3 Introduction To Probabilistic Seismic Hazard Analysis

In this chapter, we jump ahead and go through a simplified example of a probabilistic seismic hazard analysis. Later in chapter 9, the mathematical framework for PSHA is covered in detail. The purpose of going though this example before describing the details of the methodogy is to provide an intuitive understanding of PHSA and to provide an overview of where we are heading before describing the details of the methods and models. The concepts of PSHA are discussed with the help of a numerical example calculation without getting bogged down in the mathematics.

The methods and models for the source characterization and ground motion attenuation characterization are described in Chapters 6 and 7, respectively. In this chapter, the source characterization and ground motion attenuation models are applied with very little explaination. The purpose of this chapter is not to cover the details of source characterization and ground motion attenuation. The purpose is to explain the concepts of a PSHA. To keep the example calculation to a managable size, the source characterization is greatly simplifed here. In chapter 9, a typical PSHA calculation is described without all of the simplifications used here.

3.1 Source Characterization

For this example, consider a site located between two faults as shown in Figure 3-1. There is a distant fault with a slip-rate and a nearby fault with a moderate slip-rate. The parameters of the two faults are listed in Table 3-1.

As discussed in Chapter 2, a PSHA can be considered as a large number of determinsitic analyses. The first step in a PSHA is to develop a set of relevant scenario earthquakes to consider. This step is called the source characterization. The term “relevant” here refers to the severity of the ground motions from the scenario earthquake. In developing the set of scenario earthquakes to consider, only scenarios that could produce ground motions that cause damage to the project under study. Earthquakes smaller than magnitude 5 do not cause damage to engineered structures, so in this example we limit the considered scenario earthquakes to those with magnitudes greater than 5.0.

Table 3-1. Fault parameters for the example faults shown in Figure 5-1.

	Fault 1	Fault 2
Fault Length (km)	26	200
Fault Width (km)	12	15
Dip (degrees)	90	90
Slip-rate (mm/yr)	2	10
Style-of-faulting	Strike-slip	Strike-slip
Characteristic Magnitude	6.5	7.5

In its simplest form, a scenario earthquakes is described in terms of its magnitude, rupture dimension (rupture length and rutpure width), and location. To keep the size of the example manageable for a hand calculation, a very small set of scenario earthquakes are considered. The magnitudes, rupture dimensions, and locations of the scenario earthquakes considered in this example are described below.

First, the magnitudes for the scenario earthquakesare determined. The faults are assumed to follow theYoungs and Coppersmith (1985) characteristic earthquake model (see Chapter 6). For each fault, three magnitudes are considered for the scenario earthquakes. For fault 1, the magnitudes are M=5.5, M=6.0, and M=6.5. For fault 2, the magnitudes are M=5.5, M=6.5, and M=7.5.

Next, the rupture length and rupture width for each scenario magnitude are determined. In general, there is more than one possible rupture length and rupture width for a given magnitude, but to keep this example simple, only one value is used here. The rupture lengths and rupture widths are computed using source scaling relations (described in Chapter 6). The rupture dimensions used in this example are listed in Table 3-2.

Finally, the location of each scenario earthquake on the fault plane is determined. Again, to keep this example manageable, a small number of possible locations are considered. For the two smaller magnitudes for each fault, three possible locations of the earthquake rupture are considered (Figure 3-3) along the length of the fault (e.g. along strike) and just one location is considered along the width of the fault (e.g. down dip). For the largest magnitudes for fault 1 and fault 2, the rupture dimension is equal to the fault dimension (e.g. the scenario earthquake ruptures the entire fault) so only one rupture location is needed. For the smaller magnitude scenarios, the three locations are modeled to be equally likely.

Using the source characterization methods described later in Chapter 6, the annual rate of each scenario earthquake is computed. The resulting rates are listed in Table 3-2.

Table 3-2. Rates of Scenario Earthquakes

Fault	Magnitude	Length (km)	Width (km)	Rupture Location	Scenario Earthquake Rate (per year)
1	5.5	6	6	West	0.00100
1	5.5	6	6	Center	0.00100
1	5.5	6	6	East	0.00100
1	6.0	14	7	West	0.00018
1	6.0	14	7	Center	0.00018
1	6.0	14	7	East	0.00018
1	6.5	26	12	Center	0.00240
2	5.5	6	6	West	0.03800
2	5.5	6	6	Center	0.03800
2	5.5	6	6	East	0.03800
2	6.5	26	12	West	0.00300
2	6.5	26	12	Center	0.00300
2	6.5	26	12	East	0.00300
2	7.5	200	15	Center	0.00330

3.2 Ground Motions

With the set of earthquake scenarios, the next step is to compute the severity of shaking for each scenario earthquake. For this example, assume that the structure of interest is sensitive to high frequency ground motions and that the severity of shaking can be described by the horizontal spectral acceleration at a frequency of 5 Hz. The ground motion can be estimated using ground motion prediction equations (commonly called attenuation relations) as described in Chapter 6. In this example, the empirical ground motion prediction equation of Abrahamson and Silva (1997) for 5 Hz horizontal spectral acceleration on a rock site is used.

The ground motion prediction equation depends on the earthquake magnitude, the closest distance from the rupture to the site, the style-of-faulting, and the site condition. Therefore, we need to compute the closest distance from the rupture to the site for each scenario earthquake. These distances are listed in Table 3-3.

