Epsilon Capping: A new procedure for deterministic capping of probabilistic MCE_R ground motions

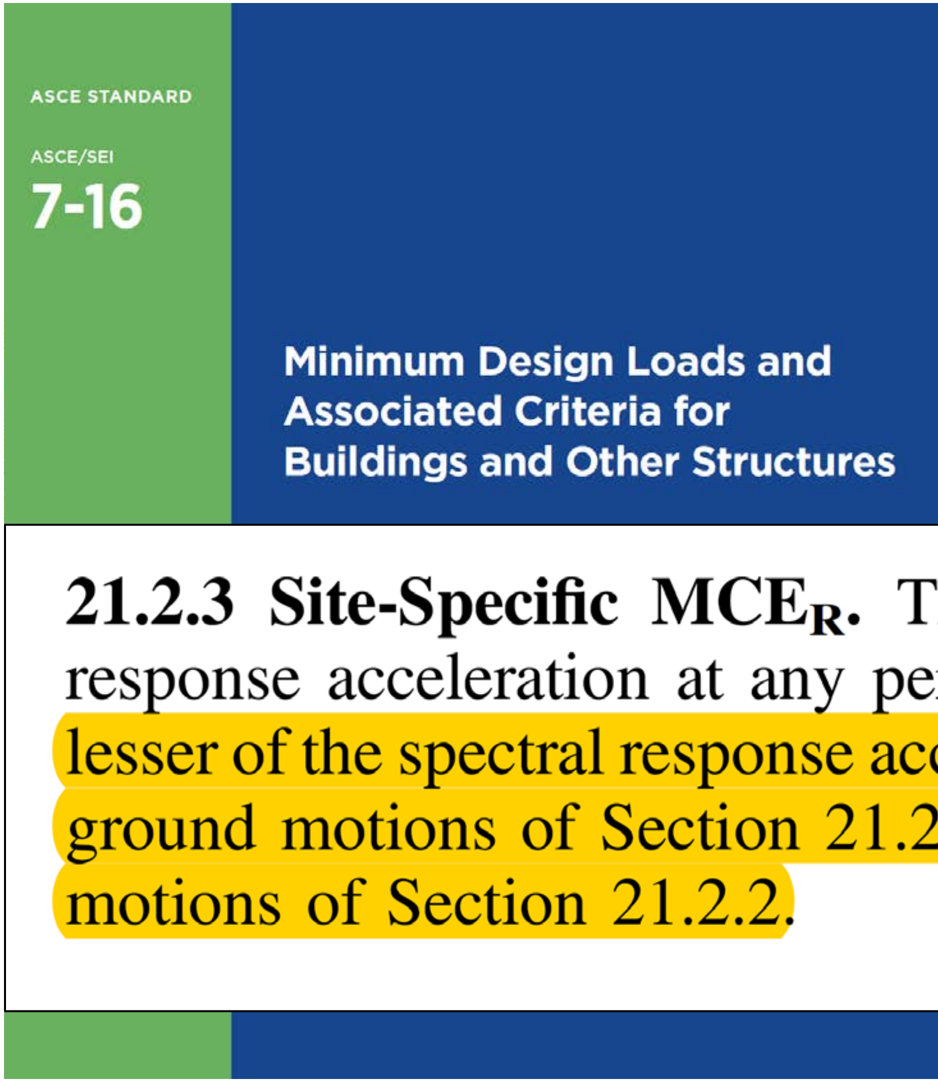
Project '17 Deterministic Capping Subcommittee

C.B. Crouse (Chair)	AECOM
Nicolas Luco	USGS
Jonathan Stewart	UCLA
John Hooper	MKA
Sanaz Rezaeian	USGS
Charles Kircher	CK&A
Edward (Ned) Field	USGS

Subcommittee Meetings on Epsilon Capping

1) April 3 – Project ’17 meeting (briefly)
2) May 23 – Web conference
3) July 10 – Web conference
4) July 26 – Web conference
5) August 10 – Web conference
6) August 13 – USGS brown bag
7) August 14 – Project ‘17 meeting

Reminder: *ASCE 7-16* Deterministic Capping



CHAPTER 21
SITE-SPECIFIC GROUND MOTION PROCEDURES FOR SEISMIC DESIGN

21.1 SITE RESPONSE ANALYSIS

The requirements of Section 21.1 shall be satisfied where site response analysis is performed or required by Section 11.4.7. The analysis shall be documented in a report.

