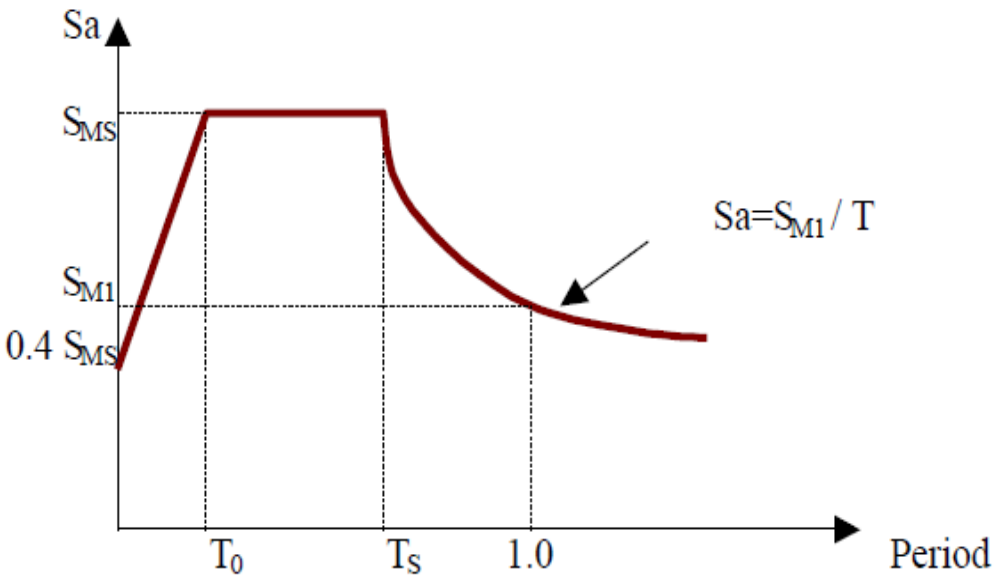
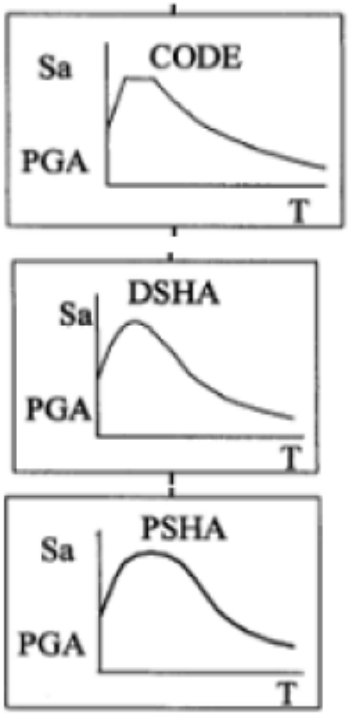
SEISMIC RECORDS SELECTION

HOW TO GET DESIGN SPECTRUM ?

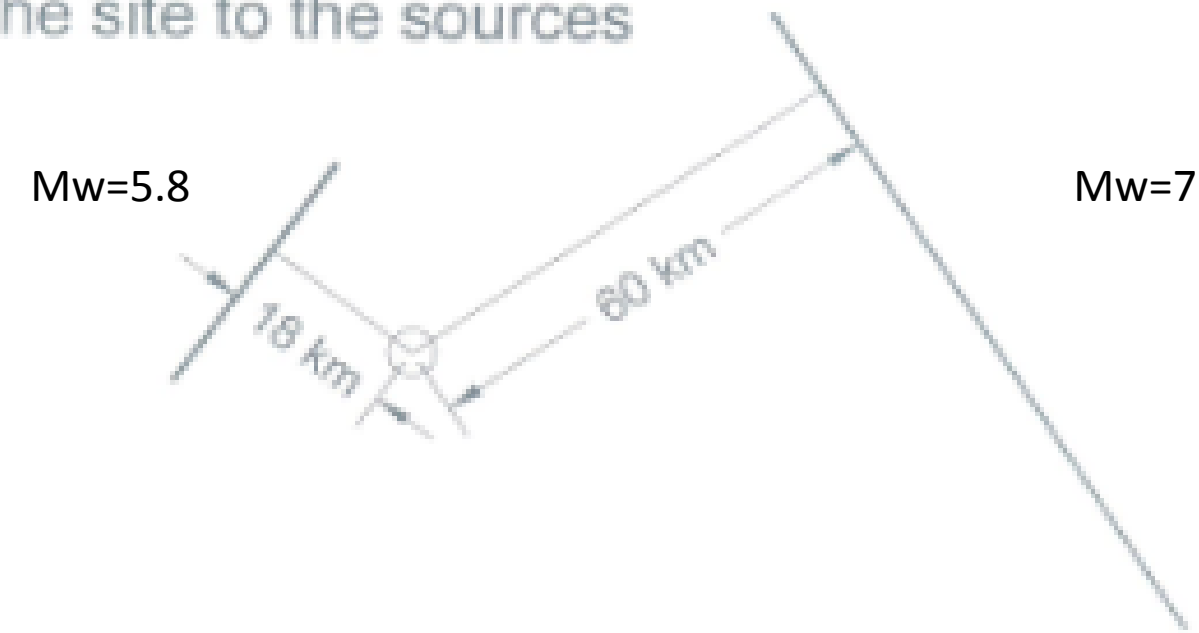
- **Earthquake Design Codes (*NEHRP 1997, IBC2003, EuroCode 8*)**
- **Deterministic and Probabilistic Hazard Analysis**





Deterministic Seismic Hazard Analysis

STEP 2: Select ground motion prediction relation(s) and measure the distances from the site to the sources