Table 3-3. Scenario Ground Motions at 5 Hz

Fault	Magnitude	Location	Rupture Distance (km)	Median Spectral Acceleration (g)	Standard Deviation Of Spectral Acceleration (LN units)
1	5.5	West	10.4	0.28	0.70
1	5.5	Center	11.6	0.25	0.70
1	5.5	East	18.3	0.15	0.70
1	6.0	West	10.3	0.46	0.63
1	6.0	Center	10.4	0.46	0.63
1	6.0	East	12.5	0.38	0.63
1	6.5	Center	10.0	0.73	0.56
2	5.5	West	106.6	0.017	0.70
2	5.5	Center	50.2	0.043	0.70
2	5.5	East	106.6	0.017	0.70
2	6.5	West	89.3	0.074	0.56
2	6.5	Center	50.0	0.14	0.56
2	6.5	East	89.3	0.074	0.56
2	7.5	Center	50.0	0.25	0.50

To compute the ground motion at the site, we need to know the scenario earthquake magnitude and distance and also the number of standard deviations for the ground motion. By tradition, deterministic analyses typically select either the median ground motion (zero standard deviations above the median) or the 84th percentile ground motion (one standard deviation above the median). The number of standard deviations, denoted ε, is a continuous variable and the values of 0 and 1 traditionally used in deterministic analyses do not cover the possible range of values.

In developing the table of scenario ground motions, we will consider the full range of ε. To keep the example to a manageable size, we will consider only 7 discrete values of e ranging from –3 to 3. The discrete probabilities for these 7 epsilon values are listed in Table 3-4.

Table 3-4. Discrete Probabilities for the number of standard deviation for the ground motion

ε	$P(\varepsilon)$
-3.0	0.0060
-2.0	0.0605
-1.0	0.2420
0.0	0.3830
1.0	0.2420
2.0	0.0605
3.0	0.0060

For each scenario earthquake, a scenario ground motion is computed for each epsilon value (each number of standard deviations). This leads to a table of 49 scenario ground motions (7 scenario earthquakes times 7 epsilon values) for each fault. These scenario ground motions are listed in Table 3-5 for both faults. The rate of the scenario ground motion is computed by multiplying the rate of the scenario earthquake by the probability of the epsilon value.

$$Rate(M,R,\varepsilon) = Rate(M,R)\ P(\varepsilon)$$

At this point, we simple have a large number of deterministic analyses of the ground motion at the site and the rate at which each scenario ground motion occurs.

How do we select which of these scenarios to use? We begin by ranking the scenarios in order of decreasing severity of shaking. In this example, the severity of shaking is measured in terms of the T=0.2 second spectral acceleration. Table 3-6 shows the scenario ground motions ranked from most severe to least severe. The worst-case ground motion is at the top of the Table. In this example, the worst case spectral acceleration is 3.9 g and comes from the fault 1 scenario with M=6.5, Distance = 10 km, and $\varepsilon=3$. The rate at which this scenario occurs is 1.4E-5/year. If we wanted to be "safe" as discussed in Chapter 2, then we would need to use the worst case ground motion for design. In practice this worst case ground motion is not used because it would be very costly and its chance of occurring is too small to justify the expense.

The next step is the key step in which the probabilistic approach differs from the deterministic approach. In the probabilistic approach, the rates of the scenario ground motions are summed from the most sever shaking to the least severe shaking (e.g. the rates are summed from top down in Table 3-6). This summed rate is given the last column of Table 3-6. It is the rate at which the ground motion is exceeded. Plotting this rate against the ground motion level leads to the hazard curve (Figure 3-3).

In the probabilistic approach, we back off from the worst-case ground motion until the chance of exceeding a ground motion level is large enough (e.g. no longer too rare) that it warrants consideration or the cost of designing for the ground motion does not have a major cost impact. In practice, the second condition may be imposed on a broad basis by requiring a minimum ground motion level for design regardless of its probability of being exceeded. The first condition requires that an acceptable hazard level be defined (e.g. what is not too rare?). This is typically defined by regulation. For example, the 2003 CBC uses a hazard level of 0.0021 per year (corresponding to 10% chance of being exceeded in 50 years). In this example, the ground motion corresponding to an annual hazard level of 0.0021 is 0.68 g. If we were developing ground motions for a critical structure we would use a lower hazard level. For example, the ground motion for a hospital would be based on an annual probability of 10^{-3}. In this case corresponding to a spectral accelertion of 0.86g.

From Table 3-6, we can see that a probabilistic analysis is just a large number of deterministic scenarios, ranked in order of decreasing severity of shaking. It contains a complete set of relevant and credible scenarios. There should not be any physically unrealizable scenarios considered in a PSHA.

For comparison, the traditional deterministic ground motions from the largest magnitude earthquake for the median and 84th percentile ground motions are highlighted in Table 3-6. The traditional deterministic approach also involves backing off from the worst-case ground motion. The difference is that the deterministic approach backs off from the worst-case based only on the probability of the ground motion given that a large earthquake has occurred without regard to the rate at which the scenario ground motion occurs (is exceeded). In this example, the rate at which the deterministic median and 84th percentile ground motions are exceeded are 0.0020/yr and 0.0008/yr, respectively.

Once a ground motion level has been selected, often a scenario earthquake needs to be selected (magnitude and distance) for developing engineering inputs such as time histories. The hazard curve by itself does not give information on the magnitude-distance pairs of the earthquakes. It is a summation of the rates of all magnitudes and distances that cause ground motions above a test threshold. Going back to the table of scenario ground motions, all of the information on the magnitudes and distances of the scenario earthquakes that contribute to the hazard at a given ground motion level are in the table.

This information is parameterized by a "deaggregation" of the hazard. The deaggregation of a seismic hazard curve describes the fractional contribution of different earthquake scenarios to the hazard. Getting back to the example, the ground motion corresponding to a annual hazard level of 0.0021 is 0.68g. In Table 3-6, there are 21 scenarios that cause a ground motion of 0.68g or larger. Taking just that subset of 21 scenarios, we can compute how much each scenario contributes to the hazard of 0.0021 by dividing the rate of the scenario by the hazard level of 0.0021. This fractional contribution to the hazard is listed in Table 3-7. It shows that the most likely scenario causing a ground motion of 0.68g or larger is M=6.5, D=10km, epsilon=0.

In practice, there are many more scenarios than considered in this simple example. To avoid having a huge list of scenarios to consider, the scenarios are grouped with other scenarios with similar magnitudes and distances. This is more fully described in Chapter 9.

