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A PRELIMINARY ASSESSMENT OF EARTHQUAKE GROUND SHAKING HAZARD AT YUCCA MOUNTAIN, NEVADA AND IMPLICATIONS TO THE LAS VEGAS REGION

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ABSTRACT

As part of early design studies for the potential Yucca Mountain nuclear waste repository, we have performed a *preliminary* probabilistic seismic hazard analysis of ground shaking. A total of 88 Quaternary faults within 100 km of the site were considered in the hazard analysis. They were characterized in terms of their probability of being seismogenic, and their geometry, maximum earthquake magnitude, recurrence model, and slip rate. Individual faults were characterized by maximum earthquakes that ranged from moment magnitude (M_w) 5.1 to 7.6. Fault slip rates ranged from a very low 0.00001 mm/yr to as much as 4 mm/yr. An areal source zone representing background earthquakes up to M_w 6¼ ± ¼ was also included in the analysis. Recurrence for these background events was based on the 1904-1994 historical record, which contains events up to M_w 5.6.

Based on this analysis, the peak horizontal rock accelerations are 0.16, 0.21, 0.28, and 0.50 g for return periods of 500, 1,000, 2,000, and 10,000 years, respectively. In general, the dominant contributor to the ground shaking hazard at Yucca Mountain are background earthquakes because of the low slip rates of the Basin and Range faults. A significant effect on the probabilistic ground motions is due to the inclusion of a new attenuation relation developed specifically for earthquakes in extensional tectonic regimes (Spudich *et al.*, 1996). This relation gives significantly lower peak accelerations than five other predominantly California-based relations used in the analysis, possibly due to the lower stress drops of extensional earthquakes compared to California events. Because Las Vegas is located within the same tectonic regime as Yucca Mountain, the seismic sources and path and site factors

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affecting the seismic hazard at Yucca Mountain also have implications to Las Vegas. These implications are discussed in this paper.

INTRODUCTION

Yucca Mountain is located about 130 km northwest of Las Vegas (Figure 1) in the southern Great Basin of the Basin and Range province. As the proposed site of the nation's first nuclear waste repository, it has been the focus of extensive geological, seismological, and geophysical investigations for more than a decade. An objective of these studies is to provide basic information and data for the evaluation of potential seismic hazards and the development of appropriate seismic design criteria for facilities at Yucca Mountain. Based on the results of these studies, a *preliminary* probabilistic seismic hazard analysis of earthquake ground shaking has been performed. A final assessment of seismic hazards for Yucca Mountain is currently ongoing involving an evaluation of seismic sources, ground motions, and fault displacement by a panel of experts.

Because of their proximity, Yucca Mountain and the city of Las Vegas share some similarities with regard to potential seismic hazards. Specifically, some of the seismic sources that could generate ground shaking at Yucca Mountain could also affect Las Vegas. Additionally, the rate at which ground motions attenuate with distance should be similar for both areas. In this paper, we describe the results of our *preliminary* probabilistic seismic hazard analysis of Yucca Mountain and discuss its implications to Las Vegas and the surrounding vicinity.

Approach

The probabilistic analysis described herein revises an earlier study performed for the Exploratory Studies Facility (ESF) (Wong *et al.*, 1996; CRWMS M&O, 1994). Available geological, geophysical, and seismological data were used to evaluate the seismic sources significant to the Yucca Mountain site, the probability of earthquakes occurring on those seismic sources, and the level of ground motions at a specified probability level. The seismic hazard model used in this assessment is similar to the original model developed by Cornell (1968) and later refined by McGuire (1974). The probabilistic methodology provides for the explicit inclusion of the range of uncertainty in interpretations of parameters for the model, including seismic source characterization and ground motion attenuation. Uncertainties in seismic sources and other input are included in the probabilistic analysis using logic trees. Discrete values of the source input parameters have been included along with an assessment of the likelihood that the discrete value represents the actual value. A more detailed description of our approach can be found in Wong *et al.* (1996).

SEISMIC SOURCE CHARACTERIZATION

Two types of seismic sources were characterized in this analysis: Quaternary faults and an areal source representing "background" earthquakes not associated with the faults specifically modeled in this study.

Quaternary Faults

Available geologic data show that 88 faults having known or suspected Quaternary (≤ 2 Ma) activity are located within about 100 km of Yucca Mountain (Pezzopane, 1996; Keefer and Pezzopane, 1996) (Table 1; Figure 1). Within about 15 km of the site, 19 "local" faults have been identified of which 10 exhibit definitive evidence for Quaternary activity. Some of the faults may be structurally related, such that they may rupture together in a future event. In these cases, we have evaluated their structural settings and assigned weights to characterize this capability (see following section).

In general, the seismic source characterization of the local Yucca Mountain faults was the result of detailed paleoseismic investigations (Whitney *et al.*, 1996). Parameters for most of the regional faults (beyond a distance of 15 km) are from map compilations, literature reviews, and reconnaissance investigations (Piety, 1995; Anderson *et al.*, 1995a; 1995b) (Table 1).

Seismogenic Capability

In this analysis, all known faults having documented or suspected geologic evidence of Quaternary displacement were considered as potential seismic sources. For the most part, the association of seismicity has not been a definitive criteria to classify faults as being seismogenic, typical of the Basin and Range province. The numbers, sizes, and activity rates of fault populations in the Yucca Mountain region span many orders of magnitude, and in order to evaluate the range of possible seismic sources in the region, we have characterized the seismogenic capability for each fault. In this study, we have assessed seismogenic capability based on two factors: 1) whether the fault is considered an independent seismogenic source, one that is responsible for the principal seismic energy release; and 2) whether the fault is active or has been recently active, as evidenced by having a spatial association with historical seismicity, fault offsets or a sharp geomorphic expression in young surficial Quaternary deposits, or direct structural relation and kinematic connection with another active Quaternary fault. These two factors, as explained below, were assessed for each fault using a weighting scheme wherein the product of the weights is the value in Table 1.

The structural setting and mapped length were the primary basis to weight each fault as to whether it could form an independent, co-dependent, or co-independent rupture. Independent seismogenic sources are characterized by mapped traces longer than 15 km and cumulative

throws of hundreds of meters or more in Tertiary or younger deposits. These faults probably penetrate to seismogenic depths of 5 to 15 km. Independent seismic sources are commonly range-bounding or block-bounding faults that show repeated displacements in late Quaternary time. Co-dependent faults have continuous mapped lengths less than 5 km; sporadic, if any, evidence of Quaternary activity, and traces that usually merge with, and/or strike parallel to, and are in the immediate vicinity of a much longer (> 15 km) independent fault. Co-dependent faults probably move in structural association with and only when the nearby independent fault ruptures. Co-independent faults are characterized by mapped lengths ranging from 5 to 15 km and traces that usually merge with or form a smaller geometric fault segment of a much longer (independent) fault. Co-independent faults are thought to occasionally rupture simultaneously with the independent fault, and sometimes rupture randomly on their own.

According to this subjective structural evaluation, independent and likely co-independent faults were assigned weights ranging from 0.5 to 1.0 (Table 1). Co-dependent faults were assigned lower weights ranging from 0.1 to 0.5 because they are not likely to be principal sources of earthquakes. The weighting factor of independent versus co-dependent seismic sources accounts for possible fault segmentation models and thus, the relative likelihood that the fault source could produce an earthquake independently. The main advantage of this scheme is to allow the possibility that short (< 10 km) faults within 10 km of Yucca Mountain could be independent earthquake sources.

The second factor considered in the evaluation of seismogenic capability is whether the fault has been active. For some of the local and many of the regional faults, evaluation of Quaternary movement is more uncertain because they have not been mapped in detail or trenched. Many of the regional faults were recognized from interpretations of aerial photography, and only some have been examined in the field. Even given detailed studies of suspected Quaternary faults, commonly it is difficult to demonstrate that an apparently inactive fault has not moved during Quaternary time because complete stratigraphic sections including older Quaternary deposits are not preserved over the fault traces. Consequently, this study considers three alternatives to describe the state of evidence for Quaternary fault activity.

Faults having documented Quaternary displacement are assigned a probability of activity of 1.0 (Table 1). Faults for which there is evidence to suspect but not conclusively demonstrate Quaternary displacement are assigned probabilities of activity ranging from 0.1 to 0.9 based on an evaluation of the available geological evidence of young activity. These faults have relatively youthful geomorphic expressions as seen on aerial photography and appear to offset middle to late Quaternary deposits. However, the faults or photolineaments have commonly not been investigated in the field, which leads to equivocal interpretations of their activity. Faults that lack youthful-looking displacements or a sharp geomorphic signature, but for which an absence of Quaternary movement cannot be proved are assigned probabilities of activities less than 0.5 on the basis of the geological evidence of activity.

Fault Geometry and Sense of Slip

The mapped locations of local Yucca Mountain faults were generally adopted from Simonds *et al.* (1995), and regional fault locations were modified from Piety (1995). Although some of the faults show slight curvature in map view at the surface, the hazard calculations modeled all faults as single planes along-strike and downdip. The downdip geometry of almost all of the faults is uncertain; hence a range of dips was used in this analysis. In all cases, three values of dip were chosen on the basis of the dominant sense of slip of the fault as seen from surface offsets and inferred from its tectonic setting. Predominantly normal-slip faults were assigned dips of 45°, 60°, and 75°, and weighted 0.3, 0.4, and 0.3, respectively (Table 1). Most strike-slip faults were assigned dips of 70°, 80°, and 90°; whereas some strike-slip and most normal-oblique slip faults were assigned dips of 60°, 75°, and 90°, all weighted 0.3, 0.4, and 0.3, respectively. The range of dip values also accounts for possible differences in the style of slip insofar as the style of faulting is reflected in different downdip geometries. Except for seismic sources located within a few tens of km from the Yucca Mountain site, dip uncertainties contribute to variations in maximum magnitude values, which indirectly affect the ground motion values.