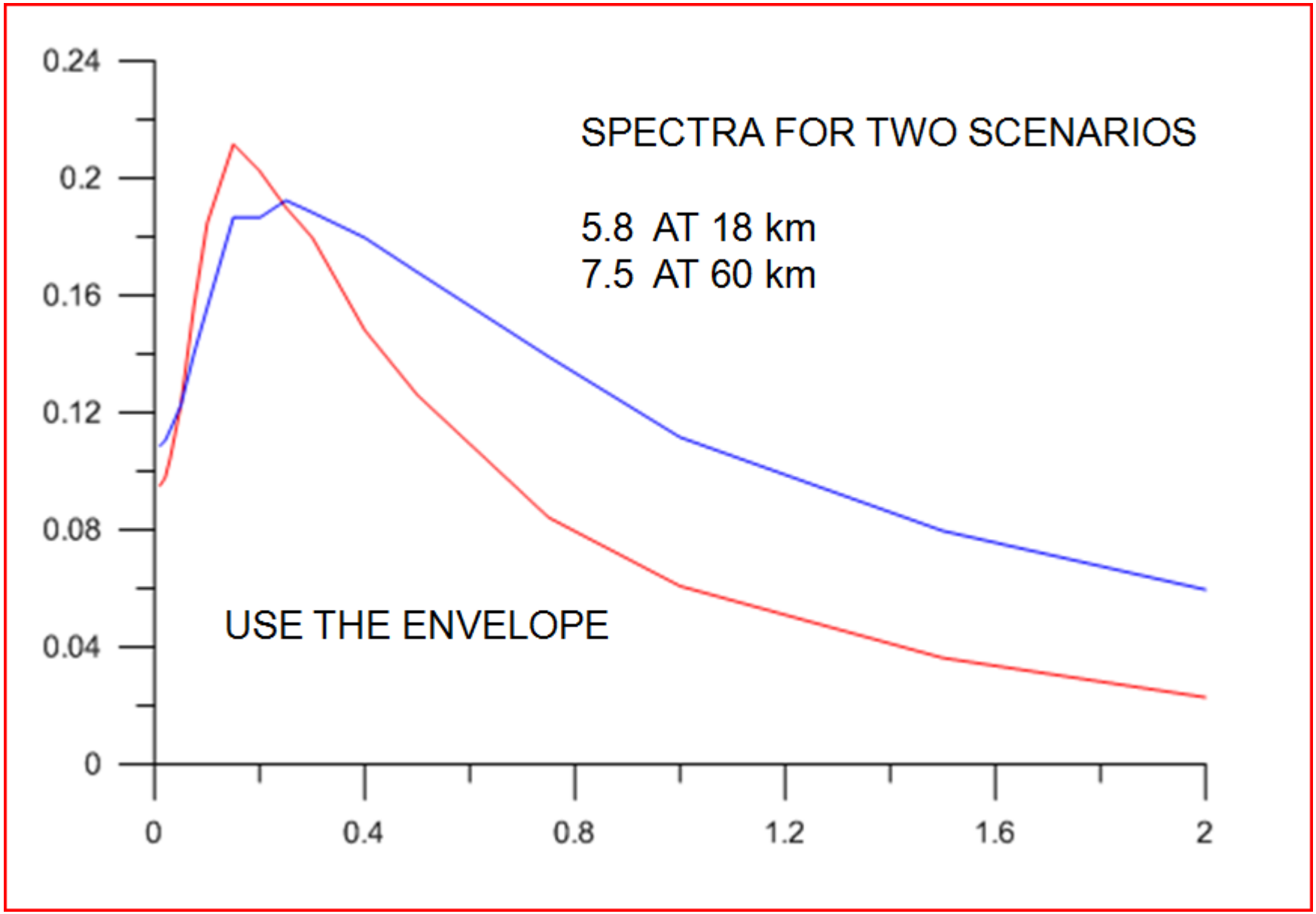


P. K. Malhotra, 2005

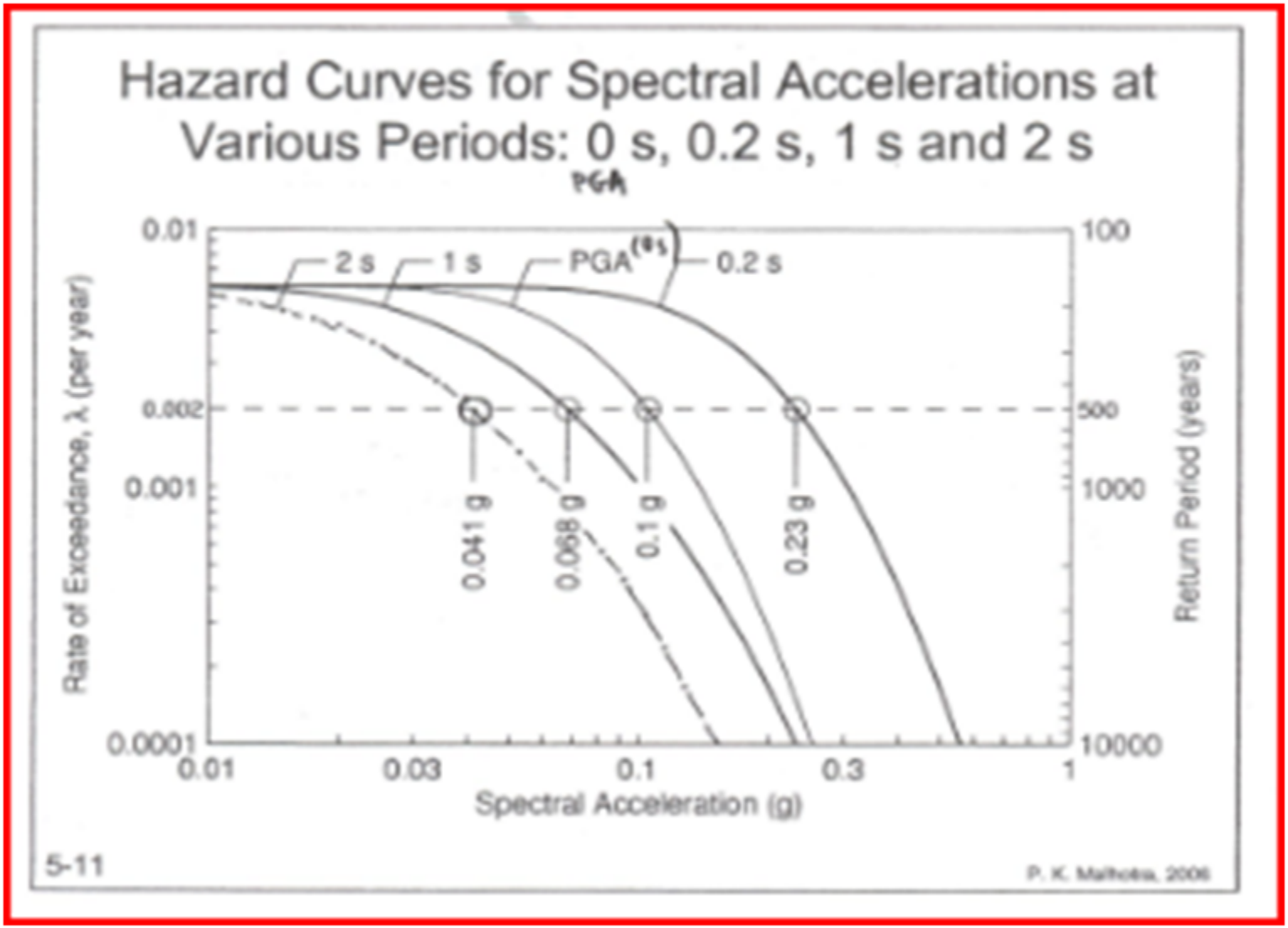
Boore-Atkinson model

$$\ln Y = F_M(\mathbf{M}) + F_D(R_{JB}, \mathbf{M}) + F_S(V_{S30}, R_{JB}, \mathbf{M}) + \varepsilon\sigma_T,$$