There is an apparent inconsistency in the use of the deaggregation to define the earthquake scenarios from a PSHA. The hazard curve gives the rate of a ground motion value being exceeded. That is, all of the scenarios considered in the deaggregation produce ground motions greater than the ground motion of the selected hazard level, yet we use the scenarios for the ground motion of the selected hazard level. The deaggregation is typiclly domianted by scenarios with ground motins close to the selected hazard level. This will also be discussed furtter in Chapter 9.

Table 3-5. Ground Motion Scenarios

flt	M	Loc	Dist (km)	med Sa (g)	std dev	eqk rate	ε	p(ε)	Sa (g)	Rate
1	5.5	West	10.4	0.28	0.7	0.001	-3	0.006	0.034	0.0000060
1	5.5	Center	11.6	0.25	0.7	0.001	-3	0.006	0.031	0.0000060
1	5.5	East	18.3	0.15	0.7	0.001	-3	0.006	0.018	0.0000060
1	6	West	10.3	0.46	0.63	0.00018	-3	0.006	0.069	0.0000011
1	6	Center	10.4	0.46	0.63	0.00018	-3	0.006	0.069	0.0000011
1	6	East	12.5	0.38	0.63	0.00018	-3	0.006	0.057	0.0000011
1	6.5	Center	10	0.73	0.56	0.0024	-3	0.006	0.136	0.0000144
2	5.5	West	106.6	0.017	0.7	0.038	-3	0.006	0.002	0.0002280
2	5.5	Center	50.2	0.043	0.7	0.038	-3	0.006	0.005	0.0002280
2	5.5	East	106.6	0.017	0.7	0.038	-3	0.006	0.002	0.0002280
2	6.5	West	89.3	0.074	0.56	0.003	-3	0.006	0.014	0.0000180
2	6.5	Center	50	0.14	0.56	0.003	-3	0.006	0.026	0.0000180
2	6.5	East	89.3	0.074	0.56	0.003	-3	0.006	0.014	0.0000180
2	7.5	Center	50	0.25	0.5	0.0033	-3	0.006	0.056	0.0000198
1	5.5	West	10.4	0.28	0.7	0.001	-2	0.0605	0.069	0.0000605
1	5.5	Center	11.6	0.25	0.7	0.001	-2	0.0605	0.062	0.0000605

1	5.5	East	18.3	0.15	0.7	0.001	-2	0.0605	0.037	0.0000605
1	6	West	10.3	0.46	0.63	0.00018	-2	0.0605	0.130	0.0000109
1	6	Center	10.4	0.46	0.63	0.00018	-2	0.0605	0.130	0.0000109
1	6	East	12.5	0.38	0.63	0.00018	-2	0.0605	0.108	0.0000109
1	6.5	Center	10	0.73	0.56	0.0024	-2	0.0605	0.238	0.0001452
2	5.5	West	106.6	0.017	0.7	0.038	-2	0.0605	0.004	0.0022990
2	5.5	Center	50.2	0.043	0.7	0.038	-2	0.0605	0.011	0.0022990
2	5.5	East	106.6	0.017	0.7	0.038	-2	0.0605	0.004	0.0022990
2	6.5	West	89.3	0.074	0.56	0.003	-2	0.0605	0.024	0.0001815
2	6.5	Center	50	0.14	0.56	0.003	-2	0.0605	0.046	0.0001815
2	6.5	East	89.3	0.074	0.56	0.003	-2	0.0605	0.024	0.0001815
2	7.5	Center	50	0.25	0.5	0.0033	-2	0.0605	0.092	0.0001997
1	5.5	West	10.4	0.28	0.7	0.001	-1	0.242	0.139	0.0002420
1	5.5	Center	11.6	0.25	0.7	0.001	-1	0.242	0.124	0.0002420
1	5.5	East	18.3	0.15	0.7	0.001	-1	0.242	0.074	0.0002420
1	6	West	10.3	0.46	0.63	0.00018	-1	0.242	0.245	0.0000436
1	6	Center	10.4	0.46	0.63	0.00018	-1	0.242	0.245	0.0000436
1	6	East	12.5	0.38	0.63	0.00018	-1	0.242	0.202	0.0000436
1	6.5	Center	10	0.73	0.56	0.0024	-1	0.242	0.417	0.0005808
2	5.5	West	106.6	0.017	0.7	0.038	-1	0.242	0.008	0.0091960
2	5.5	Center	50.2	0.043	0.7	0.038	-1	0.242	0.021	0.0091960
2	5.5	East	106.6	0.017	0.7	0.038	-1	0.242	0.008	0.0091960
2	6.5	West	89.3	0.074	0.56	0.003	-1	0.242	0.042	0.0007260
2	6.5	Center	50	0.14	0.56	0.003	-1	0.242	0.080	0.0007260
2	6.5	East	89.3	0.074	0.56	0.003	-1	0.242	0.042	0.0007260
2	7.5	Center	50	0.25	0.5	0.0033	-1	0.242	0.152	0.0007986
1	5.5	West	10.4	0.28	0.7	0.001	0	0.383	0.280	0.0003830
1	5.5	Center	11.6	0.25	0.7	0.001	0	0.383	0.250	0.0003830
1	5.5	East	18.3	0.15	0.7	0.001	0	0.383	0.150	0.0003830
1	6	West	10.3	0.46	0.63	0.00018	0	0.383	0.460	0.0000689
1	6	Center	10.4	0.46	0.63	0.00018	0	0.383	0.460	0.0000689
1	6	East	12.5	0.38	0.63	0.00018	0	0.383	0.380	0.0000689
1	6.5	Center	10	0.73	0.56	0.0024	0	0.383	0.730	0.0009192
2	5.5	West	106.6	0.017	0.7	0.038	0	0.383	0.017	0.0145540
2	5.5	Center	50.2	0.043	0.7	0.038	0	0.383	0.043	0.0145540
2	5.5	East	106.6	0.017	0.7	0.038	0	0.383	0.017	0.0145540
2	6.5	West	89.3	0.074	0.56	0.003	0	0.383	0.074	0.0011490
2	6.5	Center	50	0.14	0.56	0.003	0	0.383	0.140	0.0011490
2	6.5	East	89.3	0.074	0.56	0.003	0	0.383	0.074	0.0011490
2	7.5	Center	50	0.25	0.5	0.0033	0	0.383	0.250	0.0012639
1	5.5	West	10.4	0.28	0.7	0.001	1	0.242	0.564	0.0002420
1	5.5	Center	11.6	0.25	0.7	0.001	1	0.242	0.503	0.0002420
1	5.5	East	18.3	0.15	0.7	0.001	1	0.242	0.302	0.0002420
1	6	West	10.3	0.46	0.63	0.00018	1	0.242	0.864	0.0000436
1	6	Center	10.4	0.46	0.63	0.00018	1	0.242	0.864	0.0000436
1	6	East	12.5	0.38	0.63	0.00018	1	0.242	0.713	0.0000436
1	6.5	Center	10	0.73	0.56	0.0024	1	0.242	1.278	0.0005808
2	5.5	West	106.6	0.017	0.7	0.038	1	0.242	0.034	0.0091960
2	5.5	Center	50.2	0.043	0.7	0.038	1	0.242	0.087	0.0091960
2	5.5	East	106.6	0.017	0.7	0.038	1	0.242	0.034	0.0091960
2	6.5	West	89.3	0.074	0.56	0.003	1	0.242	0.130	0.0007260
2	6.5	Center	50	0.14	0.56	0.003	1	0.242	0.245	0.0007260
2	6.5	East	89.3	0.074	0.56	0.003	1	0.242	0.130	0.0007260
2	7.5	Center	50	0.25	0.5	0.0033	1	0.242	0.412	0.0007986
1	5.5	West	10.4	0.28	0.7	0.001	2	0.0605	1.135	0.0000605
1	5.5	Center	11.6	0.25	0.7	0.001	2	0.0605	1.014	0.0000605
1	5.5	East	18.3	0.15	0.7	0.001	2	0.0605	0.608	0.0000605
1	6	West	10.3	0.46	0.63	0.00018	2	0.0605	1.622	0.0000109
1	6	Center	10.4	0.46	0.63	0.00018	2	0.0605	1.622	0.0000109
1	6	East	12.5	0.38	0.63	0.00018	2	0.0605	1.340	0.0000109
1	6.5	Center	10	0.73	0.56	0.0024	2	0.0605	2.237	0.0001452
2	5.5	West	106.6	0.017	0.7	0.038	2	0.0605	0.069	0.0022990
2	5.5	Center	50.2	0.043	0.7	0.038	2	0.0605	0.174	0.0022990

