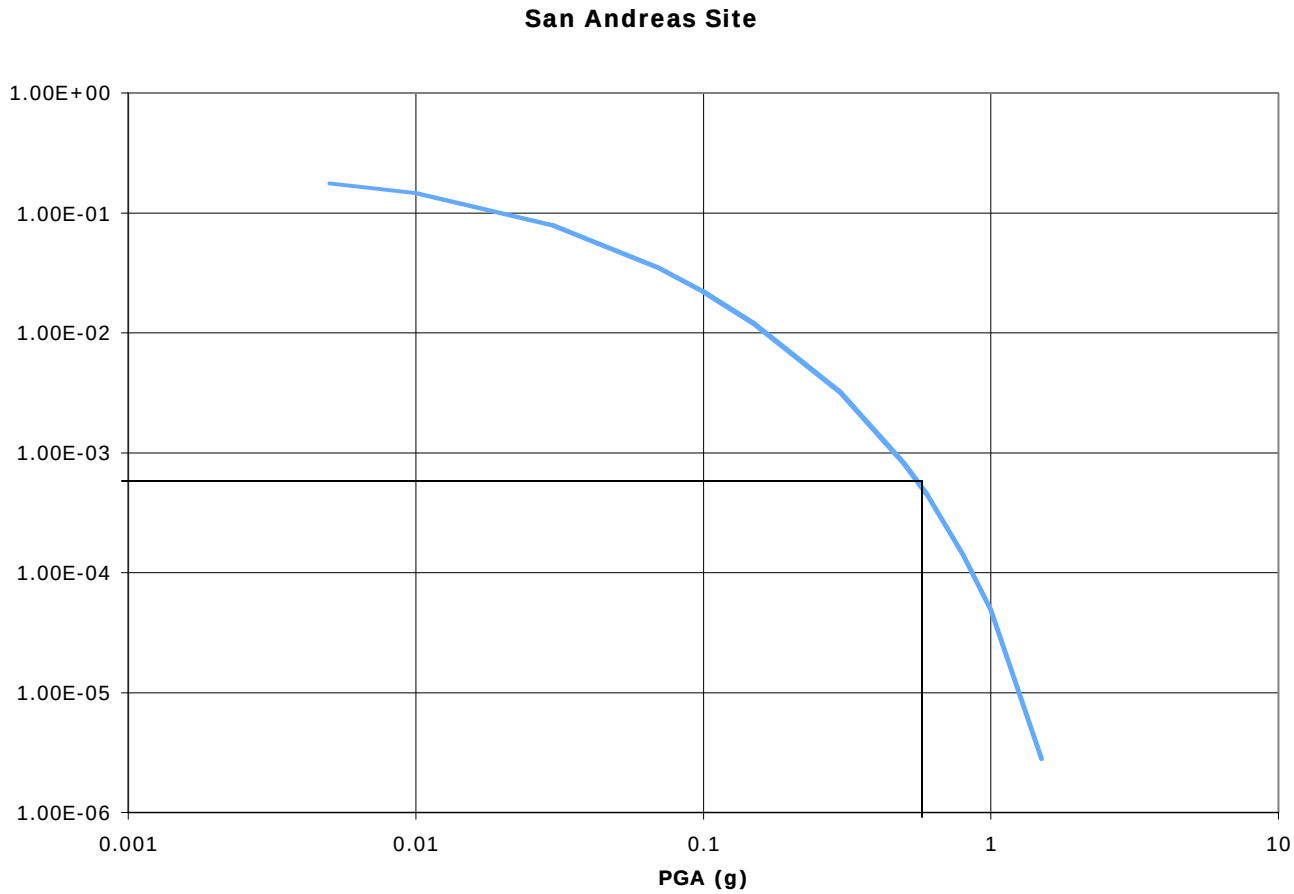
Fig. 19. Variation of effective peak acceleration, k_{max}, with depth of base of potential slide mass (after Makdisi and Seed)

Determine the Design Ground Motion Return Period

- Umax is 0.625g, we estimate a base PGA of 0.5g.



