The 2008 USGS Seismic Hazard Model for the Conterminous U.S.

The 2008 national seismic hazard model for conterminous U.S. is described in detail by Petersen et al. (2008). This model is an update of previous work (Frankel et al., 1996; Frankel et al., 2002). Here we describe the OpenQuake-engine implementation of the 2008 model.

The Seismic Source Model

To reproduce earthquake activity in various tectonic settings, the seismic source model employs two main source typologies: gridded seismicity and fault sources. Gridded seismicity is used to model spatially variable seismicity (obtained through a smoothed seismicity approach) as well as zones of uniform seismicity. Fault sources are instead used to model shallow crustal faults and large subduction interface faults.
The full source model can be divided into a number of sub-models:

- Western U.S. active shallow crust gridded seismicity
- Western U.S. subduction intraslab (deep) gridded seismicity
- Western U.S. crustal faults
- Cascadia subduction interface faults
- Central and eastern U.S. stable continental crust gridded seismicity
- Central and eastern U.S. faults
- Charleston gridded seismicity model

Gridded seismicity models are implemented as collections of point sources (following the NRML pointSource definition). For shallow seismicity (in both western and eastern U.S.) the hypocentral depth is fixed at 7.5 km and the seismogenic layer is assumed to extend from 0 to 15 km. Deep (subduction intraslab) seismicity is instead associated to an hypocentral depth equal to 50.0 km with a seismogenic layer extending from 50 to 100 km. In case a model defines uncertain rupture strikes, ruptures in a point source are distributed over multiple strike angles, otherwise a single strike is defined. Depending on the model, ruptures can be vertical (strike-slip) or inclined (dip angle assumed equal to 50 degrees).

Shallow crustal faults are implemented as simple fault sources (NRML simpleFaultSource) or as characteristic fault sources with simple geometry (NRML characteristicFaultSource (with simple geometry)). Large subduction interface events are instead implemented as complex fault sources (NRML complexFaultSource) or as characteristic fault sources with complex geometry (NRML characteristicFaultSource (with complex geometry)).

The map below depicts the annual occurrence rate per source (between minimum and maximum magnitudes) for the different source models included in the hazard model. Click the *show map layers* icon to view different source models and base layer maps.

Total occurrence rate
(number of events / year)

- < 1e-6
- 1e-6 - 1e-5
- 1e-5 - 1e-4
- 1e-4 - 1e-3
- 1e-3 - 1e-2
- 1e-2 - 1e-1
- 1e-1 - 1
- 1 - 10
- >= 10

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The Ground Motion Model

The ground motion model distinguishes between four main tectonic regions:

- Active Shallow Crust (western U.S.)
- Stable Continental Crust (eastern U.S.)
- Subduction Interface (Cascadia)
- Subduction Intraslab (northern California and Oregon/Washington)

For each tectonic region, various GMPEs are used to account for epistemic uncertainties. For each tectonic region, the model considers multiple ground motion prediction equations organized in a logic tree structure.

Active Shallow Crust	**Weight**
Boore and Atkinson 2008	0.333
Campbell and Bozorgnia 2008	0.333
Chiou and Youngs 2008	0.333

Stable Continental Crust	**Weight**
Toro et. al. 1997	0.25
Frankel et. al. 1996	0.125
Campbell 2003	0.125
Atkinson and Boore 2006 (140 bar stress drop)	0.125
Atkinson and Boore 2006 (200 bar stress drop)	0.125
Tavakoli and Pezeshk 2005	0.125

Silva et. al. 2002	0.125

Stable Continental Crust - (Charleston/CEUS faults)	Weight
Toro et. al. 1997	0.2
Frankel et. al. 1996	0.1
Campbell 2003	0.1
Atkinson and Boore 2006 (140 bar stress drop)	0.1
Atkinson and Boore 2006 (200 bar stress drop)	0.1
Tavakoli and Pezeshk 2005	0.1
Silva et. al. 2002	0.1
Somerville et. al. 2001	0.2