2	5.5	East	106.6	0.017	0.7	0.038	2	0.0605	0.069	0.0022990
2	6.5	West	89.3	0.074	0.56	0.003	2	0.0605	0.227	0.0001815
2	6.5	Center	50	0.14	0.56	0.003	2	0.0605	0.429	0.0001815
2	6.5	East	89.3	0.074	0.56	0.003	2	0.0605	0.227	0.0001815
2	7.5	Center	50	0.25	0.5	0.0033	2	0.0605	0.680	0.0001997
1	5.5	West	10.4	0.28	0.7	0.001	3	0.006	2.287	0.0000060
1	5.5	Center	11.6	0.25	0.7	0.001	3	0.006	2.042	0.0000060
1	5.5	East	18.3	0.15	0.7	0.001	3	0.006	1.225	0.0000060
1	6	West	10.3	0.46	0.63	0.00018	3	0.006	3.045	0.0000011
1	6	Center	10.4	0.46	0.63	0.00018	3	0.006	3.045	0.0000011
1	6	East	12.5	0.38	0.63	0.00018	3	0.006	2.515	0.0000011
1	6.5	Center	10	0.73	0.56	0.0024	3	0.006	3.917	0.0000144
2	5.5	West	106.6	0.017	0.7	0.038	3	0.006	0.139	0.0002280
2	5.5	Center	50.2	0.043	0.7	0.038	3	0.006	0.351	0.0002280
2	5.5	East	106.6	0.017	0.7	0.038	3	0.006	0.139	0.0002280
2	6.5	West	89.3	0.074	0.56	0.003	3	0.006	0.397	0.0000180
2	6.5	Center	50	0.14	0.56	0.003	3	0.006	0.751	0.0000180
2	6.5	East	89.3	0.074	0.56	0.003	3	0.006	0.397	0.0000180
2	7.5	Center	50	0.25	0.5	0.0033	3	0.006	1.120	0.0000198