Maximum Magnitudes

Maximum magnitude was derived from an empirical relation between surface rupture length and M_w determined by Wells and Coppersmith (1994) for all-slip events. The upper and lower maximum magnitude values in Table 1 account for the standard deviation of the empirical relation, taken here as ± 0.3 moment magnitude unit from the preferred value.

In determining maximum magnitudes for this analysis, we use the entire mapped length for each fault. This is a conservative choice because Quaternary displacement rarely is documented along the entire fault length and faults rarely rupture along their entire length. Thus, the maximum magnitudes determined for this analysis are likely conservative. For example, if a fault can rupture at most one-half of its length in an individual earthquake, the calculated maximum magnitudes may be about 0.4 magnitude units too high. While inclusion of conservatism is not normally appropriate in a probabilistic seismic hazard analysis, the preliminary nature of the study and our desire to simplify the calculations motivate this choice.

The numerous local Yucca Mountain faults permit many different interpretations of their maximum rupture lengths and how they may connect and behave seismogenically (see "Seismogenic Capability"). Thus although maximum fault lengths of some of the shorter (≤ 5 km) intrablock faults are proportional to M_w 5.5 to 6.0 events (Table 1), it seems unlikely that they continue to seismogenic depths and act as independent seismogenic structures,

given their relatively short lengths, close spacings, and possible terminations against the more prominent Quaternary faults.

Earthquake Recurrence and Fault Slip Rates

Earthquake recurrence for the faults is assessed using both the truncated exponential (Gutenberg-Richter) and characteristic earthquake models. The seismic moment approach of Molnar (1979) and Anderson (1979) is employed with fault slip rates as a proxy for seismic moment rate to arrive at the recurrence for the truncated exponential model. We used the numerical model of Youngs and Coppersmith (1985) for the characteristic model.

In cases for which paleoseismic investigations indicate the characteristic recurrence model is more appropriate than the exponential model, we weight the characteristic model either 0.6 or 0.7 (Table 1). For many faults, however, no paleoseismic data are available. In these cases, the two recurrence models are assumed to be equally valid (weighted 0.5 each; Table 1).

Three values of fault slip rate were characterized for each fault (Table 1) on the basis of available geologic and paleoseismic studies: a preferred rate and an upper- and lower-bound. The central slip rate was assigned a weight of 0.6, whereas the bounding values were weighted 0.2 each. Yucca Mountain faults have been trenched at numerous sites, and the number, size, and age of displacement for events have been determined for all of the longer (> 5 km) recognized Quaternary faults in the site vicinity. In addition, paleoseismic studies have also been performed for two more distant seismic sources, the Bare Mountain and Rock Valley faults. The results of many different absolute and relative dating techniques, including hundreds of uranium-series, thermoluminescence, ash lithology "fingerprinting", and many other geochronologic analyses, have helped to assess the age of paleoearthquakes and fault slip rates. The most up-to-date and complete summary of the paleoseismic study results for all Quaternary faults in the site vicinity is contained in Whitney *et al.* (1996). Most of the known Quaternary faults in the Yucca Mountain vicinity have slip rates on the order of 0.001 to 0.01 mm/yr, whereas regional faults have rates ranging from a presumed low of 0.00001 mm/yr to as much as a well-determined 4 mm/yr.

The level of study of known and suspected Quaternary faults at distances greater than about 25 km from Yucca Mountain decreases with increasing distance from Yucca Mountain, except for several of the longer and potentially more significant faults, including the Death Valley and Furnace Creek faults (within 55 km of Yucca Mountain) and the Rock Valley-Mine Mountain-Cane Springs fault system. Reconnaissance studies of several of these regional faults, as well as available data from previous studies are described in Anderson *et al.* (1995a), Anderson *et al.* (1995b), and Piety (1995). Slip rate information for these faults and other regional faults are described in Whitney *et al.* (1996).

Faults for which no slip rate information is available, either because the fault may not be active or there have been no field studies, were assigned slip rates on the basis of interpretations of aerial photographs and geomorphic comparisons to other faults for which some slip rate data exist. In many cases, the uncertainty in slip rate ranges over two orders of magnitudes. Included in this category are some of the local faults that do not show evidence of Quaternary displacement but may have a small probability of seismogenic capability (e.g., Ghost Dance and Sundance faults), as well as some that are buried (e.g., Midway Valley, Drill Hole Wash faults) and some that may not even be faults (e.g., Yucca Wash fault?). Many more regional faults appear on air photos to have scarps in Quaternary deposits, but they simply lack detailed studies and, hence, slip rate data. In many cases, the overall minimum to maximum slip rate values range between two orders of magnitude (Table 1). As will be discussed below, only a few of these regional faults contribute to the probabilistic hazard at Yucca Mountain at return periods less than 100,000 years.

Background Earthquakes

To account for the hazard from background earthquakes that are not associated with the known mapped faults already considered in the study, an areal source encompassing the region within 100 km of Yucca Mountain was incorporated into the hazard analysis (Figure 2). This background source also includes the seismicity that may be associated with shorter (<10 km long) known regional faults that have not been specifically included in the probabilistic analysis because of their small contribution to hazard (due to their greater distance and smaller maximum magnitude).

In characterizing the background source, the 100-km radius area around Yucca Mountain was considered to be, to first order, uniform in terms of its tectonic, geologic, and seismologic characteristics. A uniform distribution of events in the depth range of 0 to 15 km was also assumed. This depth distribution is consistent with observations from the Southern Great Basin seismographic network (Rogers *et al.*, 1991).

Historical Seismicity

A historical catalogue of 10,113 earthquakes within 100 km of the site and covering the time period from 1904, the date of the first reported event, through January 1994 was used (Figure 2) to characterize the earthquake recurrence for the background seismic source. The largest known earthquake in this region was the 1910 surface wave magnitude (M_s) 5.7 Goldfield event.

All known or suspected mining blasts and underground NTS nuclear explosions, cavity collapses, and induced aftershocks were removed from the catalogue. The latter were identified by assuming that all events that occurred within 12 months and within a radius of 6 km of a

nuclear explosion were induced. The distance criteria was based on the observations of Rogers *et al.* (1977). Removal of the NTS-induced aftershocks resulted in a catalogue of 3,358 earthquakes.

Maximum Magnitude

In the Basin and Range province and most regions of the western U.S., the threshold for surface faulting, and hence the upper limit for the background earthquake without surface rupture, usually ranges between Richter magnitude (M_L) 6 to 6½ (Doser, 1985; Arabasz *et al.*, 1992; dePolo, 1994; Pezzopane and Dawson, 1996). Earthquakes larger than these magnitudes are usually accompanied by surface rupture and thus repeated events of this size will produce recognizable fault or fold-related features at the earth's surface. On the basis of these observations, a maximum magnitude of M_w 6¼ ±¼ has been adopted for the background source.

The maximum magnitude range for a background source overlaps with the range of magnitudes determined for some faults on the basis of paleoseismic investigations and earthquake rupture scenarios at Yucca Mountain (Whitney *et al.*, 1996; Pezzopane *et al.*, 1996). Thus, in the Yucca Mountain vicinity, the maximum magnitude selected for the background zone may be too high. This is also suggested by results from an empirical and theoretical approach to estimating the maximum magnitude specifically for the Yucca Mountain setting (Pezzopane and Dawson, 1996). This study suggests the value for the background zone is M_w 6.1 ± 0.1. The broader range, nevertheless, is used in this analysis to encompass a greater range of uncertainty and to account for possible hidden seismic sources, mainly east and south of Yucca Mountain.

Earthquake Recurrence

The portion of the historical seismicity catalogue that can be used to evaluate background earthquake recurrence rates depends on the completeness of the catalogue for different magnitude ranges. In this analysis, the catalogue completeness was generally adopted from the analysis by Rogers *et al.* (1991). The completeness intervals represent the period of time for which earthquakes within that magnitude (M_L) range are completely reported in the catalogue. This information is used in the evaluation of recurrence relation parameters following the maximum-likelihood procedure developed by Weichert (1980).

For the catalogue used in this study, the vast majority of earthquakes have assigned M_L or equivalent M_L values. We have assumed that M_L is equivalent to M_w in the range M_w 2.5 to 5.6 which covers the range of events used in the recurrence calculations. (The 1910 Goldfield earthquake was not included due to completeness intervals). M_w is used for the completeness assessment and in the recurrence calculations.

The recurrence relation is given in the form of a truncated exponential distribution for the occurrence of independent earthquakes (Figure 3). Dependent events, either foreshocks, aftershocks, or smaller events within an earthquake swarm (the largest swarm event is assumed to be a mainshock) were identified using empirical criteria for the size in time and space of mainshock-foreshock-aftershock sequences in a procedure adopted from Youngs *et al.* (1992). If an event was identified as dependent by two of three criteria, it was not used in the assessment of recurrence parameters.

Adjusting the catalogue database for dependent events and incompleteness, 329 earthquakes remained in the range M_w 2.5 to 5.6 from which to assess recurrence for the background areal source (Figure 3). The number of earthquakes in the areal source was normalized on an annual basis and per km^2. Events were placed into 0.5 magnitude unit bins and the regression was performed on the resulting data points as described in Weichert (1980).