21.1.1 Base Ground Motions. An MCE_R response spectrum shall be developed for bedrock, using the procedure of Sections 11.4.6 or 21.2. Unless a site-specific ground motion hazard analysis described in Section 21.2 is carried out, the MCE_R rock response spectrum shall be developed using the procedure of Section 11.4.6, assuming Site Class B. If bedrock consists of Site Class A, the spectrum shall be adjusted using the site coefficients in Section 11.4.3 unless other site coefficients can be justified. At least five recorded or simulated horizontal ground motion acceleration time histories shall be selected from events that have magnitudes and fault distances that are consistent with those that control the MCE_R ground motion. Each selected time history shall be scaled so that its response spectrum is, on average, approximately at the level of the MCE_R rock response spectrum over the period range of significance to structural response.

spectrum of the base motion multiplied by the average surface-to-base response spectral ratios (calculated period by period) obtained from the site response analyses. The recommended surface ground motions that result from the analysis shall reflect consideration of sensitivity of response to uncertainty in soil properties, depth of soil model, and input motions.

21.2 RISK-TARGETED MAXIMUM CONSIDERED EARTHQUAKE (MCE_R) GROUND MOTION HAZARD ANALYSIS

The requirements of Section 21.2 shall be satisfied where a ground motion hazard analysis is performed or required by Section 11.4.7. The ground motion hazard analysis shall account for the regional tectonic setting, geology, and seismicity; the expected recurrence rates and maximum magnitudes of earthquakes on known faults and source zones; the characteristics of ground motion attenuation near source effects, if any, on ground motions; and the effects of subsurface site conditions on ground motions. The characteristics of subsurface site

21.2.3 Site-Specific MCE_R. The site-specific MCE_R spectral response acceleration at any period, S_{aM}, shall be taken as the lesser of the spectral response accelerations from the probabilistic ground motions of Section 21.2.1 and the deterministic ground motions of Section 21.2.2.

The recommended surface MCE_R ground motion response spectrum shall not be lower than the MCE_R response

shall be determined by either Method 1 of Section 21.2.1.1 or Method 2 of Section 21.2.1.2.

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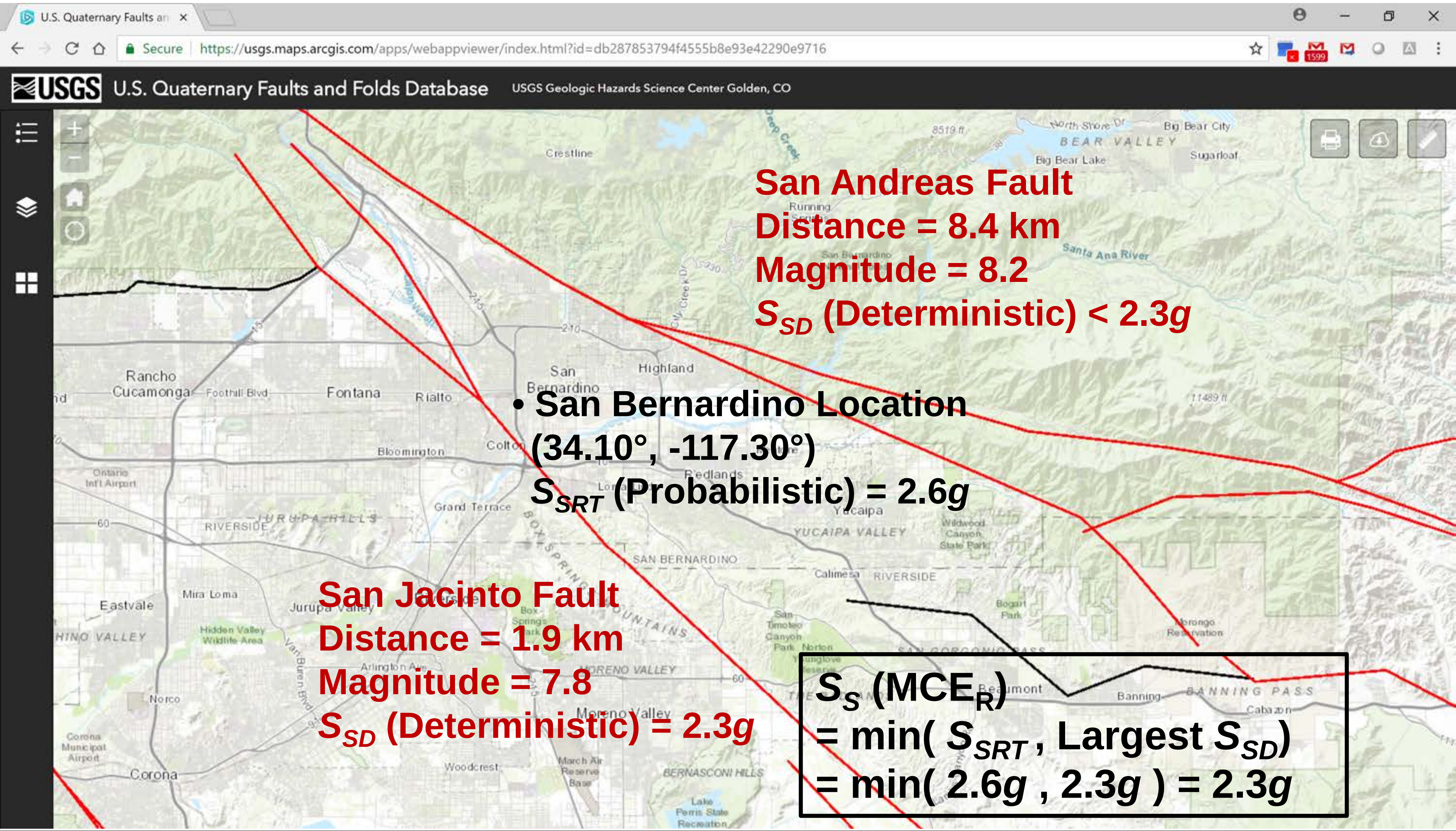
Reminder: *ASCE 7-16* Deterministic Capping