Table 3-6. Ranked Ground Motion Scenarios

flt	M	Loc	Dist (km)	med Sa (g)	std dev	eqk rate	ε	p(ε)	Sa (g)	Rate	Sum of Rate
1	6.5	Center	10	0.73	0.56	0.0024	3	0.006	3.917	0.0000144	0.0000155
1	6	West	10.3	0.46	0.63	0.00018	3	0.006	3.045	0.0000011	0.0000166
1	6	Center	10.4	0.46	0.63	0.00018	3	0.006	3.045	0.0000011	0.0000176
1	6	East	12.5	0.38	0.63	0.00018	3	0.006	2.515	0.0000011	0.0000236
1	5.5	West	10.4	0.28	0.7	0.001	3	0.006	2.287	0.0000060	0.0001688
1	6.5	Center	10	0.73	0.56	0.0024	2	0.0605	2.237	0.0001452	0.0001748
1	5.5	Center	11.6	0.25	0.7	0.001	3	0.006	2.042	0.0000060	0.0001857
1	6	West	10.3	0.46	0.63	0.00018	2	0.0605	1.622	0.0000109	0.0001966
1	6	Center	10.4	0.46	0.63	0.00018	2	0.0605	1.622	0.0000109	0.0002075
1	6	East	12.5	0.38	0.63	0.00018	2	0.0605	1.340	0.0000109	0.0007883
1	6.5	Center	10	0.73	0.56	0.0024	1	0.242	1.278	0.0005808	0.0007943
1	5.5	East	18.3	0.15	0.7	0.001	3	0.006	1.225	0.0000060	0.0008548
1	5.5	West	10.4	0.28	0.7	0.001	2	0.0605	1.135	0.0000605	0.0008746
2	7.5	Center	50	0.25	0.5	0.0033	3	0.006	1.120	0.0000198	0.0009351
1	5.5	Center	11.6	0.25	0.7	0.001	2	0.0605	1.014	0.0000605	0.0009787
1	6	West	10.3	0.46	0.63	0.00018	1	0.242	0.864	0.0000436	0.0010222
1	6	Center	10.4	0.46	0.63	0.00018	1	0.242	0.864	0.0000436	0.0010402
2	6.5	Center	50	0.14	0.56	0.003	3	0.006	0.751	0.0000180	0.0019594
1	6.5	Center	10	0.73	0.56	0.0024	0	0.383	0.730	0.0009192	0.0020030
1	6	East	12.5	0.38	0.63	0.00018	1	0.242	0.713	0.0000436	0.0022026
2	7.5	Center	50	0.25	0.5	0.0033	2	0.0605	0.680	0.0001997	0.0022631
1	5.5	East	18.3	0.15	0.7	0.001	2	0.0605	0.608	0.0000605	0.0025051
1	5.5	West	10.4	0.28	0.7	0.001	1	0.242	0.564	0.0002420	0.0027471
1	5.5	Center	11.6	0.25	0.7	0.001	1	0.242	0.503	0.0002420	0.0028161
1	6	West	10.3	0.46	0.63	0.00018	0	0.383	0.460	0.0000689	0.0028850
1	6	Center	10.4	0.46	0.63	0.00018	0	0.383	0.460	0.0000689	0.0030665
2	6.5	Center	50	0.14	0.56	0.003	2	0.0605	0.429	0.0001815	0.0036473
1	6.5	Center	10	0.73	0.56	0.0024	-1	0.242	0.417	0.0005808	0.0044459
2	7.5	Center	50	0.25	0.5	0.0033	1	0.242	0.412	0.0007986	0.0044639
2	6.5	West	89.3	0.074	0.56	0.003	3	0.006	0.397	0.0000180	0.0044819
2	6.5	East	89.3	0.074	0.56	0.003	3	0.006	0.397	0.0000180	0.0045509
1	6	East	12.5	0.38	0.63	0.00018	0	0.383	0.380	0.0000689	0.0047789
2	5.5	Center	50.2	0.043	0.7	0.038	3	0.006	0.351	0.0002280	0.0050209
1	5.5	East	18.3	0.15	0.7	0.001	1	0.242	0.302	0.0002420	0.0054039
1	5.5	West	10.4	0.28	0.7	0.001	0	0.383	0.280	0.0003830	0.0057869
1	5.5	Center	11.6	0.25	0.7	0.001	0	0.383	0.250	0.0003830	0.0070508
2	7.5	Center	50	0.25	0.5	0.0033	0	0.383	0.250	0.0012639	0.0077768
2	6.5	Center	50	0.14	0.56	0.003	1	0.242	0.245	0.0007260	0.0078203
1	6	West	10.3	0.46	0.63	0.00018	-1	0.242	0.245	0.0000436	0.0078639
1	6	Center	10.4	0.46	0.63	0.00018	-1	0.242	0.245	0.0000436	0.0080091
1	6.5	Center	10	0.73	0.56	0.0024	-2	0.0605	0.238	0.0001452	0.0081906
2	6.5	West	89.3	0.074	0.56	0.003	2	0.0605	0.227	0.0001815	0.0083721
2	6.5	East	89.3	0.074	0.56	0.003	2	0.0605	0.227	0.0001815	0.0084156
1	6	East	12.5	0.38	0.63	0.00018	-1	0.242	0.202	0.0000436	0.0107146
2	5.5	Center	50.2	0.043	0.7	0.038	2	0.0605	0.174	0.0022990	0.0115132
2	7.5	Center	50	0.25	0.5	0.0033	-1	0.242	0.152	0.0007986	0.0118962
1	5.5	East	18.3	0.15	0.7	0.001	0	0.383	0.150	0.0003830	0.0130452
2	6.5	Center	50	0.14	0.56	0.003	0	0.383	0.140	0.0011490	0.0132872
1	5.5	West	10.4	0.28	0.7	0.001	-1	0.242	0.139	0.0002420	0.0135152
2	5.5	West	106.6	0.017	0.7	0.038	3	0.006	0.139	0.0002280	0.0137432
2	5.5	East	106.6	0.017	0.7	0.038	3	0.006	0.139	0.0002280	0.0137576
1	6.5	Center	10	0.73	0.56	0.0024	-3	0.006	0.136	0.0000144	0.0137685
1	6	West	10.3	0.46	0.63	0.00018	-2	0.0605	0.130	0.0000109	0.0137794
1	6	Center	10.4	0.46	0.63	0.00018	-2	0.0605	0.130	0.0000109	0.0145054
2	6.5	West	89.3	0.074	0.56	0.003	1	0.242	0.130	0.0007260	0.0152314
2	6.5	East	89.3	0.074	0.56	0.003	1	0.242	0.130	0.0007260	0.0154734
1	5.5	Center	11.6	0.25	0.7	0.001	-1	0.242	0.124	0.0002420	0.0154843
1	6	East	12.5	0.38	0.63	0.00018	-2	0.0605	0.108	0.0000109	0.0156840
2	7.5	Center	50	0.25	0.5	0.0033	-2	0.0605	0.092	0.0001997	0.0248800
2	5.5	Center	50.2	0.043	0.7	0.038	1	0.242	0.087	0.0091960	0.0256060
2	6.5	Center	50	0.14	0.56	0.003	-1	0.242	0.080	0.0007260	0.0258480
1	5.5	East	18.3	0.15	0.7	0.001	-1	0.242	0.074	0.0002420	0.0269970
2	6.5	West	89.3	0.074	0.56	0.003	0	0.383	0.074	0.0011490	0.0281460
2	6.5	East	89.3	0.074	0.56	0.003	0	0.383	0.074	0.0011490	0.0281470
1	6	West	10.3	0.46	0.63	0.00018	-3	0.006	0.069	0.0000011	0.0281481
1	6	Center	10.4	0.46	0.63	0.00018	-3	0.006	0.069	0.0000011	0.0282086