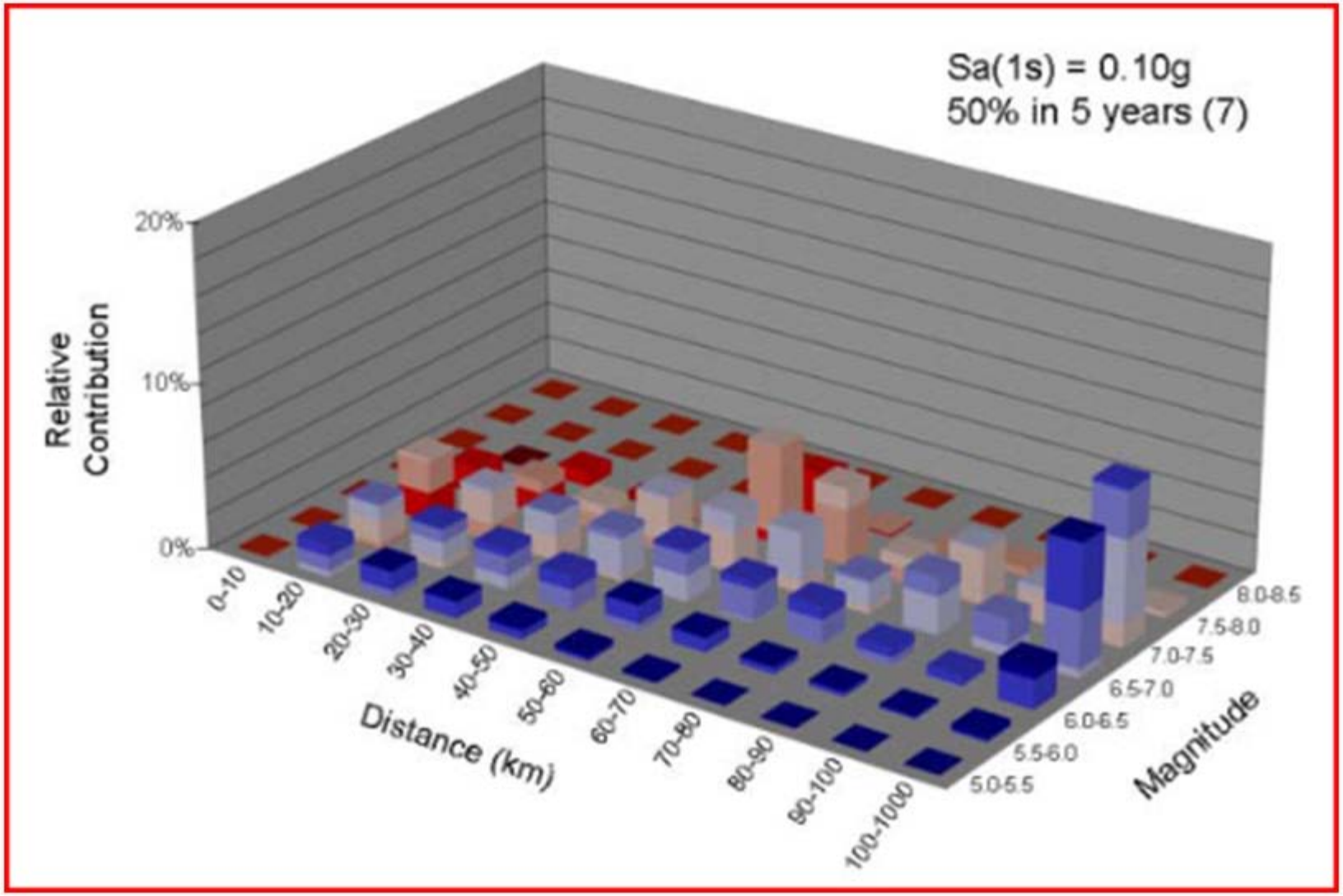
SCENARIOS 5.8 AT 18 KM , 7.5 AT 60 KM


SPECTRA FOR TWO SCENARIOS
5.8 AT 18 km
7.5 AT 60 km
USE THE ENVELOPE
0.24
0.2
0.16
0.12
0.08
0.04
0
0
0.4
0.8
1.2
1.6
2

UNIFORM HAZARD SPECTRUM



DEAGGREGATION



SOURCE OF ACCELEROGRAMS

- ***Real Accelerograms***
- ***Artificial Accelerograms***
- ***Synthetic Accelerograms***

FACTORS INFLUENCING REAL ACCELEROGRAMS

- Source
  - Magnitude
  - Rupture Mechanism
  - Directivity
  - Focal Depth
- Path
  - Crustal Structure
- Site
  - Surface Geology
  - Topography
  - Structures

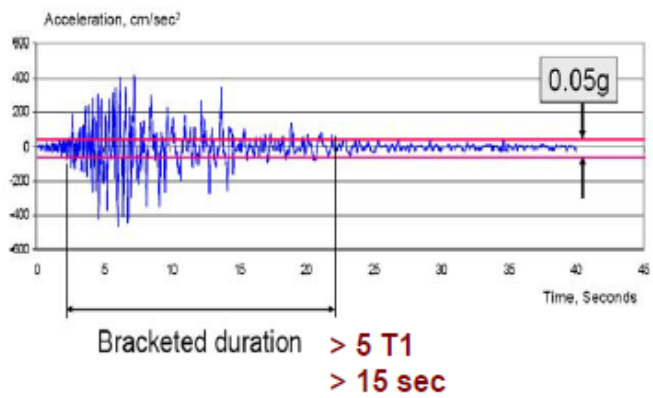
RULES FOR SCALING TIME HISTORIES ACCORDING TO FIT DESIGN CODE SPECTURM

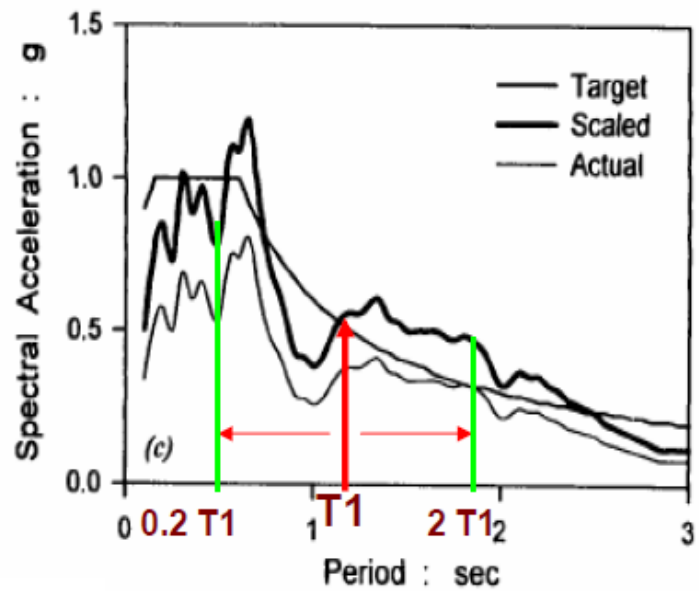
- **Guidance On How To Actually Select Appropriate Real Records Is Usually Focused On <u>Compatibility With The Response Spectrum</u> Rather Than Seismological Parameters**

- **UBC 1997 And IBC 2000**
  - ***<u>Maximum</u> Structural Response If <u>Three</u> Records Used***
  - ***<u>Average</u> Structural Response If <u>Seven</u> Records Used***
  - ***(SRSS) Of The Two Horizontal Components – Should Not Be Less Than 1.4 The Design Spectrum Ordinates In The Range From 0.2T To 1.5T (UBC 1997)***

RULES FOR SCALING TIME HISTORIES ACCORDING TO FIT DESIGN CODE SPECTURM

- **Scaled Spectrum Should Not Be Less Than 0.9 The Design Spectrum Ordinates In The Range From 0.2T1 To 2T1 (DBYBHY 2007); T1 is the first fundamental Period of the Structure**
- **Earthquake Record duration > 5 T1 and > 15 sec**





EC8 SCALING PROVISIONS

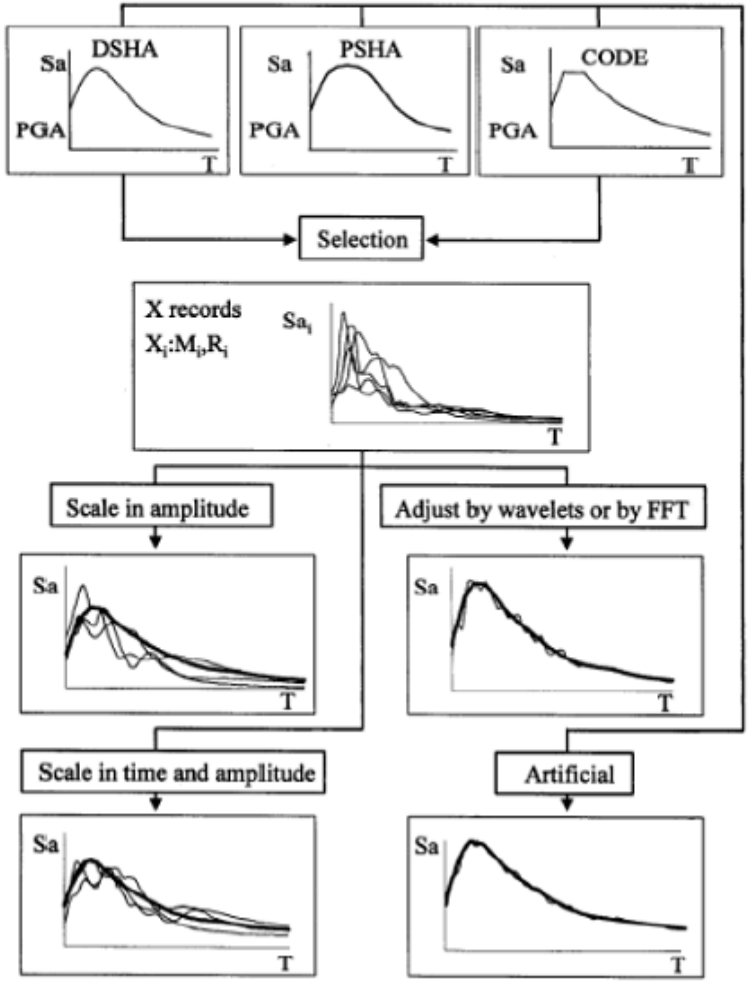
a. *a minimum of 3 accelerograms should be used;*

b. *the mean of the zero period spectral response acceleration values (calculated from the individual time histories) should not be smaller than the value of* $a_g S$ *for the site in question;*[6]

c. *in the range of periods between* $0{,}2T_1$ *and* $2T_1$*, where* T_1 *is the fundamental period of the structure in the direction where the accelerogram will be applied; no value of the mean 5% damping elastic spectrum, calculated from all time histories, should be less than 90% of the corresponding value of the 5% damping elastic response spectrum.*[7]