21.2.2 Deterministic (MCE_R) Ground Motions. The deterministic spectral response acceleration at each period shall be calculated as an 84th-percentile 5% damped spectral response acceleration in the direction of maximum horizontal response computed at that period. The largest such acceleration calculated for the characteristic earthquakes on all known active faults within the region shall be used. The ordinates of the deterministic ground motion response spectrum shall not be taken as lower than the corresponding ordinates of the response spectrum determined in accordance with Fig. 21.2-1.

FIGURE 21.2-1 Deterministic Lower Limit on MCE_R Response Spectrum

Example: *ASCE 7-16* Deterministic Capping



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Issues: *ASCE 7-16* Deterministic Capping

- Choosing “active faults”.
- Choosing “characteristic earthquake” *ruptures* (e.g. multi-fault ruptures).
- Choosing “characteristic earthquake” *magnitudes*.
- Multi-period deterministic lower limit.
- Additional (to Probabilistic Seismic Hazard Analysis) software, review.

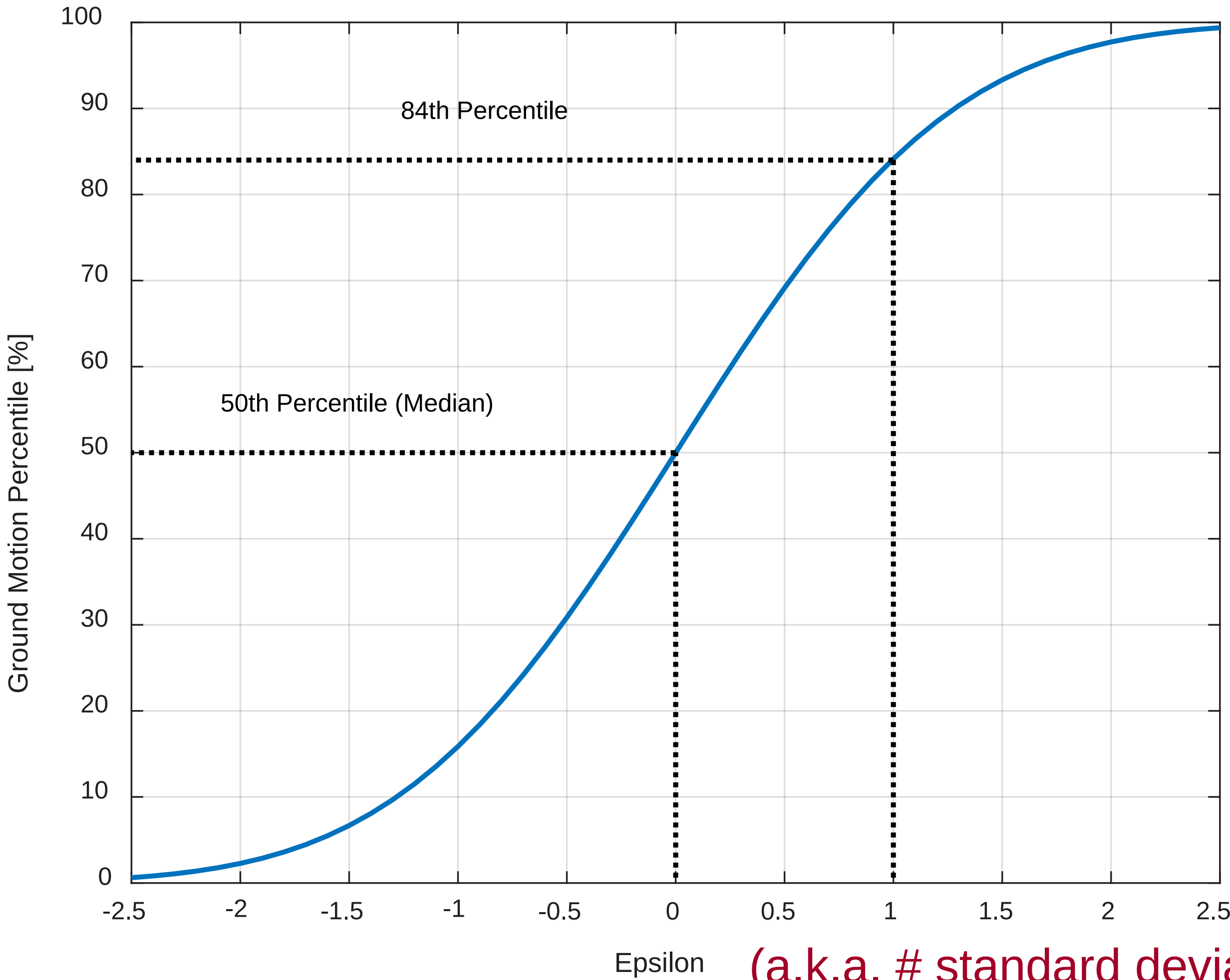
Proposal: "Epsilon Capping"

Where earthquakes occur relatively often, the *ASCE 7-16* probabilistic MCE_R ground motions correspond to higher than the 84^{th} percentile for the earthquakes that contribute most to the risk. Like *ASCE 7-16* does, we propose to cap these ground motions at the 84^{th} percentile, but with a procedure that is simpler to implement now that "characteristic earthquakes" are no longer defined for California.