Subduction Interface	Weight
Zhao et. al. 2006	0.5
Atkinson and Boore 2003	0.25
Youngs et. al. 1997	0.25

Subduction Intraslab	Weight
Geomatrix 1993	0.5
Atkinson and Boore 2003 (Cascadia model)	0.25
Atkinson and Boore 2003 (Global model)	0.25

Reference site condition

The NEHRP B/C site condition is assumed to be the reference site conditions for the 2008 U.S. national seismic hazard model. This is equivalent to a Vs30 (shear wave velocity in the uppermost 30 meters) = 760 m/s. Almost all GMPEs utilized in the western U.S. accept Vs30 as prediction variable. The remaining GMPEs are used with coefficients already calibrated for the B/C site conditions.

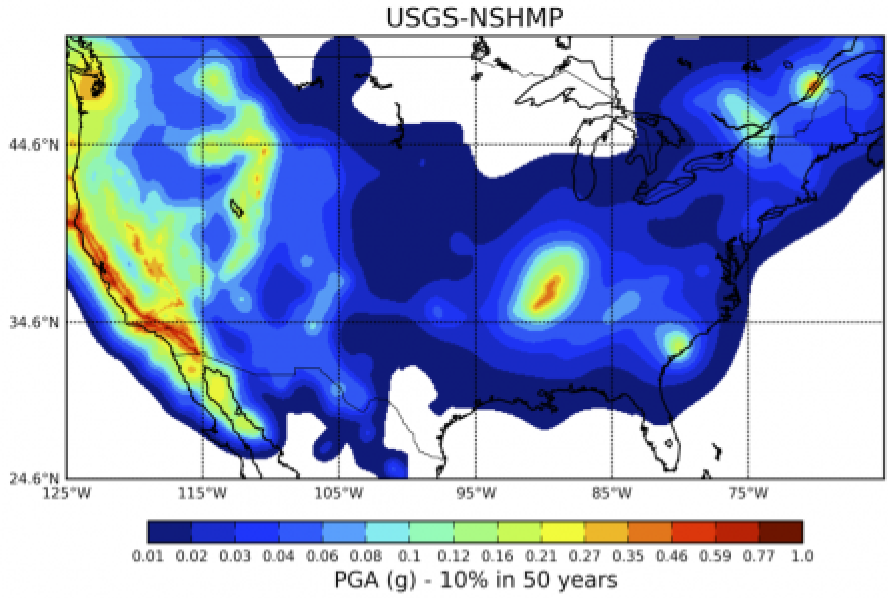
Hazard Results

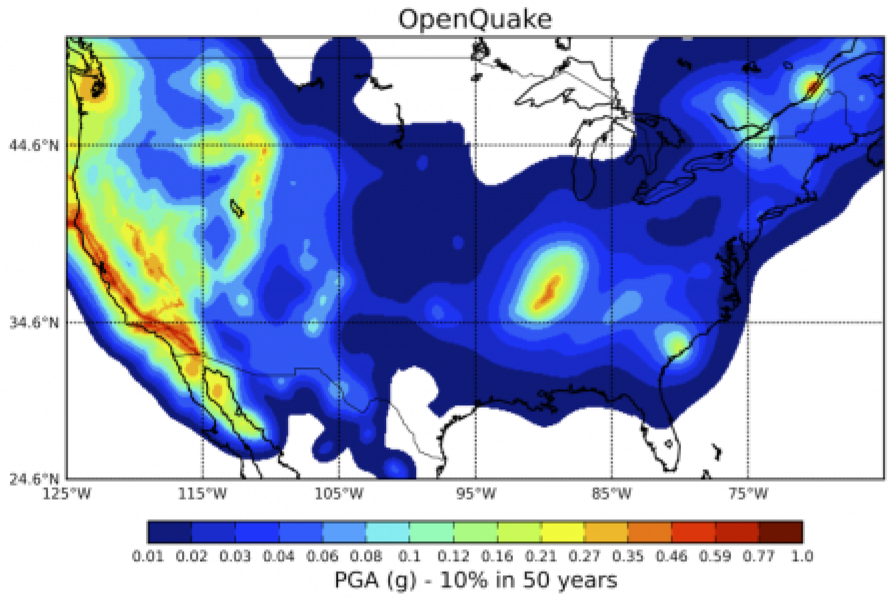
Comparison against USGS-NSHMP results