Assuming the usual form of the Gutenberg-Richter relationship ($\log N = a\text{-}bM$), the calculated b-value was 0.87 ± 0.04 and the a-value -1.08 ± 0.03 (Figure 3). For the probabilistic analysis, a- and b-values are treated as dependent on each other. Uncertainty in the a-value is taken from the calculated standard deviation; for the b-value, the uncertainty is estimated to be ± 0.1 which is larger than the calculated standard deviation. This accounts for model uncertainties related to the ability of the exponential relationship to describe future earthquake occurrence.

An important assumption in basing the recurrence of background seismicity on the historical earthquake record is that the events within the record are not associated with any of the faults considered as seismic sources in the analyses. Within the uncertainties of the epicentral locations shown in Figure 1, this assumption appears to be generally valid. Possible exceptions are the 1992 Little Skull Mountain M_w 5.6 earthquake and its aftershocks which may have occurred on the Mine Mountain fault (Meremonte *et al.*, 1995) and a sequence of shallow earthquakes along the Rock Valley fault zone in 1993 (Shields *et al.*, 1996). For this analysis, we assume they are not.

GROUND MOTION ATTENUATION

Six empirically-based relationships describing the attenuation of peak horizontal acceleration and spectral acceleration at a period of 1.0 sec were used to evaluate the attenuation of ground motions in the Yucca Mountain region: Abrahamson and Silva (1997); Sadigh *et al.* (1993); Boore *et al.* (1993) (Class B); Campbell and Bozorgnia (1994) (Campbell [1993] for spectral accelerations); Idriss (1991; 1994); and Spudich *et al.* (1996). These relationships are appropriate for rock sites. With the exception of the last relationship, they are based primarily on strong motion recordings of California earthquakes. The Spudich *et al.* (1996) relationship

has been developed specifically for earthquakes occurring in extensional tectonic regimes like the Basin and Range province.

A comparison between the various attenuation relationships shows that, for distances of 50 km or less, the Spudich *et al.* (1996) relationship gives significantly lower peak horizontal accelerations than any of the others with the exception of the Boore *et al.* (1993) relation which gives similar values. Some previous seismic hazard studies (e.g., Wong *et al.*, 1991) have also assumed that ground motions generated by Basin and Range province earthquakes are lower than those from California events due to their lower stress drops (Stark *et al.*, 1992; Becker and Abrahamson, 1997). The Spudich *et al.* (1996) relationship was weighted 0.50 in the probabilistic analysis because of its more region-specific relevance, and the remaining five relationships were weighted 0.10 each. Data uncertainty of up to three standard deviations for the attenuation relationship was included in the analysis.

HAZARD RESULTS FOR GROUND MOTIONS

The results of the analysis are presented in terms of the annual number of events for which peak acceleration exceeds a given value. The annual number of exceedances is the reciprocal of the average return time. Figure 4 presents the computed mean hazard along with the 10th, 16th, 50th (median), 84th, and 90th percentile hazard curves for peak horizontal acceleration and 1.0 sec spectral acceleration. The peak horizontal accelerations at return periods of 500, 1,000, 2,000 and 10,000 years are 0.16, 0.21, 0.28, and 0.50 g, respectively.

To gain a better understanding of the hazard results, including the contribution and sensitivity of various inputs, the effects of various interpretations on the results are examined. The marginal contributions of the seismic sources to the total hazard for peak horizontal acceleration and 1.0 sec spectral acceleration is presented in Figure 5. For exceedance probabilities less than about 10^{-2} (return periods greater than 100 years), the peak acceleration hazard at the site is overwhelmingly dominated by background earthquakes. Given the long recurrence intervals of most faults in the Basin and Range province (a few thousand to more than 100,000 years), the background source zone, within which the site of interest is located, is often the dominant contributor to hazard at return periods less than about 10,000 years (Wong *et al.*, 1995).

In terms of the small contribution of faults to the peak acceleration hazard, distant faults capable of large earthquakes and with relatively high recurrence rates are the more significant seismic sources for probabilities greater than about 10^{-2} (return periods less than about 100 years). Seismic sources in this category are the Furnace Creek and Death Valley faults (Figure 5). At lower probabilities (return periods greater than 1,000 years), the Paintbrush Canyon fault is the most significant fault due to its comparatively high slip rate (0.01 mm/yr) among the local faults (Figure 5). Its contribution to the total hazard is, however, less than 5%. For long-period

ground motions (e.g., 1.0 sec spectral acceleration), the Furnace Creek and Death Valley faults are almost as significant as the background earthquakes (Figure 5).

In addition to looking at the marginal contribution of each seismic source to the total hazard results, the contribution from different magnitude and distance ranges can also be examined, independent of seismic source. The contributions to the total peak horizontal acceleration and 1.0 sec spectral acceleration hazard for different magnitude and distance ranges, and for return periods of 2000 and 10,000 years is shown in Figure 6. At 2,000 years, the peak acceleration hazard is dominated by background earthquakes of M_w 5 to 6½ at short distances (< 10 km) with a small contribution from the distant active faults. At a 10,000-year return period, the contribution of the Paintbrush Canyon fault becomes more significant and the dominant magnitude range shifts to slightly higher values (Figure 6). For the 1.0 sec spectral acceleration, background earthquakes continue to dominate, but the Furnace Creek and Death Valley faults also contribute significantly, particularly at return periods less than about 5,000 years (Figure 6).

Comparison of the peak acceleration hazard computed using each of the six attenuation relationships individually indicates that four of the five western U.S. empirical relationships give nearly the same peak acceleration hazard results (Figure 7). The fifth relationship, that of Boore *et al.* (1993), gives lower peak accelerations. Most significantly, as discussed earlier, the Spudich *et al.* (1996) relationship which was weighted 0.5, gives the lowest peak values, significantly lower than the five western U.S. relationships.

IMPLICATIONS TO THE LAS VEGAS REGION

The locations of both Yucca Mountain and Las Vegas in the southern Great Basin portion of the Basin and Range province suggest that the potential sources and level of seismic hazards might be similar. Within 100 km of both locations are numerous Quaternary faults characterized by maximum earthquakes of M_w 6½ to 7½ and slip rates of 0.00001 to 4 mm/yr. At Yucca Mountain, the relatively short local faults pose a low probabilistic ground shaking hazard because of their very low slip rates (less than 0.01 mm/yr). Although fewer in number, the local faults within the Las Vegas area such as the Eglington and Frenchman Mountain faults may pose a relatively greater hazard to this locale because of their higher slip rates (up to 0.1 mm/yr or more; Slemmons, 1996). Longer, more active but more distant faults (M_{max} 7 to 7½ and 1 to 4 mm/yr), such as Pahrump Valley and Death Valley faults, will contribute to the long-period seismic hazard at both locations.

Background earthquakes will contribute significantly to the hazard at both locations particularly at short return periods. The level of background seismicity in the Las Vegas area, however, appears to be lower than at Yucca Mountain (although this may not be real given the short and

incomplete historical record) and thus the contribution to hazard may be lower in Las Vegas from this source.

Given that both sites are in the southern Great Basin, the attenuation of seismic waves will probably be similar. In contrast, other path and site factors that may increase ground shaking will be more significant in Las Vegas than Yucca Mountain. Specifically, because Las Vegas is located within an alluvial valley, basin effects and the presence of low-velocity unconsolidated sediments will likely amplify ground shaking at both high and low frequencies. In summary, the probabilistic ground motions at Yucca Mountain may be comparable to Las Vegas on rock sites at return periods less than 10,000 years. However, because the latter will be subjected to enhanced ground shaking due to the above effects, the level of seismic hazard is likely greater in the Las Vegas area than at Yucca Mountain.

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TABLE 1

KNOWN AND SUSPECTED QUATERNARY FAULTS IN THE YUCCA MOUNTAIN REGION MODELED IN THE SEISMIC HAZARD ANALYSIS

Fault	Closest Distance (km)	Capability	Length (km)	Dip (degrees)		Maximum Magnitude (M_w)		Recurrence Model		Fault Slip Rate mm/yr	
Ghost Dance (GD)	0	0.1	3	45	(0.3)	5.3	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	5.6	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	5.9	(0.2)			0.001	(0.2)
Sundance (SD)	0	0.1	1	60	(0.3)	4.8	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				75	(0.4)	5.1	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				90	(0.3)	5.4	(0.2)			0.001	(0.2)
Solitario Canyon (SC)	1	1	20	45	(0.3)	6.3	(0.2)	Exponential	(0.3)	0.005	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.7)	0.01	(0.6)
				75	(0.3)	6.9	(0.2)			0.03	(0.2)
Drill Hole Wash (DHW)	1.5	0.1	4	60	(0.3)	5.6	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				75	(0.4)	5.9	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				90	(0.3)	6.2	(0.2)			0.001	(0.2)
Dune Wash (DW)	2	0.1	3	60	(0.3)	5.3	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				75	(0.4)	5.6	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				90	(0.3)	5.9	(0.2)			0.001	(0.2)
Bow Ridge (BR)	2.5	0.5	10	45	(0.3)	5.9	(0.2)	Exponential	(0.4)	0.0005	(0.2)
				60	(0.4)	6.2	(0.6)	Characteristic	(0.6)	0.003	(0.6)
				75	(0.3)	6.5	(0.2)			0.005	(0.2)
Pagany Wash (PW)	2.5	0.1	4	60	(0.3)	5.6	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				75	(0.4)	5.9	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				90	(0.3)	6.2	(0.2)			0.001	(0.2)
Iron Ridge (IR)	2.5	0.5	9	45	(0.3)	5.9	(0.2)	Exponential	(0.5)	0.0005	(0.2)
				60	(0.4)	6.2	(0.6)	Characteristic	(0.5)	0.003	(0.6)
				75	(0.3)	6.5	(0.2)			0.01	(0.2)
Boomerang Point (BP)	2.5	0.1	5	45	(0.3)	5.6	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	5.9	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	6.2	(0.2)			0.001	(0.2)
Midway Valley (MV)	3	0.1	8	45	(0.3)	5.8	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	6.1	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	6.4	(0.2)			0.001	(0.2)
Sever Wash (SW)	3	0.1	4	60	(0.3)	5.6	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				75	(0.4)	5.9	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				90	(0.3)	6.2	(0.2)			0.001	(0.2)
Fatigue Wash (FW)	3.5	0.5	17	45	(0.3)	6.2	(0.2)	Exponential	(0.4)	0.0005	(0.2)
				60	(0.4)	6.5	(0.6)	Characteristic	(0.6)	0.002	(0.6)
				75	(0.3)	6.8	(0.2)			0.01	(0.2)