Draft Changes to *Provisions*

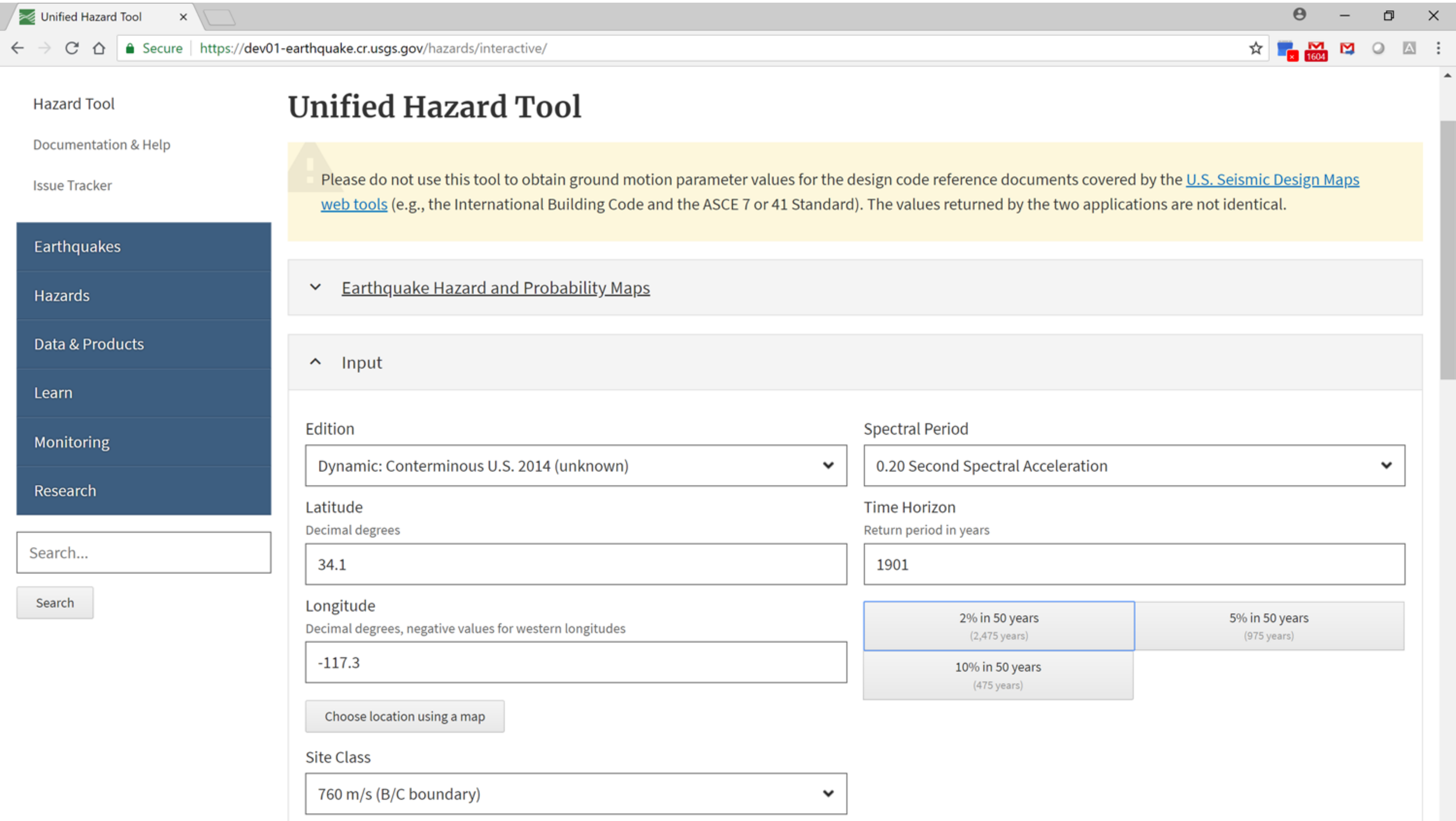
21.2.2 Deterministic (MCE_R) Ground Motions. The deterministic spectral response acceleration at each period shall be calculated as an 84th-percentile 5% damped spectral response acceleration in the direction of maximum horizontal response computed at that period. The largest such acceleration calculated for ~~the characteristic~~ scenario earthquakes on all known ~~active~~ faults within the region shall be used. The scenario earthquakes shall be determined from deaggregation for the probabilistic spectral response acceleration at each period. Scenario earthquakes contributing less than 10% of the largest contributor to the probabilistic ground motion shall be ignored. The ordinates of the deterministic ground motion response spectrum shall not be taken as lower than the corresponding ordinates of the response spectrum determined in accordance with Fig. 21.2-1.