Processing Of Ground Motion To Fit Response Spectra (Real and Artificial Accelerograms)

- Ground Motion Scaling in Time Domain
- Spectral Matching in Frequency Domain
- Spectral Matching by Wavlets
- Spectrum Compatible Artificial Record Generation



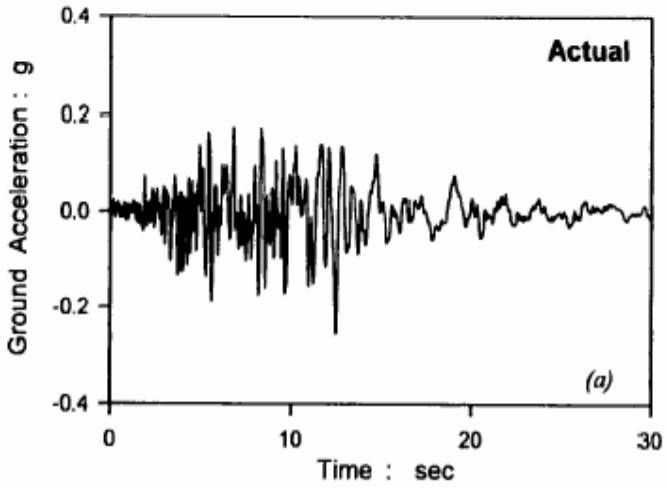
REAL ACCELEROGRAMS

Advantages

- Ground-motion Characteristics (Amplitude, Frequency And Energy Content, Duration And Phase Characteristics)
- Characteristics Of The Source, Path And Site

Disadvantages

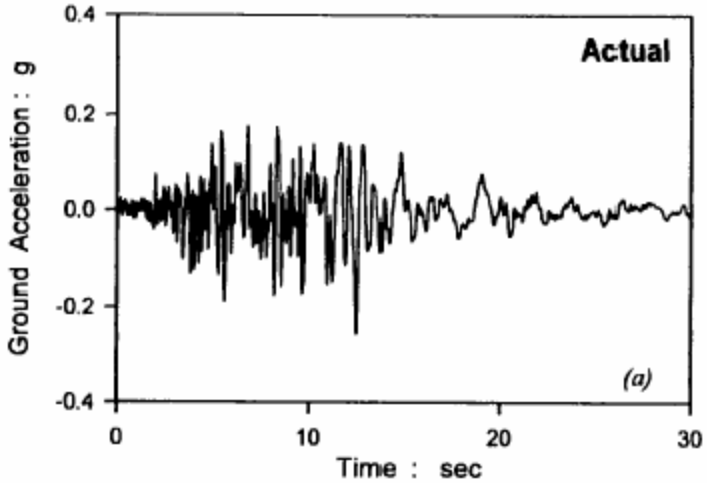
- Not All Magnitude-Distance-Soil Combinations Are Covered
- Response Spectra Are Generally Not Smoothed.

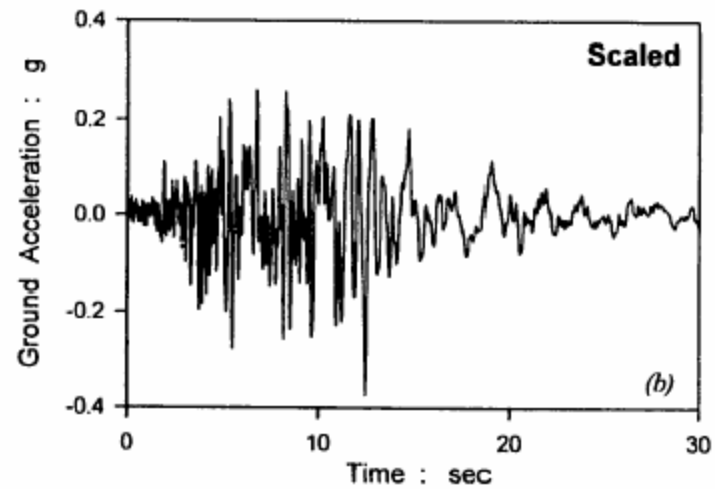


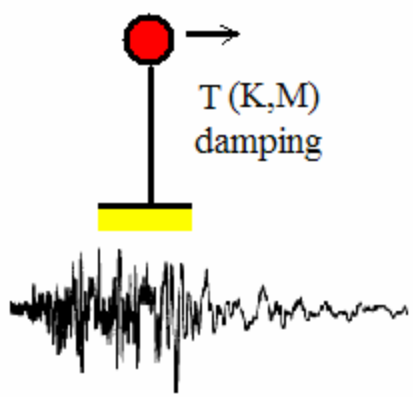
PEER STRONG MOTION DATABASE

- **Focal Mechanism**
  Strike slip, Normal, Reverse normal, Reverse-oblique, Normal-oblique
- **Magnitude (ML, M, MS)**
- **Distance to Fault**
  Closest, Hypocentral, Projection of fault plane
- **Site Classification and Mapped Local Geology**
- **Instrument Housing**
  Free-field, shelter Type

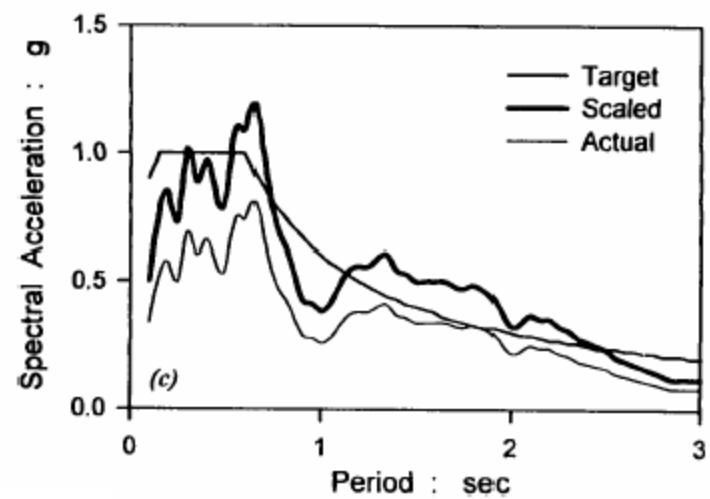
GROUND MOTION SCALING IN TIME DOMAIN





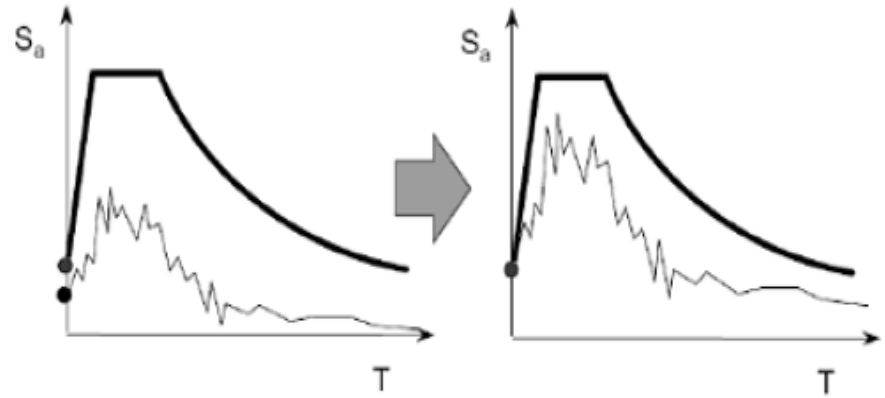


$$\left| Difference \right| = \int_{T_A}^{T_B} \left[\alpha \; S_a^{actual}(T) - S_a^{target}(T) \right]^2 dT$$