1	5.5	West	10.4	0.28	0.7	0.001	-2	0.0605	0.069	0.0000605	0.0305076
2	5.5	West	106.6	0.017	0.7	0.038	2	0.0605	0.069	0.0022990	0.0328066
2	5.5	East	106.6	0.017	0.7	0.038	2	0.0605	0.069	0.0022990	0.0328671
1	5.5	Center	11.6	0.25	0.7	0.001	-2	0.0605	0.062	0.0000605	0.0328682
1	6	East	12.5	0.38	0.63	0.00018	-3	0.006	0.057	0.0000011	0.0328880
2	7.5	Center	50	0.25	0.5	0.0033	-3	0.006	0.056	0.0000198	0.0330695
2	6.5	Center	50	0.14	0.56	0.003	-2	0.0605	0.046	0.0001815	0.0476235
2	5.5	Center	50.2	0.043	0.7	0.038	0	0.383	0.043	0.0145540	0.0483495
2	6.5	West	89.3	0.074	0.56	0.003	-1	0.242	0.042	0.0007260	0.0490755
2	6.5	East	89.3	0.074	0.56	0.003	-1	0.242	0.042	0.0007260	0.0491360
1	5.5	East	18.3	0.15	0.7	0.001	-2	0.0605	0.037	0.0000605	0.0491420
1	5.5	West	10.4	0.28	0.7	0.001	-3	0.006	0.034	0.0000060	0.0583380
2	5.5	West	106.6	0.017	0.7	0.038	1	0.242	0.034	0.0091960	0.0675340
2	5.5	East	106.6	0.017	0.7	0.038	1	0.242	0.034	0.0091960	0.0675400
1	5.5	Center	11.6	0.25	0.7	0.001	-3	0.006	0.031	0.0000060	0.0675580
2	6.5	Center	50	0.14	0.56	0.003	-3	0.006	0.026	0.0000180	0.0677395
2	6.5	West	89.3	0.074	0.56	0.003	-2	0.0605	0.024	0.0001815	0.0679210
2	6.5	East	89.3	0.074	0.56	0.003	-2	0.0605	0.024	0.0001815	0.0771170
2	5.5	Center	50.2	0.043	0.7	0.038	-1	0.242	0.021	0.0091960	0.0771230
1	5.5	East	18.3	0.15	0.7	0.001	-3	0.006	0.018	0.0000060	0.0916770
2	5.5	West	106.6	0.017	0.7	0.038	0	0.383	0.017	0.0145540	0.1062310
2	5.5	East	106.6	0.017	0.7	0.038	0	0.383	0.017	0.0145540	0.1062490
2	6.5	West	89.3	0.074	0.56	0.003	-3	0.006	0.014	0.0000180	0.1062670
2	6.5	East	89.3	0.074	0.56	0.003	-3	0.006	0.014	0.0000180	0.1085660
2	5.5	Center	50.2	0.043	0.7	0.038	-2	0.0605	0.011	0.0022990	0.1177620
2	5.5	West	106.6	0.017	0.7	0.038	-1	0.242	0.008	0.0091960	0.1269580
2	5.5	East	106.6	0.017	0.7	0.038	-1	0.242	0.008	0.0091960	0.1271860
2	5.5	Center	50.2	0.043	0.7	0.038	-3	0.006	0.005	0.0002280	0.1294850
2	5.5	West	106.6	0.017	0.7	0.038	-2	0.0605	0.004	0.0022990	0.1317840
2	5.5	East	106.6	0.017	0.7	0.038	-2	0.0605	0.004	0.0022990	0.1320120
2	5.5	West	106.6	0.017	0.7	0.038	-3	0.006	0.002	0.0002280	0.1322400
2	5.5	East	106.6	0.017	0.7	0.038	-3	0.006	0.002	0.0002280	0.0000155

Table 3-7. Deaggregation Table

flt	Mag	Dist	epsilon	Sa	Rate	Hazard	Deagg
1	6.5	10	3	3.917	0.0000144	0.0000144	0.0065
1	6	10.3	3	3.045	0.00000108	0.00001548	0.0005
1	6	10.4	3	3.045	0.00000108	0.00001656	0.0005
1	6	12.5	3	2.515	0.00000108	0.00001764	0.0005
1	5.5	10.4	3	2.287	0.000006	0.00002364	0.0027
1	6.5	10	2	2.237	0.0001452	0.00016884	0.0659
1	5.5	11.6	3	2.042	0.000006	0.00017484	0.0027
1	6	10.3	2	1.622	0.00001089	0.00018573	0.0049
1	6	10.4	2	1.622	0.00001089	0.00019662	0.0049
1	6	12.5	2	1.340	0.00001089	0.00020751	0.0049
1	6.5	10	1	1.278	0.0005808	0.00078831	0.2637
1	5.5	18.3	3	1.225	0.000006	0.00079431	0.0027
1	5.5	10.4	2	1.135	0.0000605	0.00085481	0.0275
2	7.5	50	3	1.120	0.0000198	0.00087461	0.0090
1	5.5	11.6	2	1.014	0.0000605	0.00093511	0.0275
1	6	10.3	1	0.864	0.00004356	0.00097867	0.0198
1	6	10.4	1	0.864	0.00004356	0.00102223	0.0198
2	6.5	50	3	0.751	0.000018	0.00104023	0.0082
1	6.5	10	0	0.730	0.0009192	0.00195943	0.4173
1	6	12.5	1	0.713	0.00004356	0.00200299	0.0198
2	7.5	50	2	0.680	0.00019965	0.00220264	0.0906