We present here a number of comparisons between the hazard results (e.g. hazard maps/curves) provided by the United States Geological Survey - National Seismic Hazard Mapping Project (USGS-NSHMP) and by the OpenQuake-engine implementation.

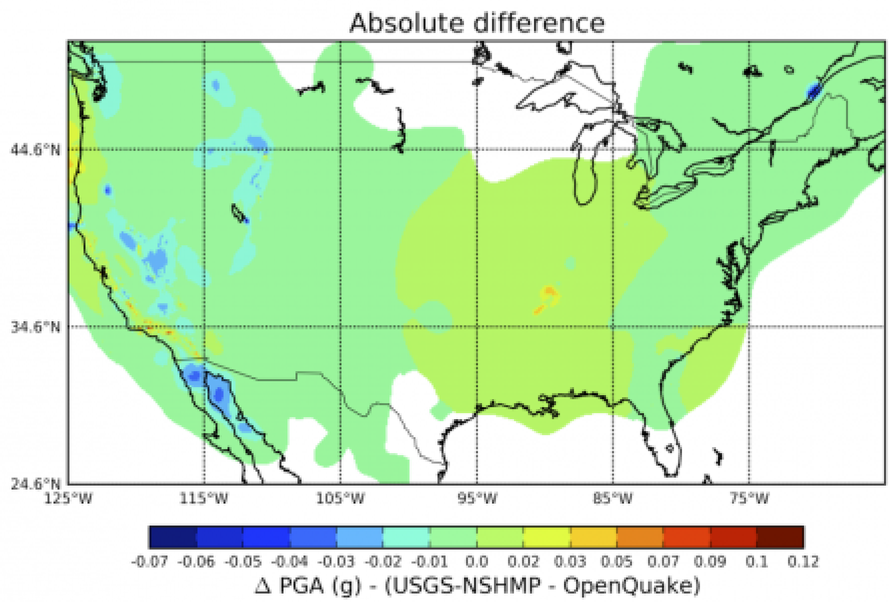
To properly judge the comparison it is worth noticing that the current the OpenQuake-engine implementation of the 2008 U.S. model does not reproduce exactly all the features as defined in the original model. In particular, the current implementation does not include the *cluster* model for the New Madrid zone (only the unclustered model is implemented) nor epistemic uncertainties on GMPE median ground motion values for shallow crustal sources in the western US. Moreover differences may arise because of the different ways earthquake ruptures are modeled in the two software used for the calculations.

The maps below represent hazard maps for PGA (10% in 50 years) as computed by the USGS-NSHMP and by the the OpenQuake-engine.