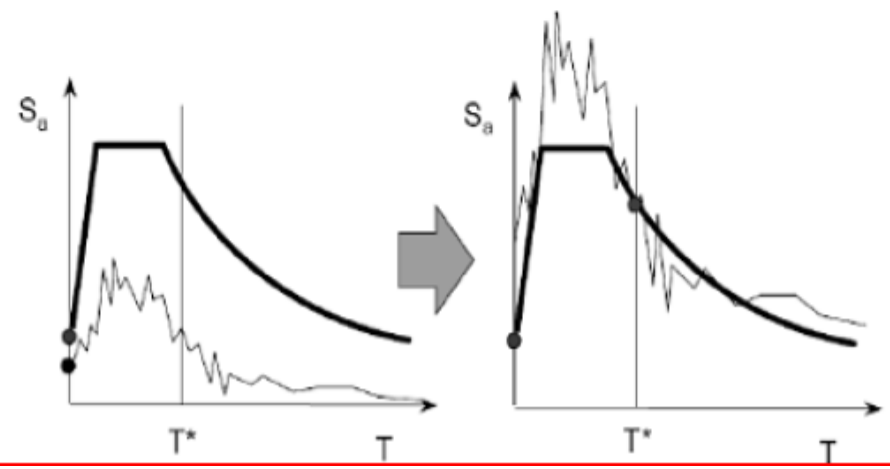


GROUND MOTION SCALING IN TIME DOMAIN (SCALING ON AMPLITUDE)

Match to Peak Ground Acceleration (PGA)

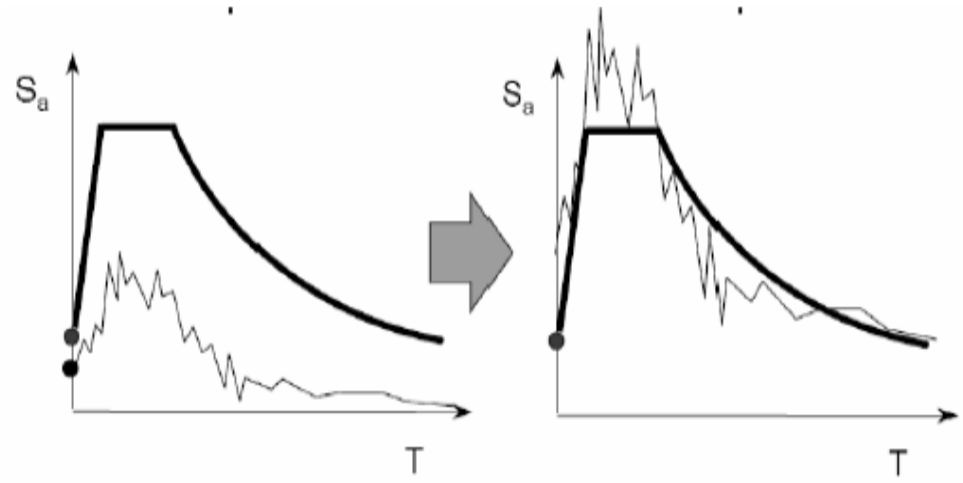


Match Spectral Acceleration at Specific Period

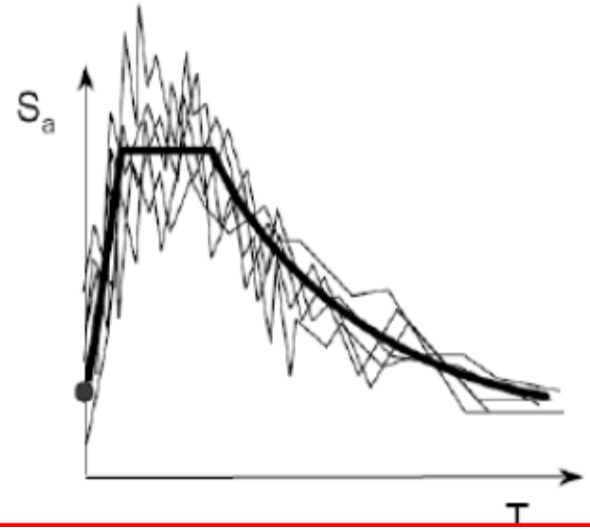


SCALING ON AMPLITUDE

Match Spectral Acceleration At Period Range using least square Method



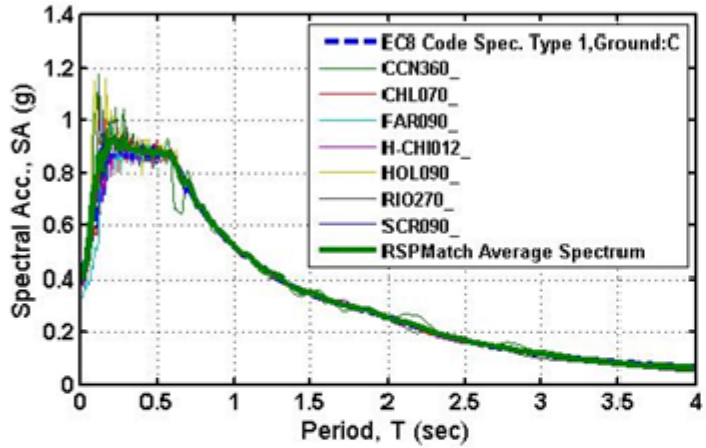
Match Multiple Motions match the median using Least Square Method

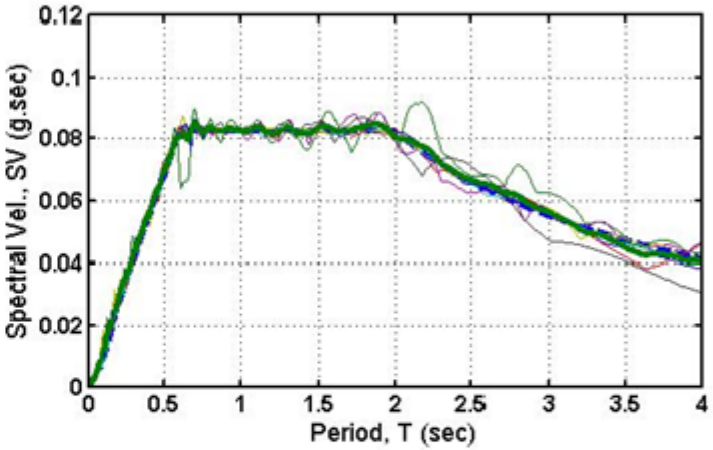


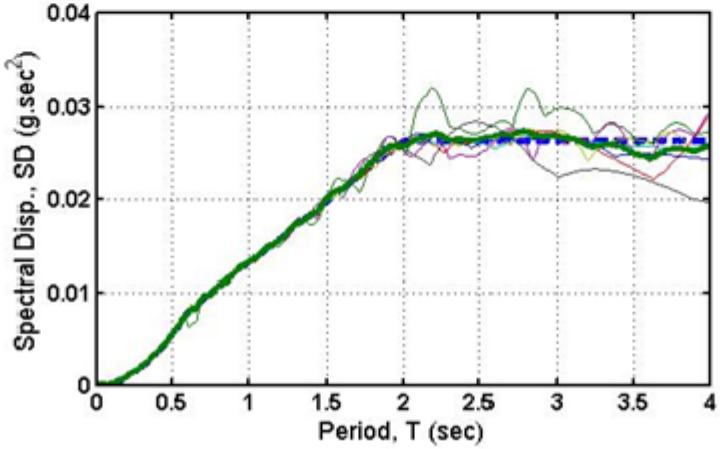
SPECTRAL MATCHING USING WAVELETS

- Adjust the original record iteratively in the time domain to achieve compatibility with a specified target acceleration response spectrum by adding wavelets having specified period ranges and limited durations to the input time history.
- RSPMATCH software developed by Abrahamson (1992)