TABLE 1

KNOWN AND SUSPECTED QUATERNARY FAULTS IN THE YUCCA MOUNTAIN REGION MODELED IN THE SEISMIC HAZARD ANALYSIS

Fault	Closest Distance (km)	Capability	Length (km)	Dip (degrees)		Maximum Magnitude (M_w)		Recurrence Model		Fault Slip Rate mm/yr	
Paintbrush Canyon (PC)	4	1	24	45	(0.3)	6.4	(0.2)	Exponential	(0.3)	0.002	(0.2)
				60	(0.4)	6.7	(0.6)	Characteristic	(0.7)	0.01	(0.6)
				75	(0.3)	7.0	(0.2)			0.04	(0.2)
Windy Wash (WW)	4.5	1	25	45	(0.3)	6.4	(0.2)	Exponential	(0.3)	0.001	(0.2)
				60	(0.4)	6.7	(0.6)	Characteristic	(0.7)	0.01	(0.6)
				75	(0.3)	7.0	(0.2)			0.03	(0.2)
Yucca Wash (YW)	5	0.1	9	60	(0.3)	5.9	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				75	(0.4)	6.2	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				90	(0.3)	6.5	(0.2)			0.001	(0.2)
Crater Flat (CRF)	6	0.7	18	45	(0.3)	6.2	(0.2)	Exponential	(0.5)	0.0005	(0.2)
				60	(0.4)	6.5	(0.6)	Characteristic	(0.5)	0.002	(0.6)
				75	(0.3)	6.8	(0.2)			0.01	(0.2)
Black Cone (BLK)	8.5	1	7	45	(0.3)	5.8	(0.2)	Exponential	(0.5)	0.0005	(0.2)
				60	(0.4)	6.1	(0.6)	Characteristic	(0.5)	0.002	(0.6)
				75	(0.3)	6.4	(0.2)			0.01	(0.2)
Stagecoach Road (SCR)	10	0.7	9	45	(0.3)	5.9	(0.2)	Exponential	(0.4)	0.005	(0.2)
				60	(0.4)	6.2	(0.6)	Characteristic	(0.6)	0.02	(0.6)
				75	(0.3)	6.5	(0.2)			0.05	(0.2)
Bare Mountain (BM)	14	1	16	45	(0.3)	6.2	(0.2)	Exponential	(0.3)	0.005	(0.2)
				60	(0.4)	6.5	(0.6)	Characteristic	(0.7)	0.01	(0.6)
				75	(0.3)	6.8	(0.2)			0.05	(0.2)
Mine Mountain (MM)	19	0.5	27	70	(0.3)	6.4	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				80	(0.4)	6.7	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				90	(0.3)	7.0	(0.2)			0.01	(0.2)
Rocket Wash-Beatty Wash (RWBW)	19	0.3	17	45	(0.3)	6.2	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	6.5	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	6.8	(0.2)			0.001	(0.2)
Wahmonie (WAH)	22	0.5	15	70	(0.3)	6.1	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				80	(0.4)	6.4	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				90	(0.3)	6.7	(0.2)			0.01	(0.2)
Oasis Valley (OSV)	24	0.4	20	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.003	(0.6)
				75	(0.3)	6.9	(0.2)			0.01	(0.2)
Rock Valley (RV)	27	1	65	70	(0.3)	6.9	(0.2)	Exponential	(0.4)	0.001	(0.2)
				80	(0.4)	7.2	(0.6)	Characteristic	(0.6)	0.01	(0.6)

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Fault	Closest Distance (km)	Capability	Length (km)	Dip (degrees)		Maximum Magnitude (M_w)		Recurrence Model		Fault Slip Rate mm/yr	
				90	(0.3)	7.5	(0.2)			0.1	(0.2)
Cane Spring (CS)	29	0.3	27	70	(0.3)	6.4	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				80	(0.4)	6.7	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				90	(0.3)	7.0	(0.2)			0.001	(0.2)
West Specter Range (WSR)	33	1	9	45	(0.3)	5.9	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.2	(0.6)	Characteristic	(0.5)	0.004	(0.6)
				75	(0.3)	6.5	(0.2)			0.01	(0.2)
Ash Meadows (AM)	34	1	60	45	(0.3)	6.8	(0.2)	Exponential	(0.4)	0.001	(0.2)
				60	(0.4)	7.1	(0.6)	Characteristic	(0.6)	0.04	(0.6)
				75	(0.3)	7.4	(0.2)			0.1	(0.2)
Yucca Lake (YCL)	36	0.6	17	45	(0.3)	6.2	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.5	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.8	(0.2)			0.01	(0.2)
Eleana Range (ER)	37	1	13	45	(0.3)	6.1	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	6.4	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	6.7	(0.2)			0.1	(0.2)
Amargosa River (AR)	38	1	15	60	(0.3)	6.1	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				75	(0.4)	6.4	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				90	(0.3)	6.7	(0.2)			0.01	(0.2)
Bullfrog Hills (BUL)	38	0.6	7	45	(0.3)	5.8	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.1	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.4	(0.2)			0.01	(0.2)
Yucca (YC)	40	1	32	45	(0.3)	6.5	(0.2)	Exponential	(0.4)	0.00005	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.6)	0.005	(0.6)
				75	(0.3)	7.1	(0.2)			0.05	(0.2)
Tolicha Peak (TOL)	42	0.6	22	60	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				75	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				90	(0.3)	6.9	(0.2)			0.01	(0.2)
Carpetbag (CB)	43	0.8	30	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.1	(0.2)			0.01	(0.2)
Keane Wonder (KW)	43	0.5	25	45	(0.3)	6.4	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.7	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.0	(0.2)			0.01	(0.2)
Area Three (AT)	44	0.6	12	45	(0.3)	6.0	(0.2)	Exponential	(0.5)	0.0001	(0.2)

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Fault	Closest Distance (km)	Capability	Length (km)	Dip (degrees)		Maximum Magnitude (M_w)		Recurrence Model		Fault Slip Rate mm/yr	
				60	(0.4)	6.3	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.6	(0.2)			0.01	(0.2)
Checkpoint Pass (CP)	44	0.3	7	45	(0.3)	5.8	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	6.1	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	6.4	(0.2)			0.001	(0.2)
Plutonium Valley-North Halfpint Ridge (PVNH)	46	0.3	26	45	(0.3)	6.4	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	6.7	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	7.0	(0.2)			0.001	(0.2)
Crossgrain Valley (CGV)	48	0.6	9	45	(0.3)	5.9	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.2	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.5	(0.2)			0.01	(0.2)
Pahute Mesa (PM)	48	0.6	9	45	(0.3)	5.9	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.2	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.5	(0.2)			0.01	(0.2)
Mercury Ridge (MER)	48	0.3	10	45	(0.3)	5.9	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	6.2	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	6.5	(0.2)			0.001	(0.2)
Ranger Mountain	49	0.6	5	45	(0.3)	5.6	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	5.9	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.2	(0.2)			0.01	(0.2)
Furnace Creek (FC)	50	1	145	70	(0.3)	7.3	(0.2)	Exponential	(0.3)	0.2	(0.2)
				80	(0.4)	7.6	(0.6)	Characteristic	(0.7)	4.0	(0.6)
				90	(0.3)	7.9	(0.2)			12.0	(0.2)
South Ridge (SOU)	50	0.6	19	70	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				80	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				90	(0.3)	6.9	(0.2)			0.01	(0.2)
Boundary	51	1	7	45	(0.3)	5.8	(0.2)	Exponential	(0.5)	0.0005	(0.2)
				60	(0.4)	6.1	(0.6)	Characteristic	(0.5)	0.005	(0.6)
				75	(0.3)	6.4	(0.2)			0.05	(0.2)
Sarcobatus Flat (SF)	52	0.6	51	45	(0.3)	6.8	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	7.1	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.4	(0.2)			0.01	(0.2)
West Springs Mountain (WSM)	53	1	60	45	(0.3)	6.8	(0.2)	Exponential	(0.3)	0.001	(0.2)
				60	(0.4)	7.1	(0.6)	Characteristic	(0.7)	0.05	(0.6)
				75	(0.3)	7.4	(0.2)			0.1	(0.2)