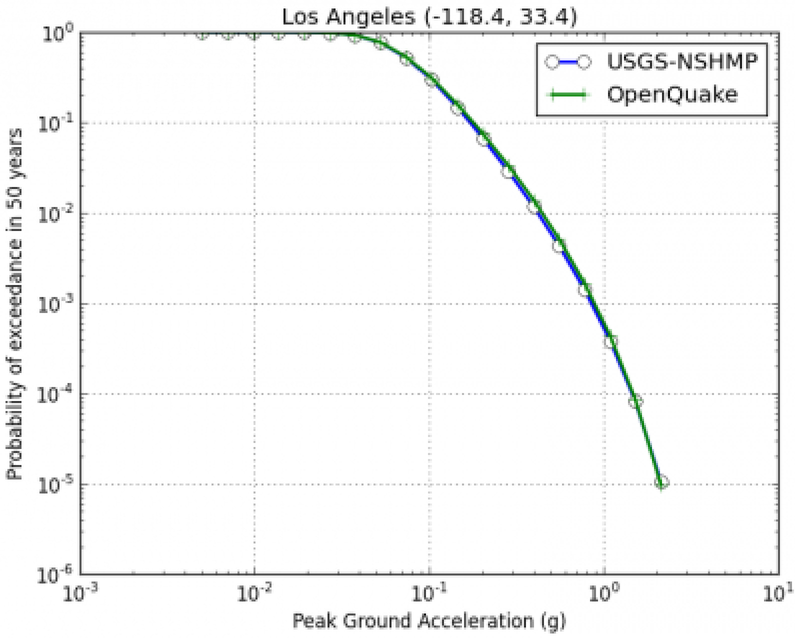




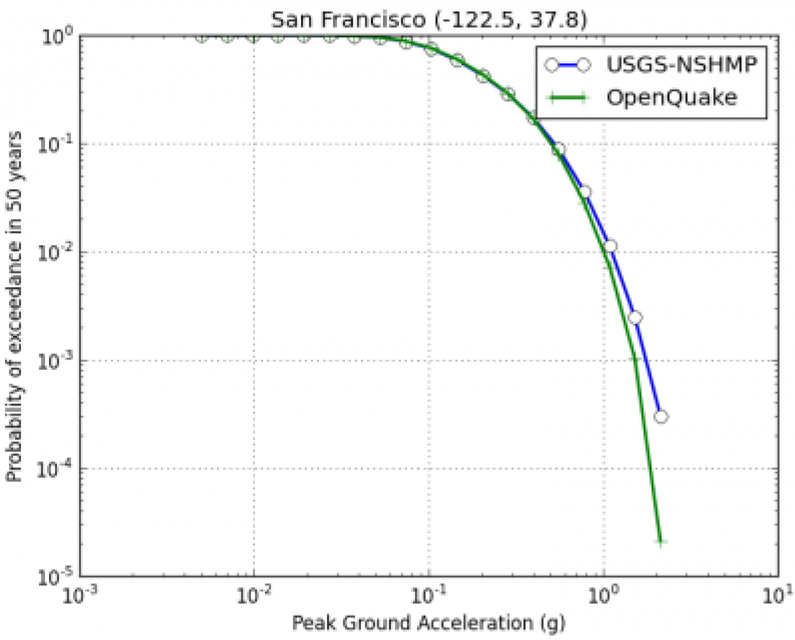
The visual comparison reveals an overall agreement. The difference map below shows in a more quantitative way the differences between the two maps.