Acceleration, Velocity And Displacement Spectra For RSPMATCH Generated Records



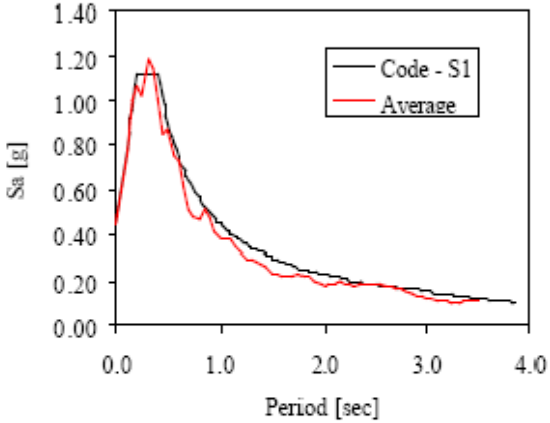


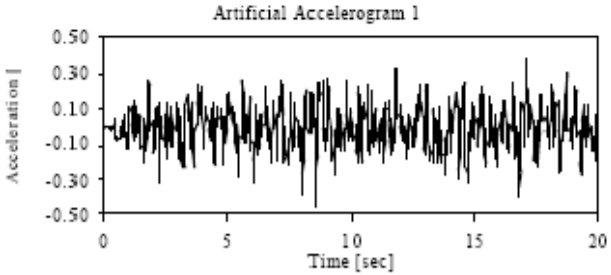


ARTIFICIAL ACCELEROGRAMS

- **Generated To Match A Target Response Spectrum**
- **Earthquake Motion As The Output From Filters And Use Of System Response For A White Noise Input**
- **Disadvantages**

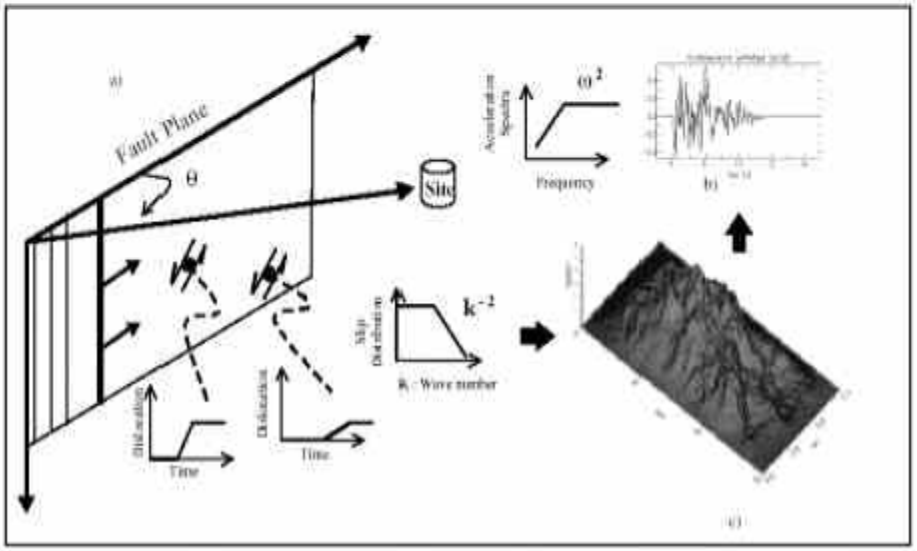
  Records Generally Have An Excessive Number Of Cycles Of Strong Motion, And Consequently Have Unrealistically High Energy Content