TABLE 1

KNOWN AND SUSPECTED QUATERNARY FAULTS IN THE YUCCA MOUNTAIN REGION MODELED IN THE SEISMIC HAZARD ANALYSIS

Fault	Closest Distance (km)	Capability	Length (km)	Dip (degrees)		Maximum Magnitude (M_w)		Recurrence Model		Fault Slip Rate mm/yr	
Buried Hills (BH)	53	0.6	26	45	(0.3)	6.4	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.7	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.0	(0.2)			0.01	(0.2)
Cockeyed Ridge-Papoose Lake (CRPL)	53	0.6	21	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.9	(0.2)			0.01	(0.2)
Death Valley (DV)	55	1	100	45	(0.3)	7.1	(0.2)	Exponential	(0.3)	1.0	(0.2)
				60	(0.4)	7.4	(0.6)	Characteristic	(0.7)	3.0	(0.6)
				75	(0.3)	7.7	(0.2)			6.0	(0.2)
Belted Range (BLR)	55	1	54	45	(0.3)	6.8	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	7.1	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	7.4	(0.2)			0.1	(0.2)
Kawich Range (KR)	57	1	84	45	(0.3)	7.0	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	7.3	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.6	(0.2)			0.01	(0.2)
Oak Spring Butte (OAK)	57	0.6	21	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.9	(0.2)			0.01	(0.2)
Grapevine (GV)	58	0.7	20	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.9	(0.2)			0.01	(0.2)
Spotted Range (SPR)	59	0.6	30	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.1	(0.2)			0.01	(0.2)
Cactus Springs	59	0.6	14	45	(0.3)	6.1	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.4	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.7	(0.2)			0.01	(0.2)
Emigrant Valley North (EVN)	60	0.6	28	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	7.1	(0.2)			0.1	(0.2)
Gold Flat	60	0.6	16	45	(0.3)	6.2	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.5	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.8	(0.2)			0.01	(0.2)
Kawich Valley (KV)	61	0.3	43	45	(0.3)	6.7	(0.2)	Exponential	(0.5)	0.0001	(0.2)

TABLE 1

KNOWN AND SUSPECTED QUATERNARY FAULTS IN THE YUCCA MOUNTAIN REGION MODELED IN THE SEISMIC HAZARD ANALYSIS

Fault	Closest Distance (km)	Capability	Length (km)	Dip (degrees)		Maximum Magnitude (M_w)		Recurrence Model		Fault Slip Rate mm/yr	
				60	(0.4)	7.0	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.3	(0.2)			0.01	(0.2)
Chert Ridge	65	0.3	14	45	(0.3)	6.1	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	6.4	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	6.7	(0.2)			0.001	(0.2)
Emigrant Valley South	66	0.6	20	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.9	(0.2)			0.01	(0.2)
Indian Springs Valley (ISV)	67	0.5	28	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.1	(0.2)			0.01	(0.2)
Grapevine Mountains (GM)	67	0.7	31	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	7.1	(0.2)			0.1	(0.2)
Pahrump (PRP)	70	1	70	70	(0.3)	6.9	(0.2)	Exponential	(0.5)	0.001	(0.2)
				80	(0.4)	7.2	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				90	(0.3)	7.5	(0.2)			0.05	(0.2)
Fallout Hills	70	0.3	8	45	(0:3)	5.8	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.1	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.4	(0.2)			0.01	(0.2)
Bonnie Claire	74	0.5	27	45	(0.3)	6.4	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.7	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.0	(0.2)			0.01	(0.2)
Stumble	74	0.5	33	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.1	(0.2)			0.01	(0.2)
West Pintwater Range (WPR)	76	1	60	45	(0.3)	6.8	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	7.1	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	7.4	(0.2)			0.1	(0.2)
Towne Pass	76	1	38	45	(0.3)	6.6	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	6.9	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	7.2	(0.2)			0.1	(0.2)
Jumbled Hills	77	0.4	27	45	(0.3)	6.4	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.7	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.0	(0.2)			0.01	(0.2)

TABLE 1

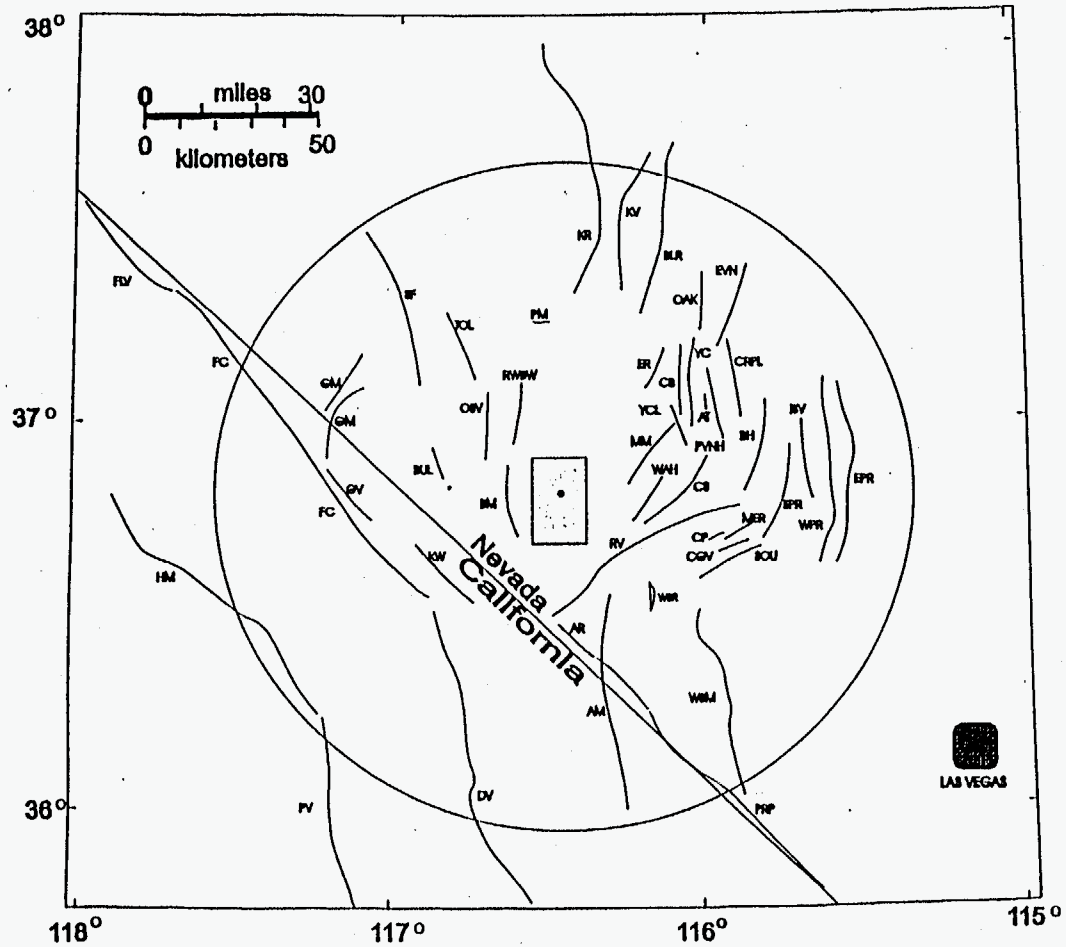
KNOWN AND SUSPECTED QUATERNARY FAULTS IN THE YUCCA MOUNTAIN REGION MODELED IN THE SEISMIC HAZARD ANALYSIS

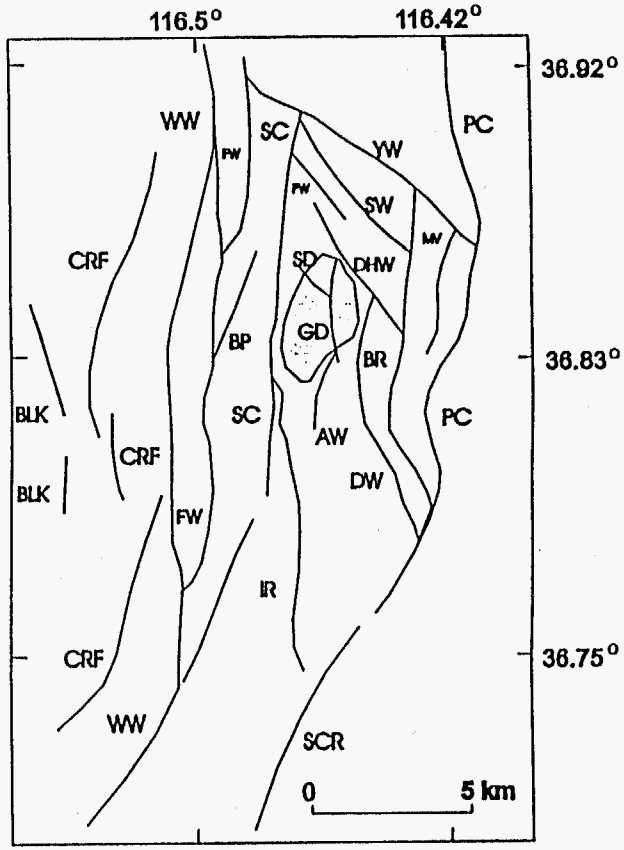
Fault	Closest Distance (km)	Capability	Length (km)	Dip (degrees)		Maximum Magnitude (M_w)		Recurrence Model		Fault Slip Rate mm/yr	
Cactus Flat-Mellan	80	0.5	35	45	(0.3)	6.6	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.9	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.2	(0.2)			0.01	(0.2)
East Pintwater Range (EPR)	81	0.6	58	45	(0.3)	6.8	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	7.1	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.4	(0.2)			0.01	(0.2)
North Desert Range	81	0.5	24	45	(0.3)	6.4	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.7	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.0	(0.2)			0.01	(0.2)
La Madre	82	0.6	33	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.1	(0.2)			0.01	(0.2)
Groom Range Central	82	0.3	31	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.1	(0.2)			0.01	(0.2)
Cactus Flat	84	0.6	50	45	(0.3)	6.8	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	7.1	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.4	(0.2)			0.01	(0.2)
Three Lakes Valley	84	0.3	27	45	(0.3)	6.4	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	6.7	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	7.0	(0.2)			0.001	(0.2)
Groom Range East	85	0.3	20	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	6.9	(0.2)			0.001	(0.2)
Cactus Range-Wellington Hills	87	0.3	29	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.00001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.0001	(0.6)
				75	(0.3)	7.1	(0.2)			0.001	(0.2)
Chalk Mountain	87	0.5	20	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	6.9	(0.2)			0.01	(0.2)
Chicago Valley	90	1	20	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	6.9	(0.2)			0.1	(0.2)
Tin Mountain	90	1	29	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	7.1	(0.2)			0.1	(0.2)