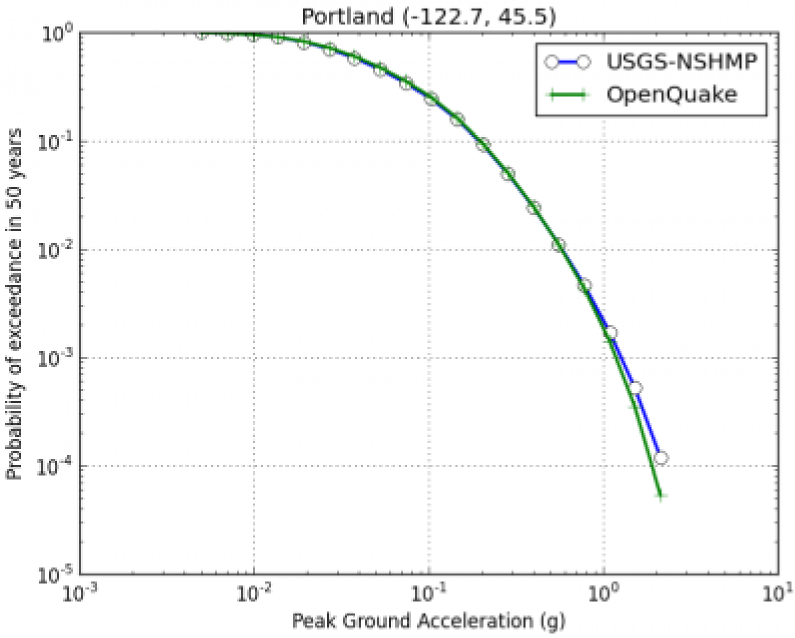


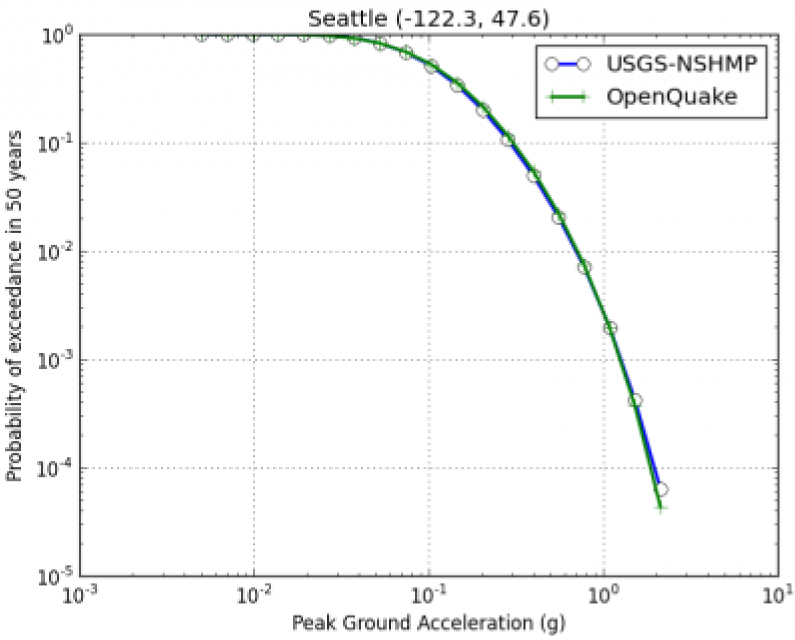
The figures below represent comparisons of hazard curves for a number of selected sites in western