Determine the Design Ground Motion Return Period



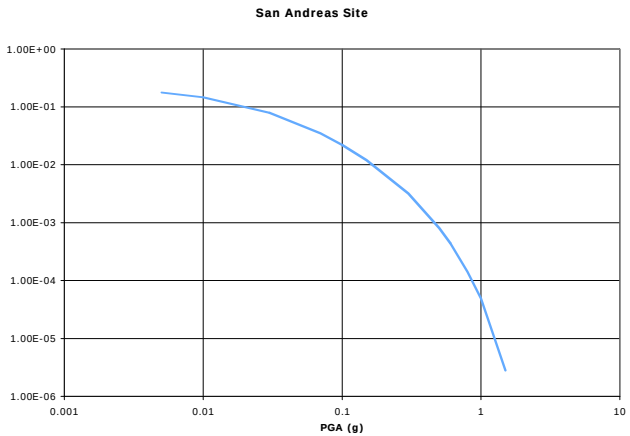
- At a location 10 km from the San Andreas fault, a PGA of 0.5 g has a rate of 8.1 E -4 and a return period of 1,200 years.

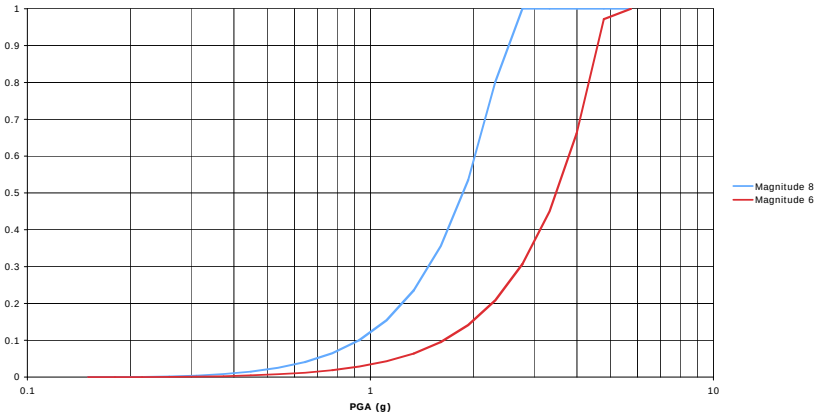
Develop Fragility Curves

- Conduct dynamic analysis of dam for a range in input ground motions and magnitudes
  - Consider a suite of relevant scenarios
- Determine the probability of URRW for each scenario (input ground motion level and magnitude)
- Here, just use a generic fragility model as an example

Calculate the Rate of URRW

- We calculate the rate of URRW by combining the PGA hazard curve with a fragility curve based on PGA developed for this dam.
- Rate of URRW is 1.2 E -4, return period is 8,100 years.