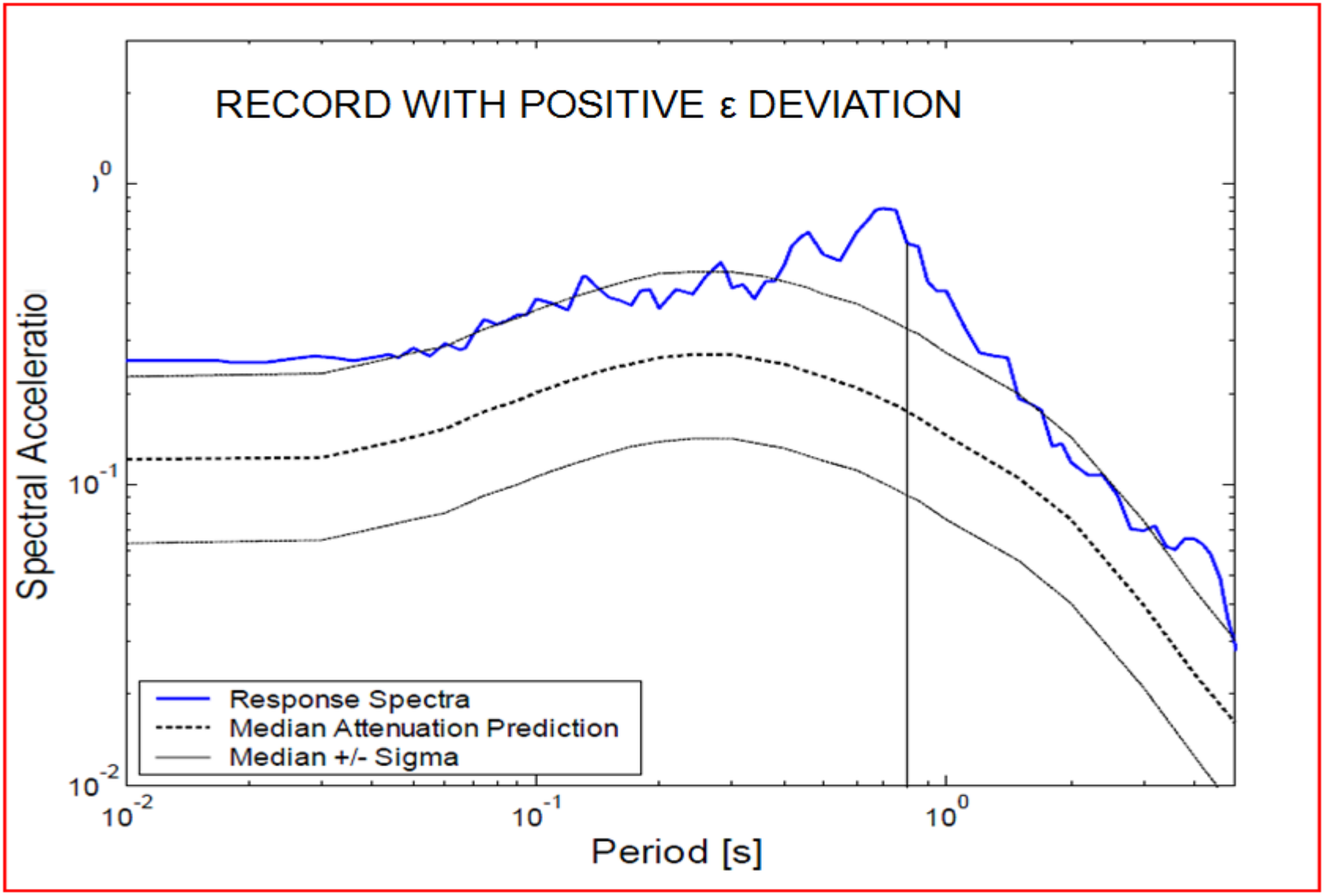


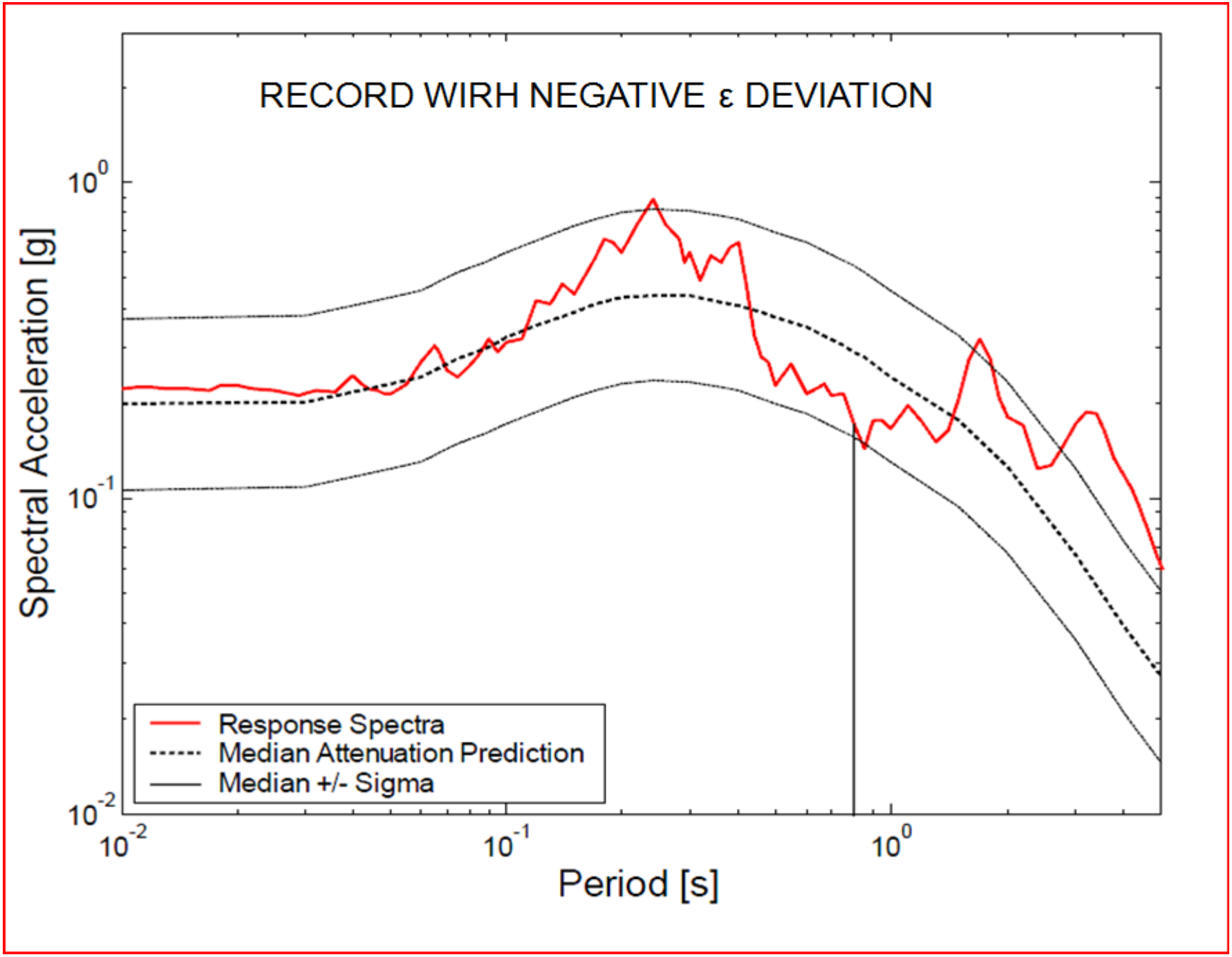
SYNTHETIC ACCELEROGRAMS

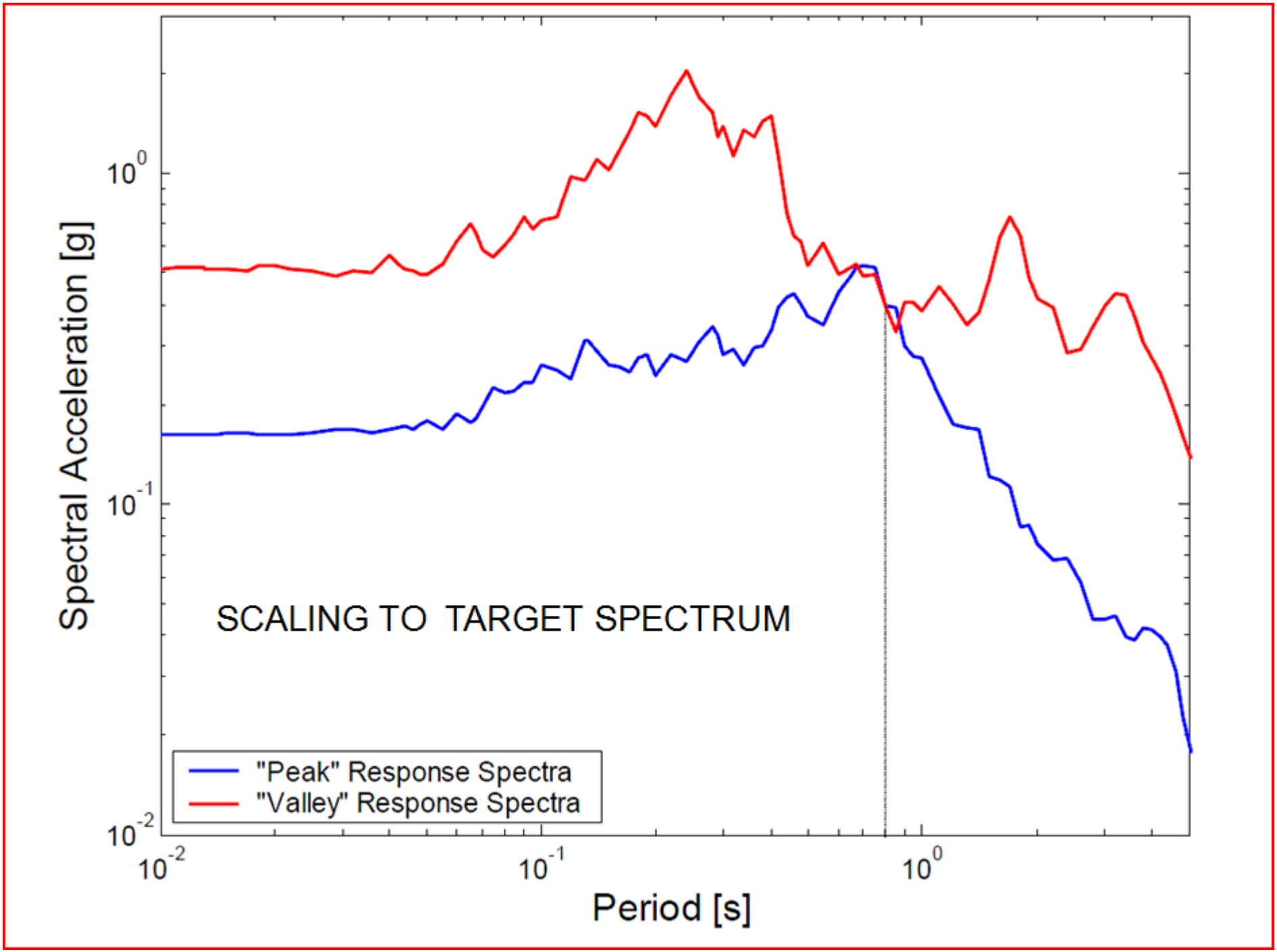
- **Stochastic Point Source and Finite Source ((Boore, 2003; Atkinson and Boore, 1997)**
- **Synthesize Earthquake Motion Using A Fault Dislocation Model Or Empirical Green's Function Model**
- **Definition Of A Specific Earthquake Scenario**
- **Most Widely used EMPSYN Program L. Hutchings (1976)**
- **Geophysical Parameters**
  - ***Hypocenter***
  - ***Seismic Moment***
  - ***Slip Vector***
  - ***Asperities***
  - ***Rupture Velocity***
  - ***Rise Time***
  - ***Stress Drop***



SCALED NATURAL RECORDS




RECORD WIRH NEGATIVE ε DEVIATION
Spectral Acceleration [g]
Period [s]
10^0
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^0
Response Spectra
Median Attenuation Prediction
Median +/- Sigma


SCALING TO TARGET SPECTRUM
"Peak" Response Spectra
"Valley" Response Spectra
Spectral Acceleration [g]
Period [s]
10^{0}
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^{0}