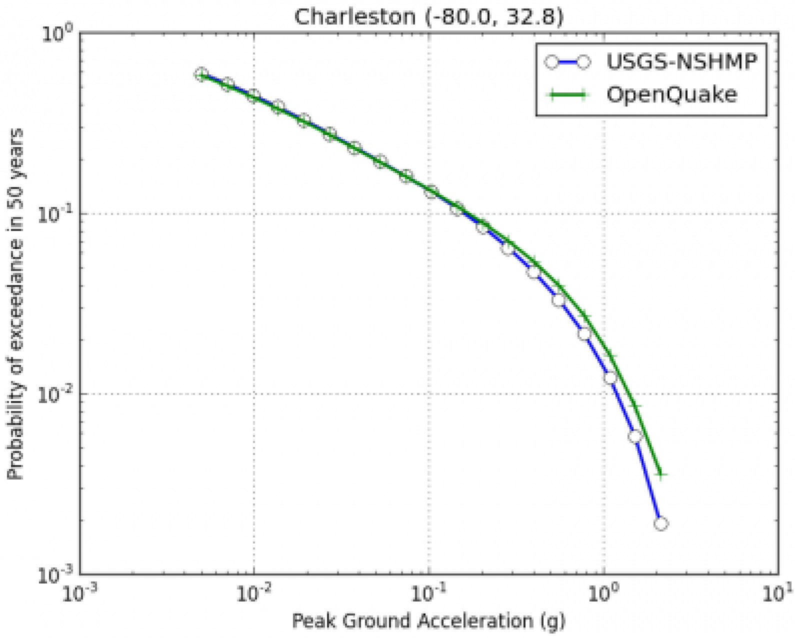


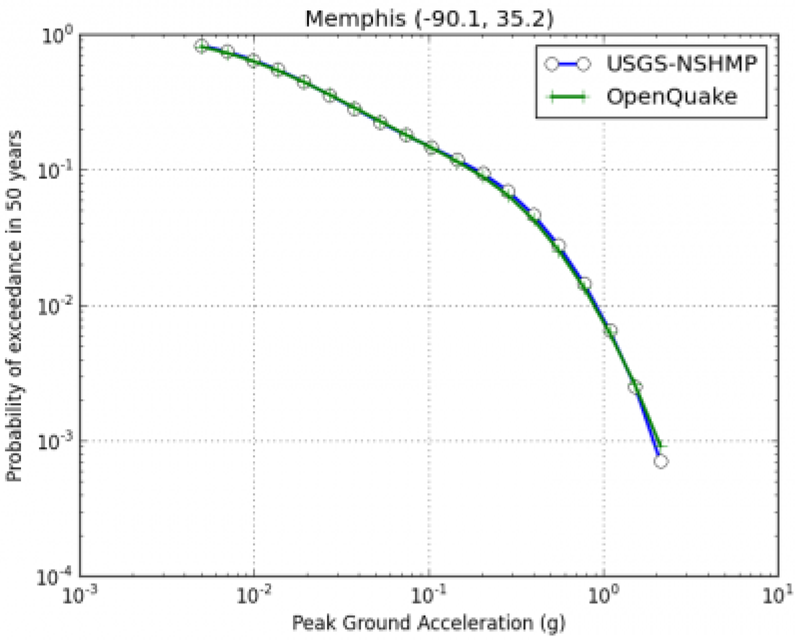
and central U.S.