TABLE 1

KNOWN AND SUSPECTED QUATERNARY FAULTS IN THE YUCCA MOUNTAIN REGION MODELED IN THE SEISMIC HAZARD ANALYSIS

Fault	Closest Distance (km)	Capability	Length (km)	Dip (degrees)		Maximum Magnitude (M_w)		Recurrence Model		Fault Slip Rate mm/yr	
Tikaboo	92	1	33	45	(0.3)	6.5	(0.2)	Exponential	(0.5)	0.0001	(0.2)
				60	(0.4)	6.8	(0.6)	Characteristic	(0.5)	0.001	(0.6)
				75	(0.3)	7.1	(0.2)			0.01	(0.2)
Stonewall Mountain	92	1	22	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	6.9	(0.2)			0.1	(0.2)
Panamint Valley (PV)	95	1	100	60	(0.3)	7.1	(0.2)	Exponential	(0.3)	1.5	(0.2)
				75	(0.4)	7.4	(0.6)	Characteristic	(0.7)	2.5	(0.6)
				90	(0.3)	7.7	(0.2)			3.5	(0.2)
Hunter Mountain (HM)	95	1	85	70	(0.3)	7.0	(0.2)	Exponential	(0.3)	1.5	(0.2)
				80	(0.4)	7.3	(0.6)	Characteristic	(0.7)	2.5	(0.6)
				90	(0.3)	7.6	(0.2)			3.5	(0.2)
Penoyer	97	1	56	45	(0.3)	6.8	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	7.1	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	7.4	(0.2)			0.1	(0.2)
Racetrack Valley	97	0.6	22	45	(0.3)	6.3	(0.2)	Exponential	(0.5)	0.001	(0.2)
				60	(0.4)	6.6	(0.6)	Characteristic	(0.5)	0.01	(0.6)
				75	(0.3)	6.9	(0.2)			0.1	(0.2)





AM	Ash Meadows	CS	Cane Spring	KR	Kawich Range	RV	Rock Valley
AR	Amargosa River	DV	Death Valley	KV	Kawich Valley	RWBW	Rocket Wash-Beatty Wash
AT	Area Three	EPR	East Pintwater Range	KW	Keane Wonder	SF	Sarcobatus Flat
BH	Buried Hills	ER	Eleana Range	MER	Mercury Ridge	SOU	South Ridge
BLR	Belted Range	EVN	Emigrant Valley North	MM	Mine Mountain	SPR	Spotted Range
BM	Bare Mountain	FC	Furnace Creek	OAK	Oak Spring Butte	TOL	Tolicha Peak
BUL	Bullfrog Hills	FLV	Fish Lake Valley	OSV	Oasis Valley	WAH	Wahmonie
CB	Carpetbag	GM	Grapevine Mountains	PM	Pahute Mesa	WPR	West Pintwater Range
CGV	Crossgrain Valley	GV	Grapevine	PRP	Pahrump	WSM	West Springs Mountain
CP	Checkpoint Pass	HM	Hunter Mountain	PV	Panamint Valley	WSR	West Specter Range
CRPL	Cockeyed Ridge-Papoose Lake	ISV	Indian Springs Valley	PVNH	Plutonium Valley-N Halfpint Range	YC	Yucca
						YCL	Yucca Lake

Figure 1 Known or suspected Quaternary faults within 100 km of Yucca Mountain. Local faults are shown in greater detail on right.

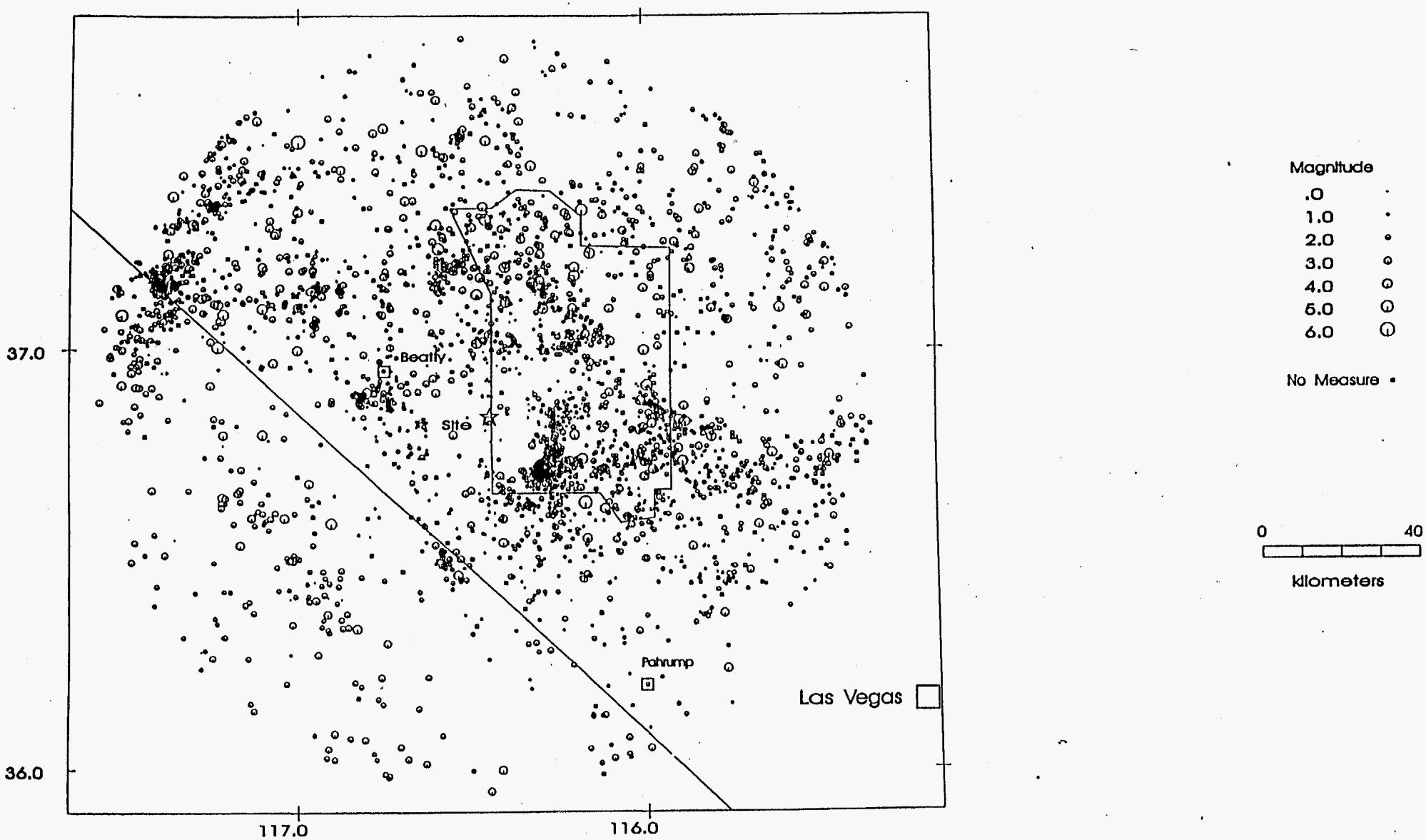


Figure 2 Historical Seismicity (1904-1996) within 100 km of the Yucca Mountain site used in recurrence.