Definition: Epsilon

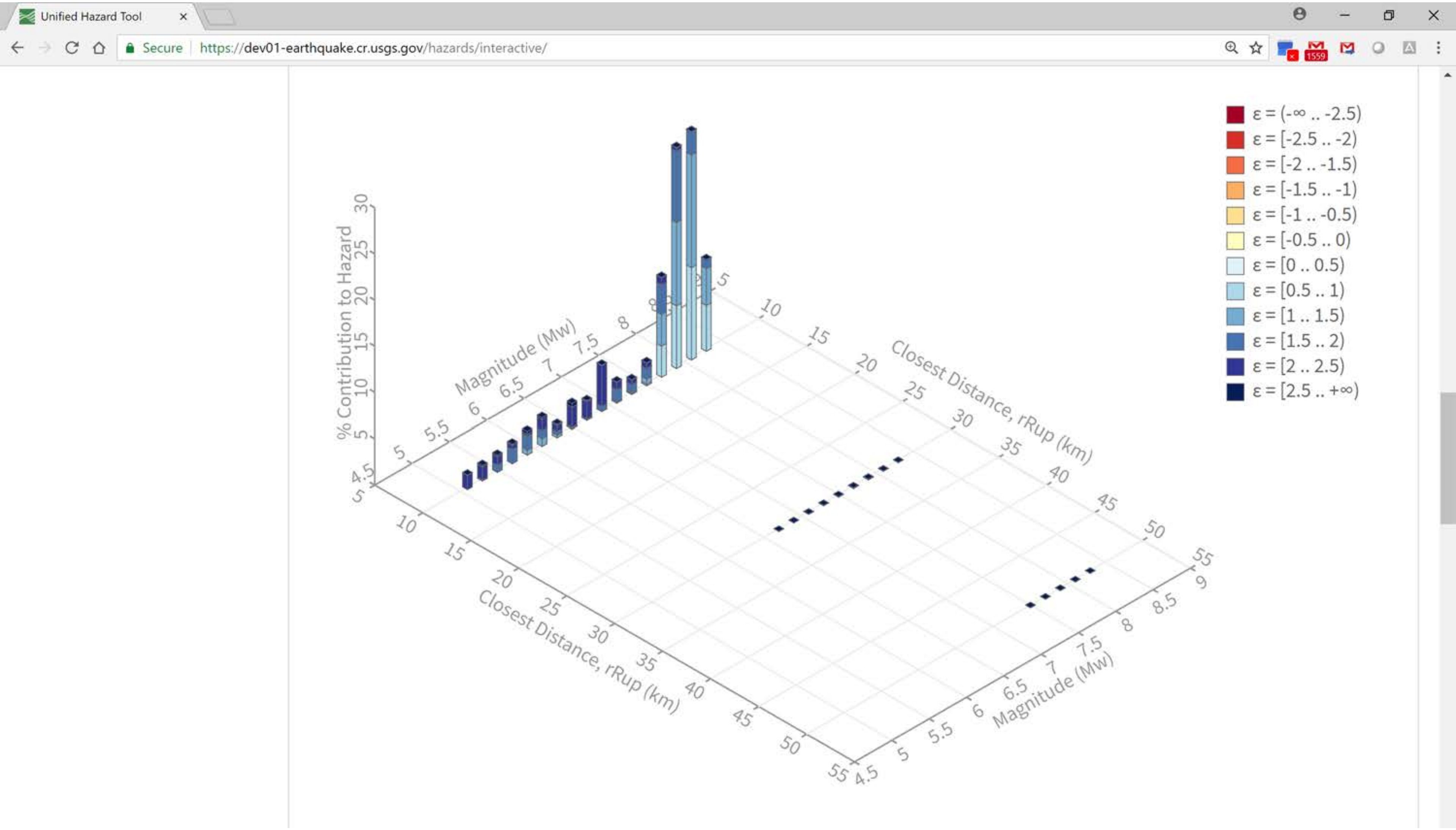


(a.k.a. # standard deviations)

Example: San Bernardino, $S_{SRT} = 2.6g$



Example: San Bernardino, $S_{SRT} = 2.6g$



Example: San Bernardino, $S_{SRT} = 2.6g$

Unified Hazard Tool

Secure | https://dev01-earthquake.cr.usgs.gov/hazards/interactive/

Deterministic scenarios that could result in 2.6g …

Epsilon≤1.0 S_S

$\boxed{2.4\ g}$

$1.7\ g$

Source Name	Distance (km)	Magnitude	Epsilon	Relative Likelihood
San Jacinto	1.9	8.0	1.1	46%
San Andreas	8.4	7.6	1.7	34%

Capping the epsilons of these scenarios at 1.0 results in 84^{th}-percentile deterministic ground motions.

ASCE 7-16
S_S = 2.3*g* (from San Jacinto, *M*=7.7)

Following the current *ASCE 7-16* deterministic capping procedure, use the largest 84^{th} percentile ground motion.

Example: San Jose, $S_{SRT} = 2.2g$

Unified Hazard Tool

Secure | https://dev01-earthquake.cr.usgs.gov/hazards/interactive/

Deterministic scenarios that could result in 2.2g …

Epsilon≤1.0 S_S	Source Name	Distance (km)	Magnitude	Epsilon	Relative Likelihood
$\boxed{1.4\ g}$	Hayward	11	7.0	1.8	52%
1.3 *g*	Calaveras	12	7.2	1.9	16%
1.2 *g*	San Andreas	20	7.9	2.0	11%
~~2.3 *g*~~	~~Silver Creek~~	~~2.0~~	~~6.9~~	~~0.9~~	~~3%~~

Following the current *ASCE 7-16* deterministic capping procedure, only use "active" faults by only using sources with, for example, Relative Likelihood ≥ 5%.