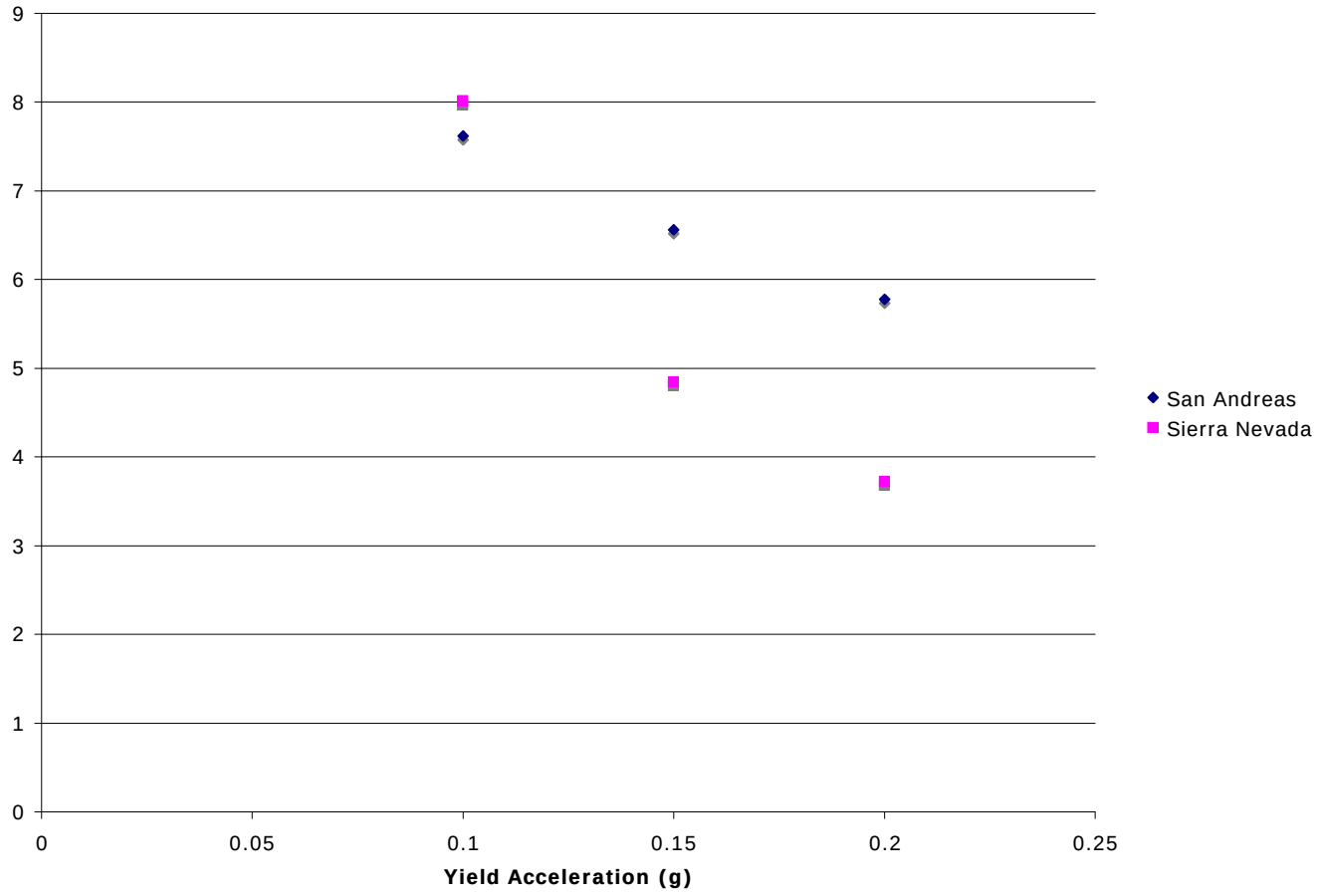


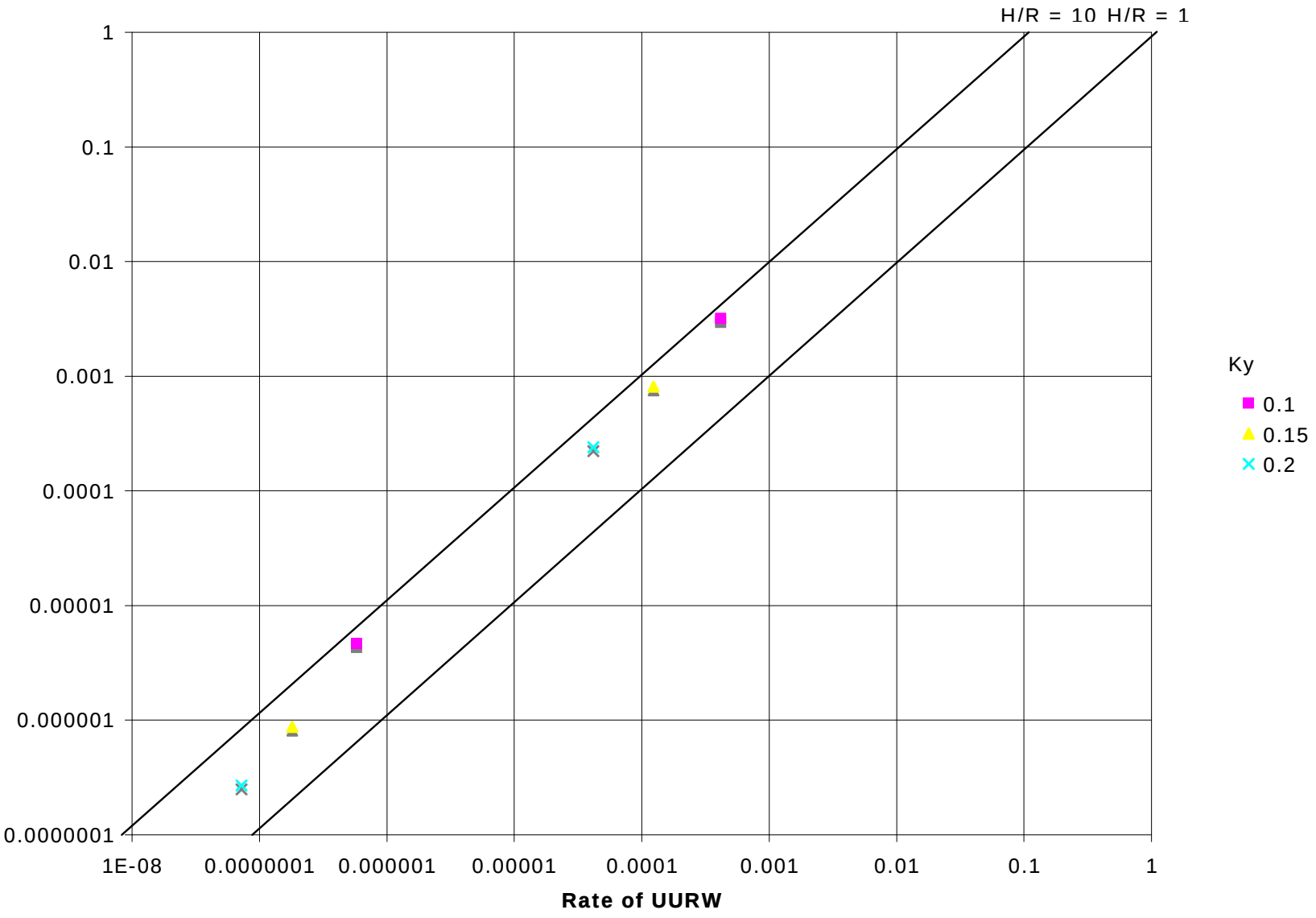


Hazard to Risk Ratio

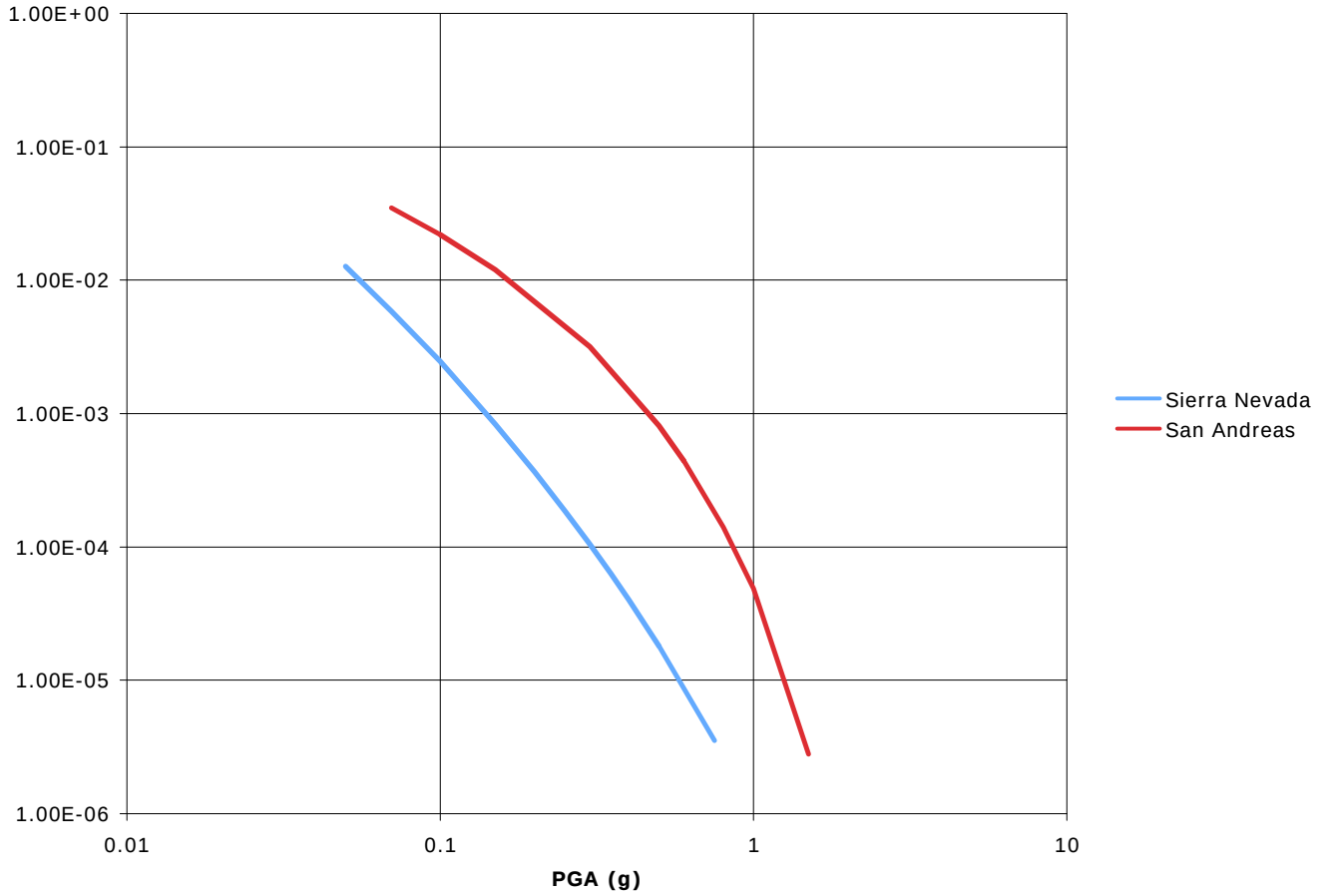
- For this dam the Hazard to Risk Ratio is 8.
- Move this dam to a new site in the Sierra Nevada
- Try two other dams (Ky of 0.1 and 0.2) at the San Andreas and Sierra Nevada locations.

Hazard to Risk Ratio




H/R = 10
H/R = 1
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
1E-08
0.0000001
0.000001
0.00001
0.0001
0.001
0.01
0.1
1
Rate of UURW
Ky
0.1
0.15
0.2

Example Results



- The Hazard to Risk ratio is a function of yield acceleration and location.

Project Participants

- Current and interested participants
  - Utilities
    - PG&E, SCE, Mid Cs, BCHydro
  - Others
    - Sinotech
  - Regulators
    - FERC, DSOD
- Other potential participants
  - Utilities
    - SFPUC
    - EBMUD
    - Meridian (NZ)

Work Plan

- Conduct PSHA studies for dams in active regions
  - Nearly complete for PG&E, SCE, Mid Cs
  - BCHydro will have updated models this year
- Select Representative dams (total of about 20)
  - Earth dams
  - Concrete dams
  - SCE has started this
- Locate the dams in various locations in WUS
- Determine the return period of the design ground motion

Work Plan

- Develop fragility curves
  - Conduct dynamic analyses of selected dams
  - Major component of work
- Compute the risk of URRW
  - Combine hazard curves and fragility
- Compute the hazard/risk ratio
- Determine if the hazard/risk ratio is stable for dams within a class
- Recommend a return period for design based on hazard/risk ratio
  - For consideration by regulators

Thank You