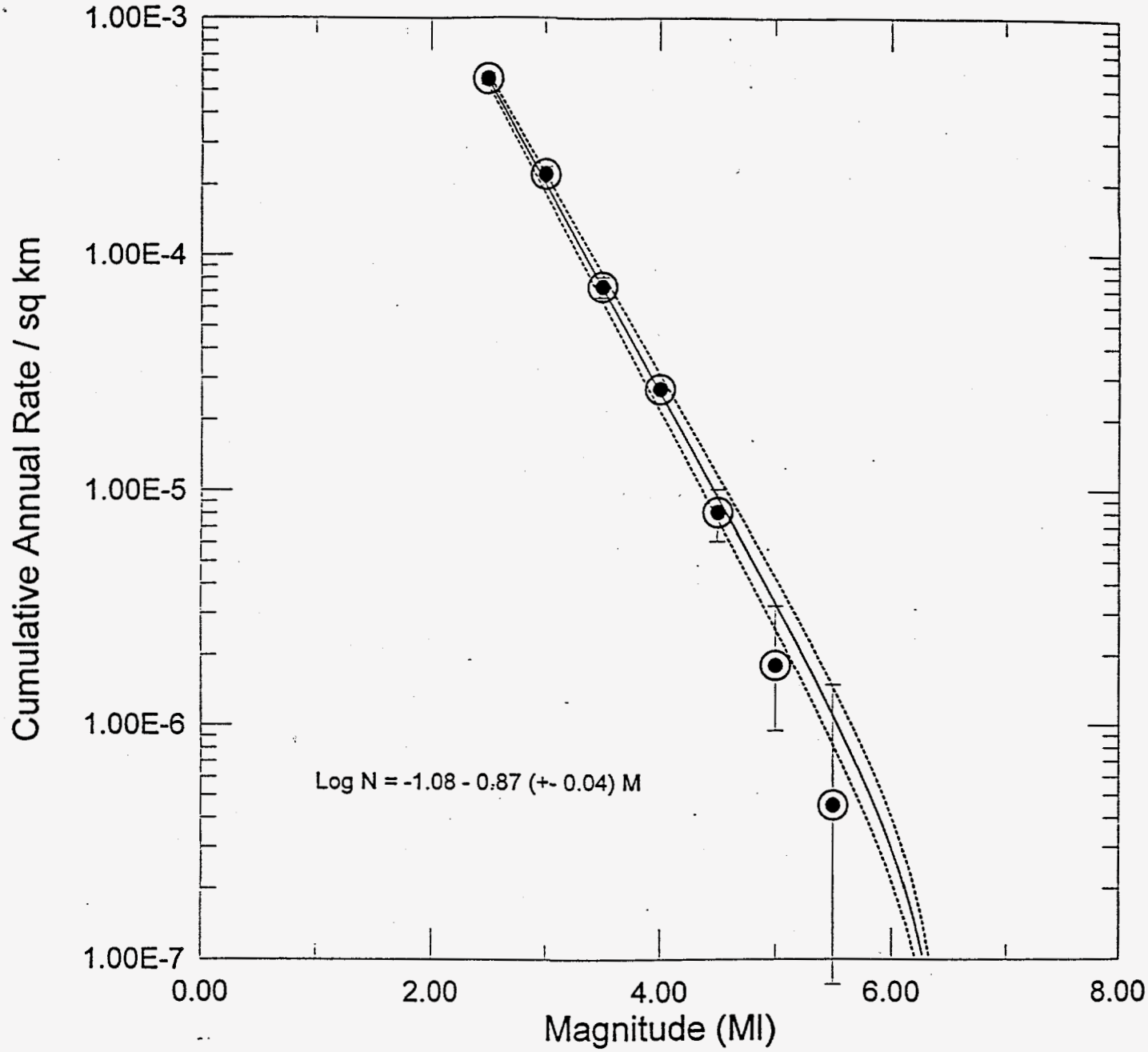


Figure 3 Truncated exponential earthquake recurrence relationship for the Yucca Mountain region. Data points are shown with their standard errors.

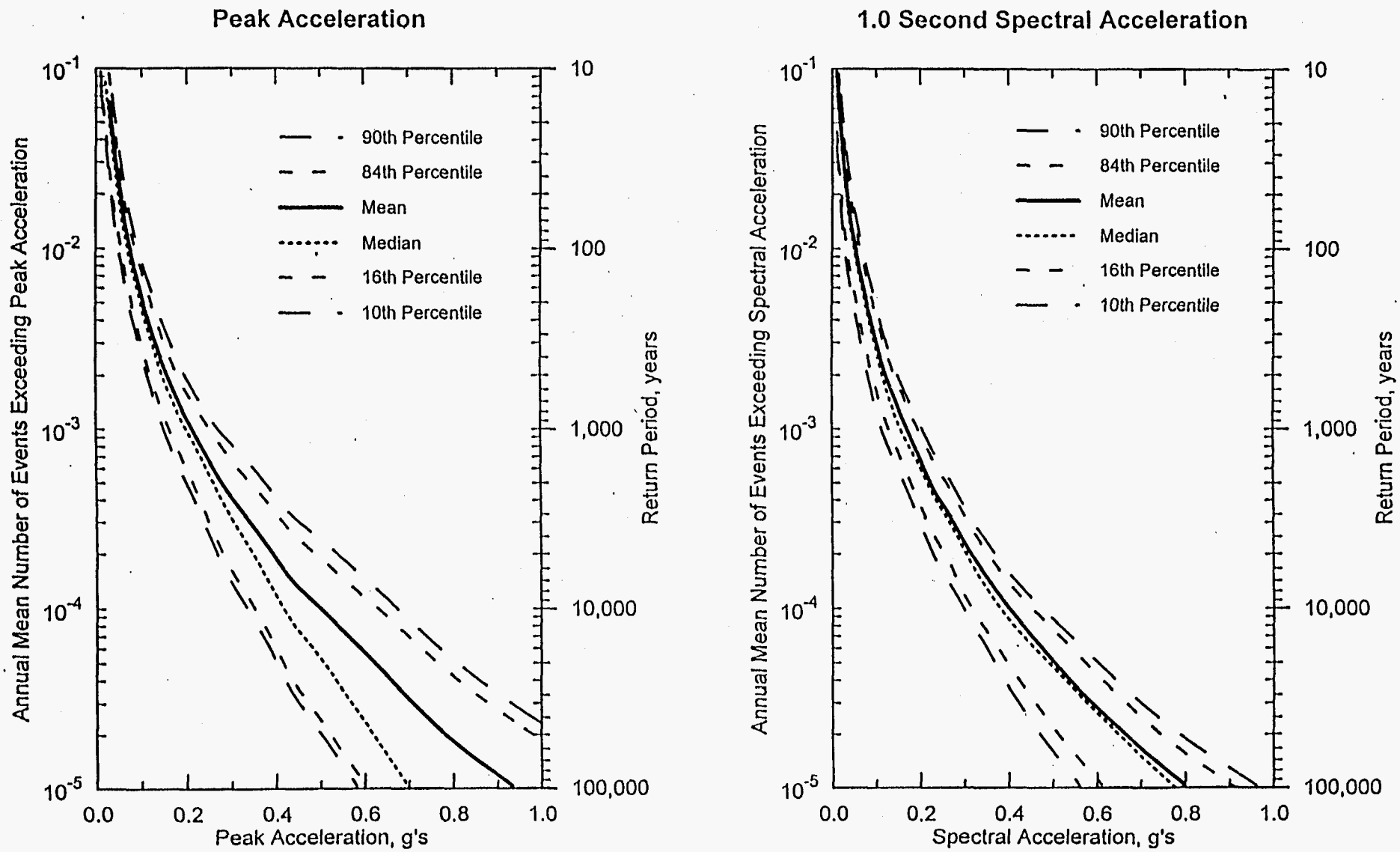


Figure 4. Mean, median and other percentile hazard curves for peak acceleration and 1.0 second spectral acceleration

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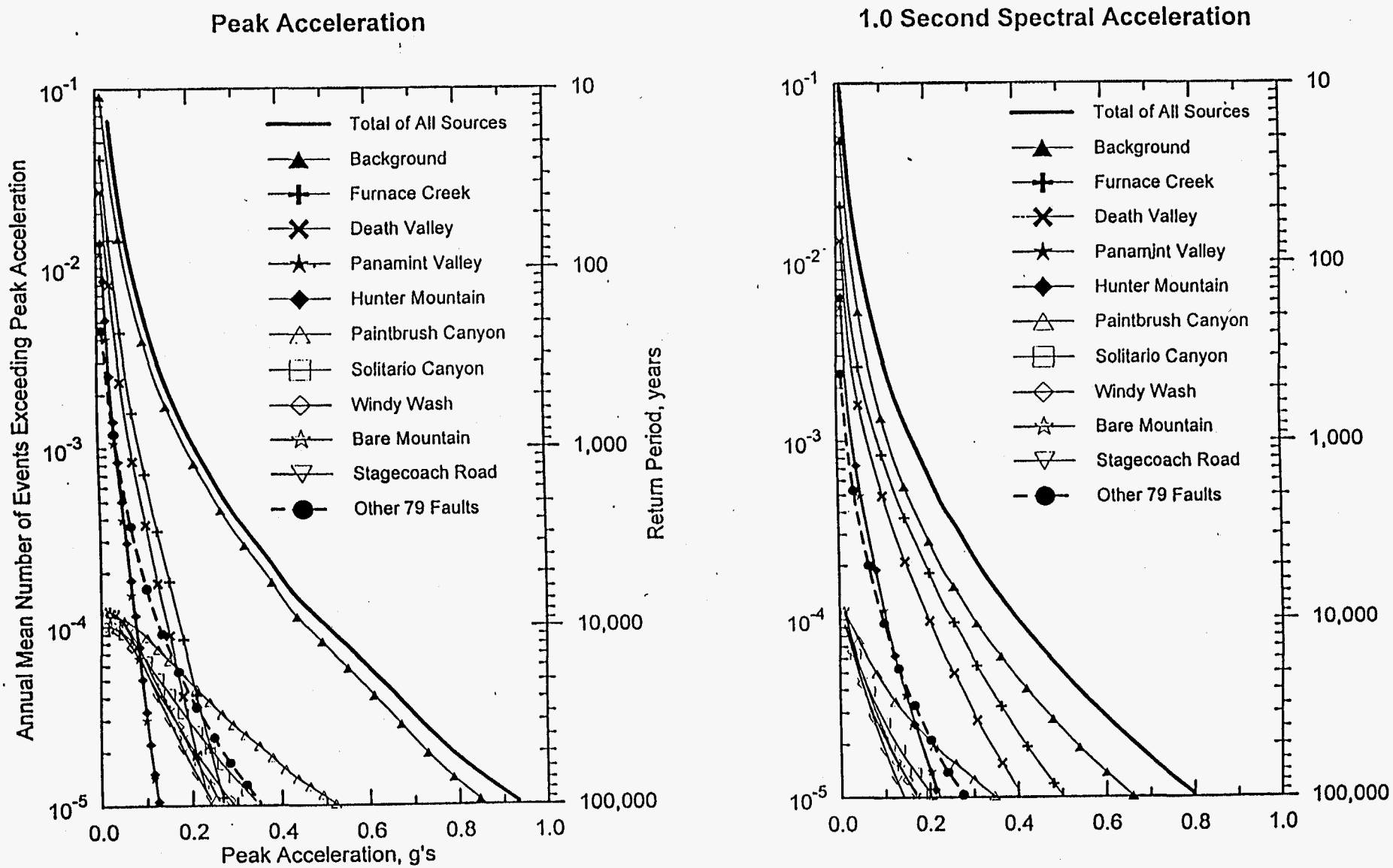