ASCE 7-16
S_S = 1.5*g*
(Plateau)

Example: Northridge, $S_{SRT} = 1.9g$

Unified Hazard Tool ×

Secure | https://dev01-earthquake.cr.usgs.gov/hazards/interactive/

Deterministic scenarios that could result in 1.9g …

Epsilon≤1.0 S_S	**Source Name**	**Distance (km)**	**Magnitude**	**Epsilon**	**Relative Likelihood**
1.5 g	Santa Susana	12	7.0	1.4	29%
$\boxed{1.8\ g}$	Compton	14	7.5	1.1	6%
1.3 g	Mission Hills	9.4	6.8	1.6	7%
1.7 g	Northridge Hills	8.7	7.7	1.2	6%
1.6 g	Northridge	16	7.2	1.3	5%
	~~Anacapa Dume~~	~~14~~	~~7.4~~	~~1.4~~	~~2%~~
	~~Hollywood~~	~~17~~	~~7.2~~	~~1.9~~	~~3%~~

ASCE 7-16
$S_S = 1.7g$
(from Compton, M=7.4)

Summary: Epsilon-Capped vs. *ASCE 7-16* S_S

City	*ASCE 7-16* S_S (*g*)	Epsilon-Capped S_S (*g*)	% Difference
Santa Rosa	2.4	2.6	7%
San Bernardino	2.3	2.5	8%
Concord	2.2	2.5	11%
Oakland	1.9	1.9	0%
San Mateo	1.8	1.9	7%
Northridge	1.7	1.8	5%
Vallejo	1.5	2.1	40%
San Jose	1.5	1.3	-13%
San Francisco	1.5	1.4	-6%
Riverside	1.5	1.3	-16%