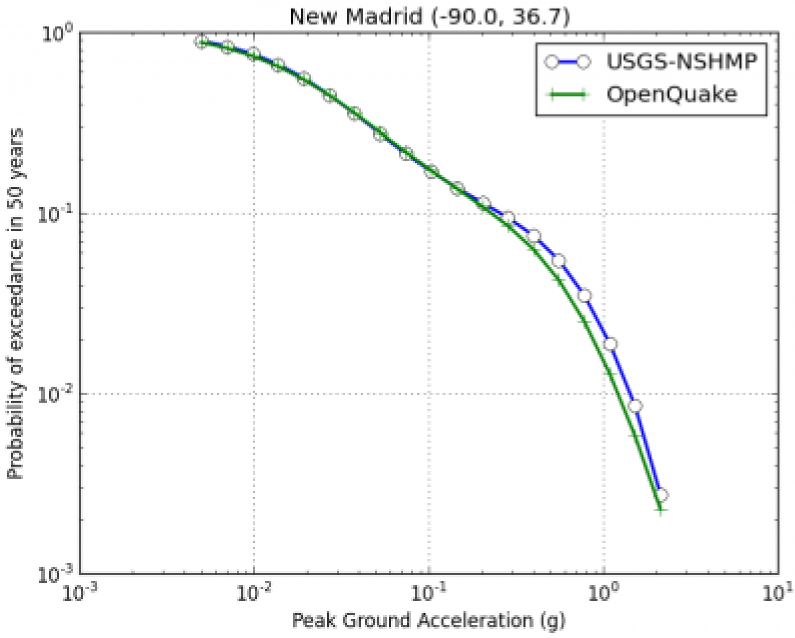


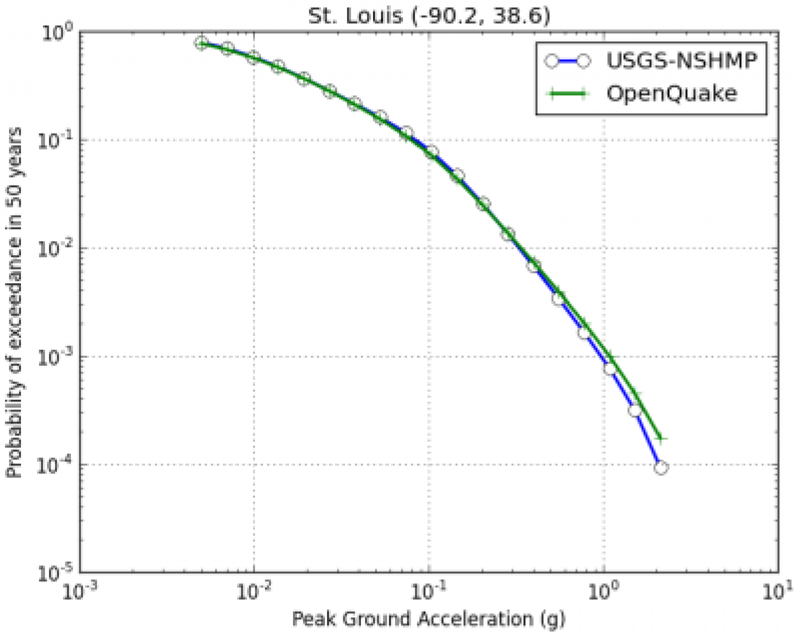

Portland (-122.7, 45.5)
USGS-NSHMP
OpenQuake
Probability of exceedance in 50 years
Peak Ground Acceleration (g)


Seattle (-122.3, 47.6)
USGS-NSHMP
OpenQuake
Probability of exceedance in 50 years
Peak Ground Acceleration (g)


Charleston (-80.0, 32.8)
USGS-NSHMP
OpenQuake
Probability of exceedance in 50 years
Peak Ground Acceleration (g)


Memphis (-90.1, 35.2)
USGS-NSHMP
OpenQuake
Probability of exceedance in 50 years
Peak Ground Acceleration (g)





References

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Model summary table

This table summarises the main characteristics of the original implementation of this model

1	**Datasets availability**	
1.1	Earthquake catalogue	Available here
1.2	Geological database	Faults database here
1.3	Strong-motion database	Not available
1.4	Site characterization database	Not available
Notes		
2	**Methodology for model development**	
2.1	Scientific participation (SSHAC levels) and review process	Level 3
2.2	Documentation describing model preparation	Petersen et al., 2008
2.3	Codes used for model preparation	Availablehere
Notes		
3	**PSHA input model**	
3.1	**Seismic Source Model**	
3.1.1	Area sources	Included (background)
3.1.2	Grid sources	Included
3.1.3	Crustal faults	Included
3.1.4	Subduction faults	Included (Cascadia subduction zone)
3.1.5	Non-parametric ruptures	Not included
3.1.6	Magnitude-area scaling relationships	Ellsworth (2003), Hanks and Bakun (2002), Wells and Coppersmith (1994)
3.2	**Ground Motion Model**	
3.2.0	Tectonic regionalisation	Included
3.2.1	Models for active shallow seismicity	Included
3.2.2	Models for subduction interface	Included (Cascadia subduction zone)
3.2.3	Models for subduction intraslab	Included (Cascadia subduction zone)
3.2.4	Models for stable continental regions	Included
3.2.5	Models for deep non-subduction sources	Included
3.2.6	Models for volcanic areas	Not included
3.3	**Site Response Model**	

3.3.1	Based on GMPEs	Yes, hazard is computed for a reference soil condition corresponding to NEHRP B/C boundary (Vs30=760 m/s)
3.3.2	Based on site-response analysis	Not included
3.4	**Epistemic uncertainties**	
3.4.1	Seismic Source Model	Included
3.4.2	Ground Motion Model	Included using a logic tree (see the ground motion model section)
3.4.3	Site Response Model	Not included
Notes		
4	**Hazard Input Description**	
4.1	Hazard input document	Not available
4.2	Input files	Availablehere
Notes		
5	**Calculation**	
5.1	Software	Suite of Fortran and C codes
5.2	***Results***	
5.2.1	Hazard curves	Available for a grid of geographic pointshere
5.2.2	Hazard maps	Available for a grid of geographic pointshere
5.2.3	Uniform hazard spectra	Not considered
5.2.4	Disaggregation	Not considered
5.2.5	Stochastic event sets	Not considered
5.2.6	Ground motion fields	Not considered
Notes		