Figure 5. Mean peak horizontal acceleration and 1.0 second spectral acceleration hazard curves and contributions of seismic sources

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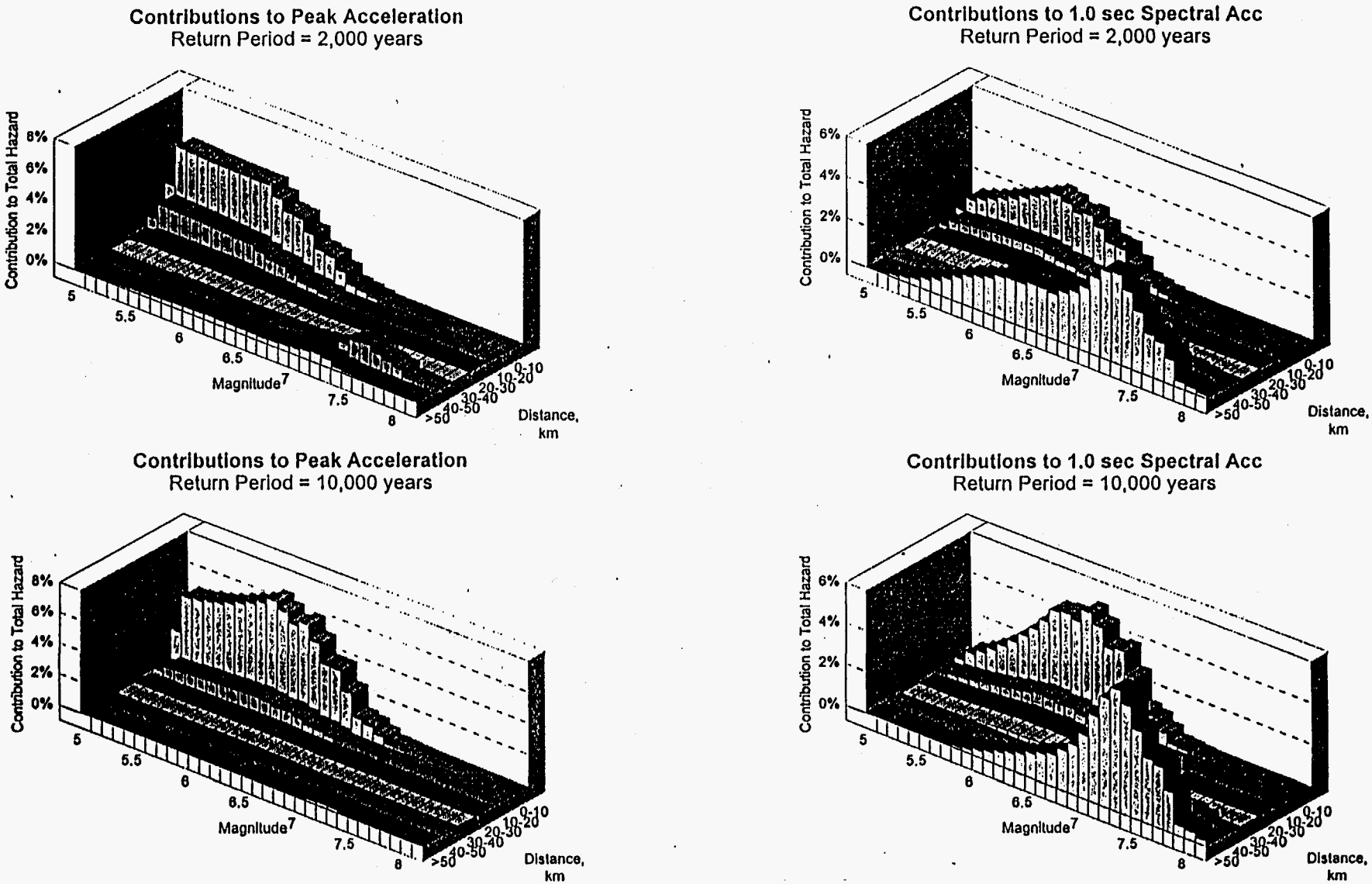

Figure 6. Magnitude and distance contributions to the mean peak horizontal acceleration and 1.0 second spectral acceleration hazard at return periods of 2,000 and 10,000 years

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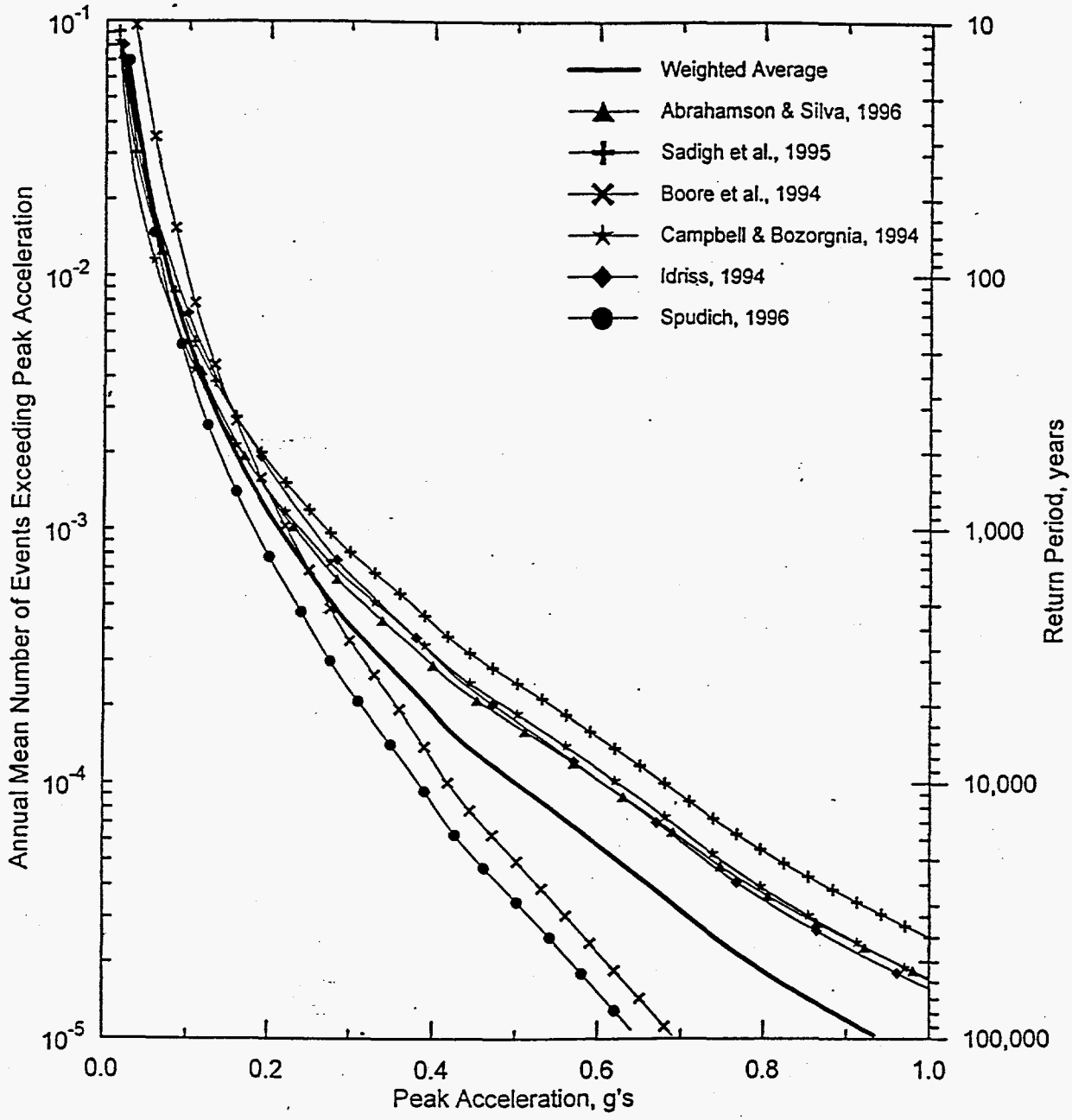

Figure 7. Sensitivity of mean peak horizontal acceleration hazard to selection of empirical attenuation relationship. Each relationship is shown when used individually in hazard calculations.