Vallejo, $S_{SRT} = 2.1g$

Unified Hazard Tool

Secure | https://dev01-earthquake.cr.usgs.gov/hazards/interactive/

Deterministic scenarios that could result in 2.1g …

Epsilon≤1.0 S_S

$\boxed{2.1\ g}$

2.0 *g*

1.2 *g*

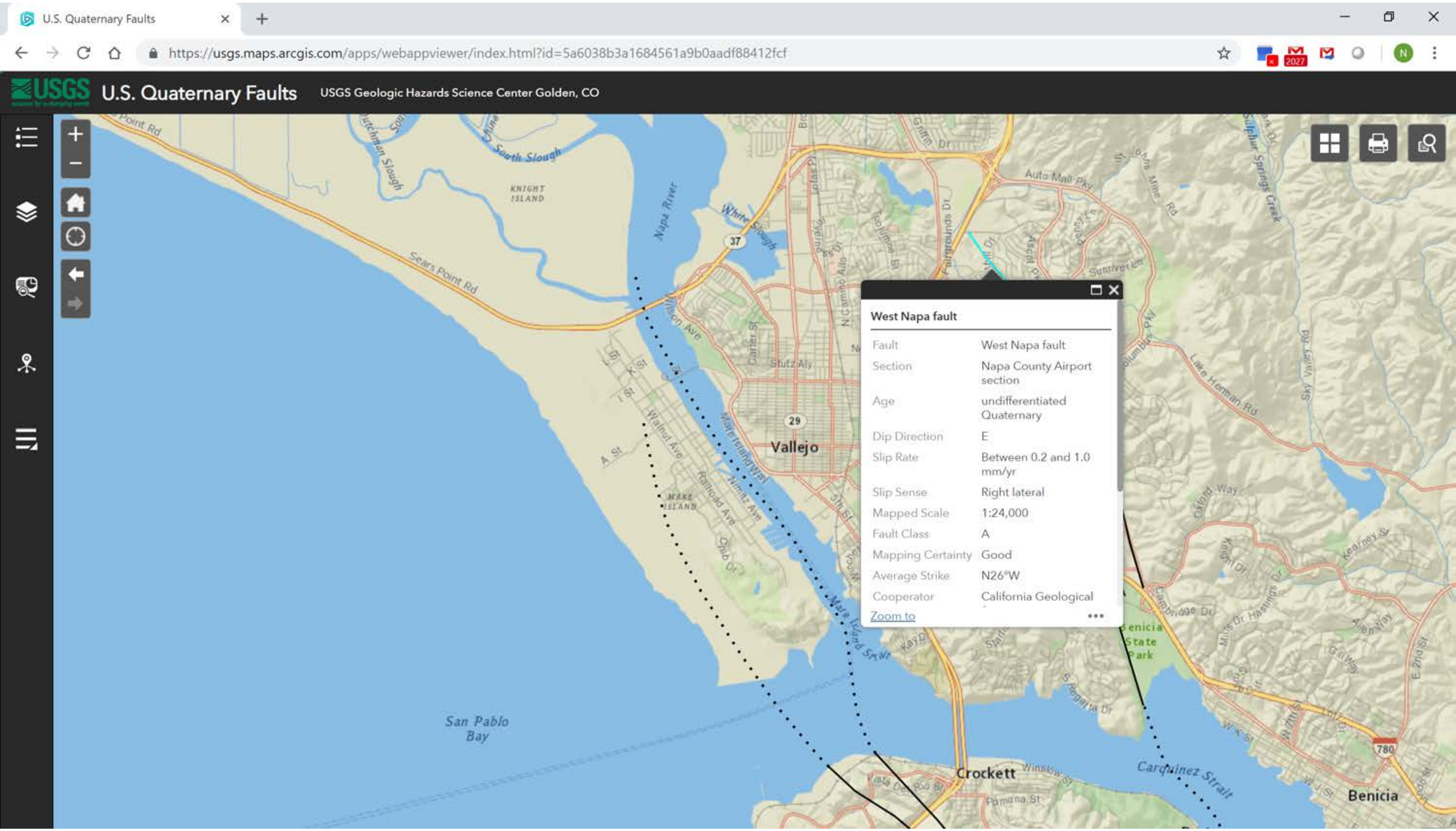
1.2 *g*

1.5 *g*

Source Name	Distance (km)	Magnitude	Epsilon	Relative Likelihood
Franklin	2.5	6.7	1.0	27%
Contra Costa	3.4	6.8	1.1	26%
Hayward	14	7.3	2.0	12%
Green Valley	15	6.8	2.0	11%
West Napa	7.1	6.6	1.6	9%

ASCE 7-16
$S_S = 1.5g$
(from West Napa, M=7.0)

Franklin and Contra Costa Faults



Building Seismic Safety Council (BSSC) Provisions Update Committee (PUC) Meeting

Locations NOT Capped in *ASCE 7-16*

(Deterministic > Probabilistic > Plateau)

City	*ASCE 7-16* S_S (g)	Epsilon-Capped S_S (g)	% Difference
Santa Barbara	2.1	2.1	0%
Century City	2.1	2.1	0%
Ventura	2.0	2.0	0%
Los Angeles	2.0	2.0	0%
Long Beach	1.7	1.7	0%
Santa Cruz	1.6	1.5	-7%
San Diego	1.6	1.6	0%
Salt Lake City	1.5	1.5	0%

Proposal: USGS Procedure at Each Location

1. Compute Risk-Targeted Ground Motion (**RTGM**).

2. If RTGM is greater than deterministic lower limit, **deaggregate hazard** at RTGM return period.

3. From deaggregation, obtain **deterministic scenarios** that could result in RTGM *(i.e., fault/source names, magnitudes, distances, epsilons, relative likelihoods)*.

4. **Adjust** each deterministic scenario to 84th-percentile ground motion by dividing RTGM by …

$$\exp(\text{Epsilon}\cdot\sigma) \, / \, \exp(1\cdot\sigma)$$

5. Use **largest** 84th-percentile ground motion amongst deterministic scenarios with relative likelihood ≥x%.

Advantages of Epsilon Capping

- ✓ PUC/Project ’17 need not choose “active” faults, “characteristic” earthquake ruptures & magnitudes.
- ✓ Results are consistent with hazard model for probabilistic ground motions (e.g., UCERF3) and its deaggregation.
- ✓ Deaggregation of probabilistic ground motions is useful for review and communication.
- ✓ USGS need not update deterministic software, which would require additional review.