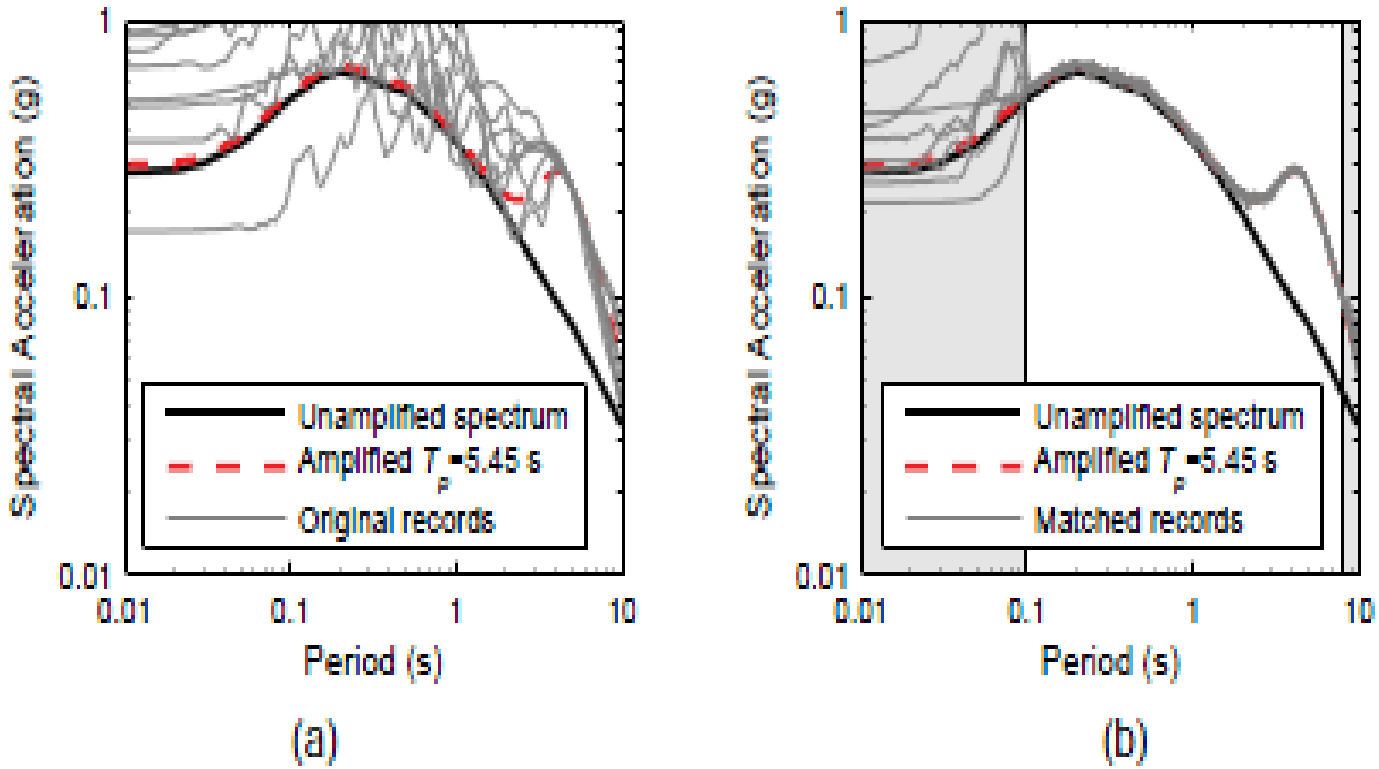


Figure B-20 Comparison of target spectrum incorporating narrow-band adjustment for T_p = 5.45s velocity pulse with record spectra (a) before and (b) after matching. Unshaded period range was considered in matching.

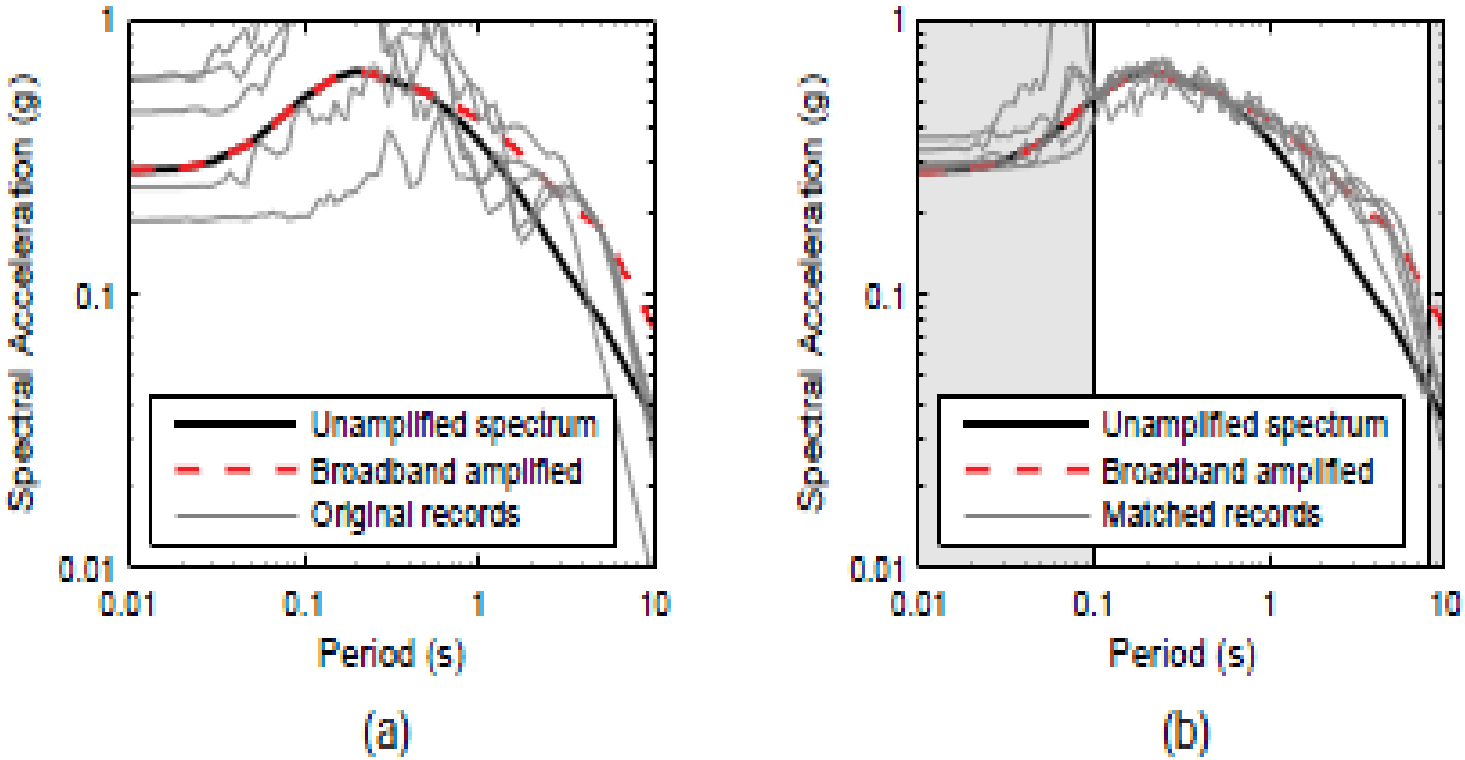


Figure B-23 Comparison of target spectrum incorporating broadband adjustment for velocity pulses with record spectra: (a) before and (b) after matching. Unshaded period range was considered in matching. Only "accepted" records in Table B-9 are shown.

An approach that met with slightly more success involved the following steps for each ground motion:

1. Extract the velocity pulse using the method of Baker (2007b).
2. Calculate the response spectrum for the original ground motion ("total") and for the residual motion after the pulse has been extracted ("residual").
3. Determine a new target spectrum by scaling the original target by the ratio of the residual spectrum to the total spectrum.
4. Run RspMatch2005 with the residual ground motion as the seed record, matching to the modified target spectrum.
5. Add the extracted velocity pulse (from Step 2) to the output of RspMatch2005.