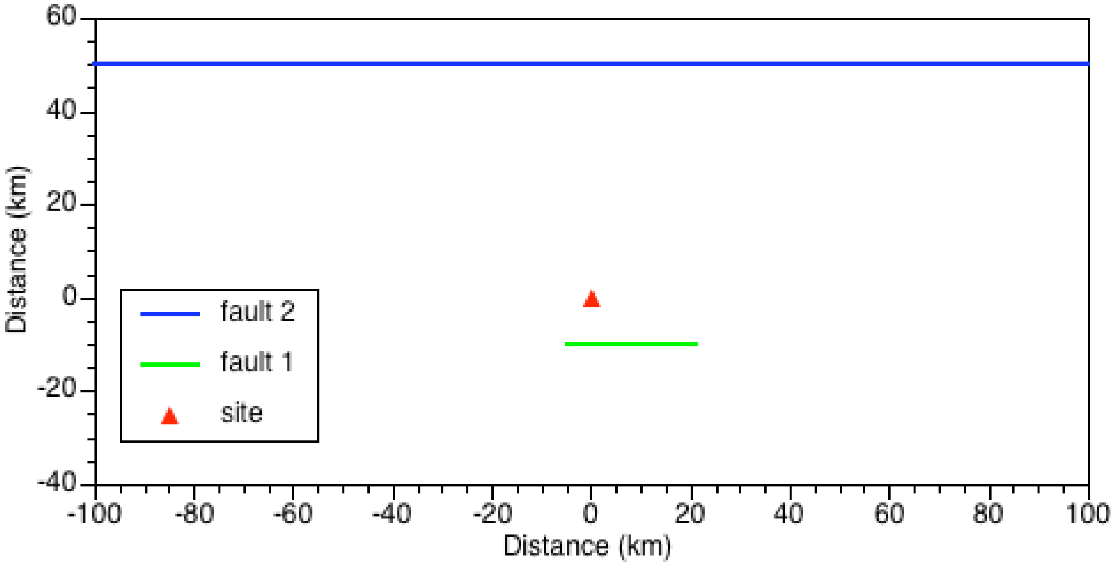

Figure 3-1. Fault source geometry used in the simplified hazard example.

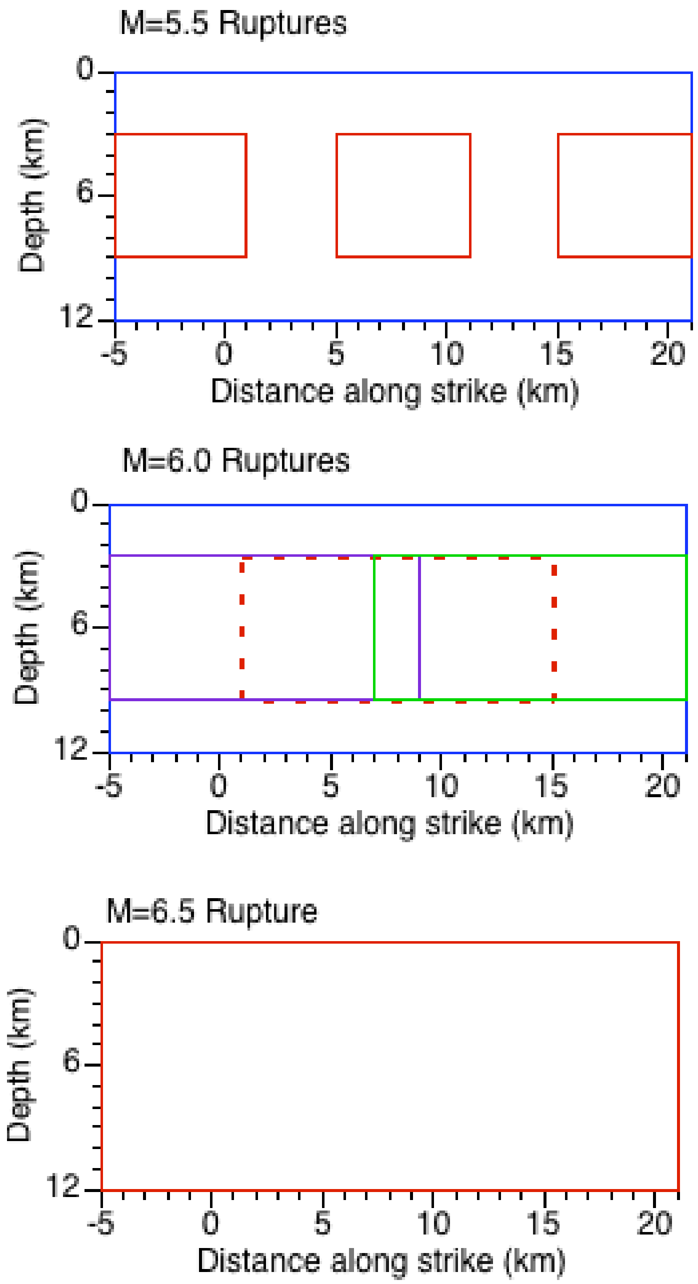

Figure 3-2a. Rupture locations for Fault1 used in the simplified hazard analysis

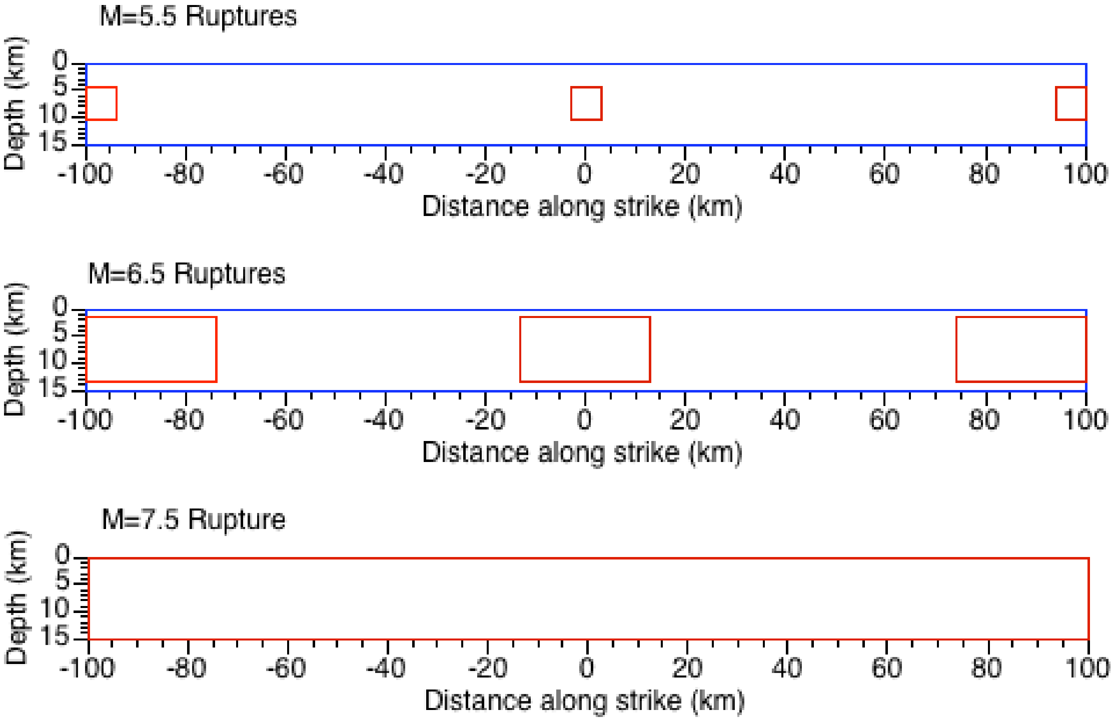

Figure 3-2b. Rupture locations for Fault 2 used in the simplified hazard example.

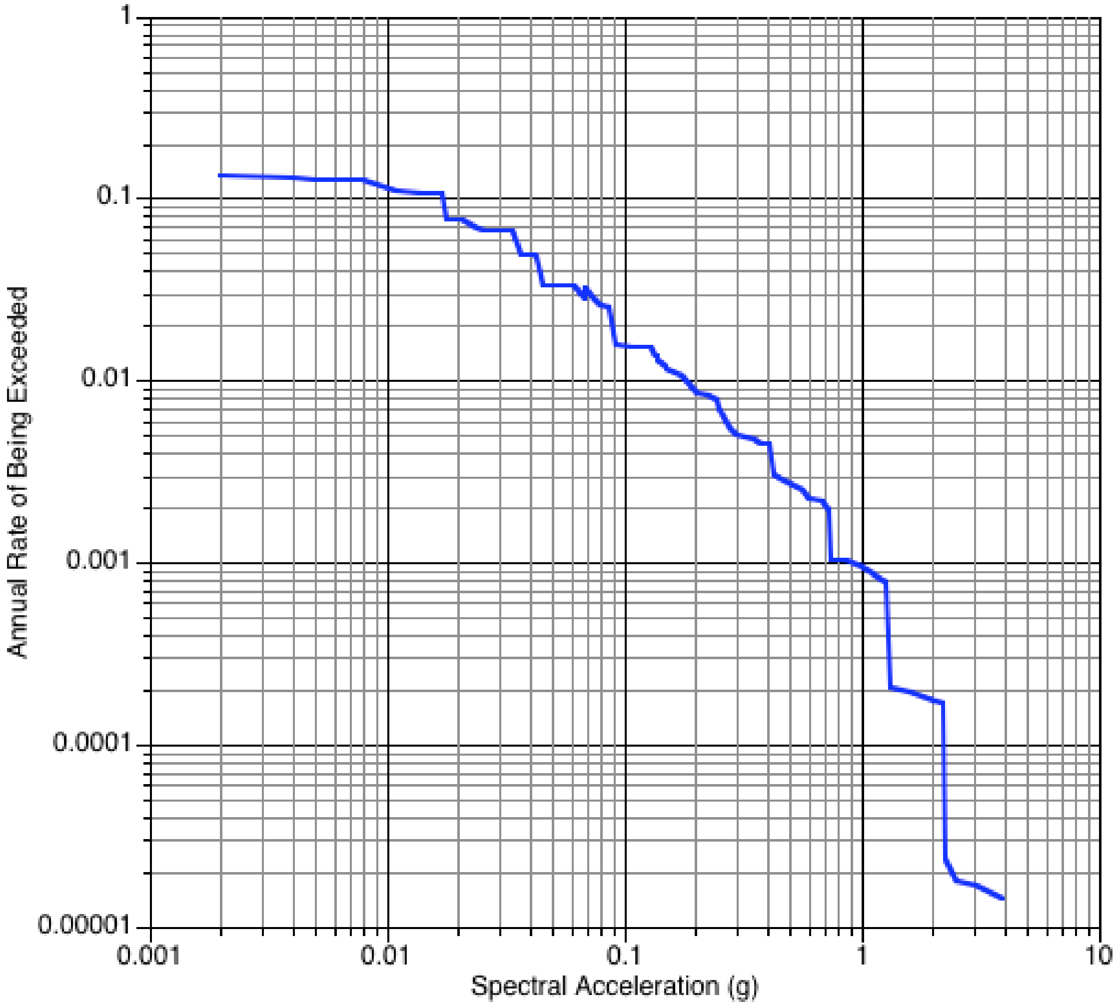

Figure 3-3. Hazard curve from the ranked scenarios in Table 3-6.