Development of Design Ground Motions for the Private Fuel Storage Facility

Private Fuel Storage Facility

Skull Valley, Utah

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DEVELOPMENT OF DESIGN GROUND MOTIONS FOR THE PRIVATE FUEL STORAGE FACILITY

Prepared for:

Private Fuel Storage Facility
Private Fuel Storage, LLC

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1.0 INTRODUCTION

This report documents the development of design ground motion response spectra for the Skull Valley Private Fuel Storage site based on the result of the probabilistic seismic hazard analysis conducted for the site (Geomatrix Consultants, Inc., 1999). The transformation from the equal-hazard response spectra to design ground motions involves application of USNRC Regulatory Guide 1.165 (USNRC, 1997) procedures and, for this site, incorporation of near-source ground motion effects.

2.0 APPLICATION OF REGULATORY GUIDE 1.165

2.1 APPROACH

Appendix F of USNRC Regulatory Guide 1.165 describes how design ground motion response spectra are to be defined based on a probabilistic seismic hazard analysis. The steps involved when using site-specific response spectra are:

1. Using the specified probability level, develop an equal-hazard response spectrum from the results of a probabilistic seismic hazard analysis (PSHA) for the site.

2. From the results of the PSHA, determine the mean magnitude, $\overline{M}$, and mean distance, $\overline{D}$, for events contributing to the design ground motion level hazard at spectral frequencies of 5 to 10 Hz and 1 to 2.5 Hz. The procedure to be used is described in Appendix C of USNRC Regulatory Guide 1.165.

3. Develop appropriate site-specific response spectra shapes for the events defined by $\overline{M}$ and $\overline{D}$ from step 2. Scale these spectral shapes to the spectral acceleration levels for the average of motions for 5 to 10 Hz and the average of motions for 1 to 2.5 Hz. The envelop of the scaled spectra and the equal-hazard spectra then defines the design-basis ground motion response spectrum.

2.2 STEP 1: EQUAL-HAZARD SPECTRA

Geomatrix Consultants, Inc. (1999) presents the PSHA analysis for the Skull Valley Private Fuel Storage Facility site. The hazard results presented in that analysis are for free-field motions at the ground surface accounting for the estimated local site effects. Using these results, equal-hazard response spectra were developed for return periods of 1,000 years and

2,000 years (mean annual probabilities of exceedance of 1×10^{-3} and 5×10^{-4}, respectively). These spectra are shown on Figure 1.

2.3 STEP 2: DETERMINATION OF $\overline{M}$ AND $\overline{D}$

The procedure to be used for determining $\overline{M}$ and $\overline{D}$ is described in Appendix C of USNRC Regulatory Guide 1.165. The process involves computing the contribution to the total hazard at the specified design level from events in discrete magnitude and distance bins. These relative contributions are multiplied times the average magnitude and distance for each bin, and the product summed over all bins to compute a weighted average magnitude, $\overline{M}$, and log average distance, $\overline{D}$, of the events contributing to the design level hazard. Two spectral frequency ranges are used, the average of motions at 5 and 10 Hz (0.2 and 0.1 sec. periods, respectively) and the average of motions at 1 and 2.5 Hz (1.0 and 0.4 sec. periods, respectively). Appendix C of USNRC Regulatory Guide 1.165 specifies the size of the magnitude and distance bins appropriate for the evaluation of sites in the central and eastern United States and indicates that other bin sizes may be necessary. Because the hazard at the Skull Valley site is primarily due to magnitude 6 to 7.25 events occurring on the nearby faults, a reduced magnitude and distance bin size was used to provide a more accurate representation of the contributions to the hazard. The magnitude bin size was set to 0.25 magnitude units centered on each ¼ magnitude from 5 to 8, and the distance bins were set to: 0-5 km, 5-10, km, 10-15 km, 15-20 km, 20-25 km, 25-30 km, 30-50 km, 50-75 km, 75-100 km, 100-150 km, and 150-200 km.

Figure 2 shows the computed percent contributions to the hazard for each of the specified return periods, spectral frequency ranges, and horizontal and vertical motions. These results indicate that the hazard is due principally to earthquakes occurring within 15 km of the site. Because the contribution from events at distances greater than 100 km is less than 1 percent in all cases, the special provisions for distant sources described in Appendix C of USNRC Regulatory Guide 1.165 need not be applied. The computed values of $\overline{M}$ and $\overline{D}$ are:

Ground Motion Parameter	Spectral Frequency Range	$\overline{M}$	$\overline{D}$ (km)
1,000-year horizontal	5 – 10 Hz	6.3	5
	1 - 2.5 Hz	6.4	5
1,000-year vertical	5 – 10 Hz	6.4	6
	1 – 2.5 Hz	6.4	7
2,000-year horizontal	5 – 10 Hz	6.3	4
	1 – 2.5 Hz	6.5	4
2,000-year vertical	5 – 10 Hz	6.5	6
	1 – 2.5 Hz	6.5	6

2.4 STEP 3: SCALING SITE-SPECIFIC SPECTRAL SHAPES TO EQUAL-HAZARD SPECTRA

Free-field ground surface response spectral shapes were developed for each of the $\overline{M}$ and $\overline{D}$ pairs listed above using the ground motion attenuation relationships developed for computing the hazard (Geomatrix Consultants, Inc., 1999). The spectral shapes were developed by computing 84th-percentile response spectra for each $\overline{M}$ and $\overline{D}$ using a weighted combination of the attenuation relationships and then dividing the resulting spectral accelerations by the computed 84th-percentile peak acceleration. The weights assigned to each of the relationships are given in Appendix F, Table F-1 of Geomatrix Consultants, Inc. (1999). These relationships have been adjusted for local site effects as described in Appendix F of Geomatrix Consultants, Inc. (1999).

Figure 3 shows the results of scaling these spectral shapes to the appropriate response spectral accelerations for each equal-hazard spectrum. In general, enveloping the three response spectra results in, at most, only minor increases in the ground motions above those specified by the equal hazard spectra. These increases arise, in part, from including more spectral frequencies in the spectral shapes than were used to compute the equal-hazard spectra, providing better interpolation and smoother spectral shapes.

3.0 INCORPORATION OF NEAR-SOURCE EFFECTS

The hazard at the Skull Valley site is due to the occurrence of large-magnitude earthquakes on nearby faults. Recent studies, focused primarily on strike-slip earthquakes, have indicated that there are effects of rupture directivity on strong ground motions that are observable and systematic in the near field of large earthquakes. These effects have been quantitatively defined by Somerville and others (1997) using empirical data. They describe two effects, one resulting from directivity of rupture (a Doppler effect) and one representing a systematic difference between fault-normal and fault-parallel motions (the horizontal response spectral attenuation relationships used to define the equal-hazard response spectra and the spectral shapes shown on Figure 3 represent the geometric mean of the two horizontal components). The effects first become significant at a spectral frequency of 1.67 (0.6-second period) and increase with decreasing spectral frequency (increasing period).

The magnitude of these effects is related to the size of the earthquake and to the geometric relationship between the site, the length of the rupture, and the location of the point of rupture initiation. For dip-slip faults, these are parameterized by the term $y\cos(\phi)$, where ϕ is the angle between the rupture surface and a line drawn from the point of rupture initiation and the site and y is the distance from the point of rupture initiation to the site measured along the fault divided by the length of rupture measured in the direction of slip (for dip slip faults, the rupture width). Because most large normal faulting earthquakes appear to initiate near the base of the seismogenic crust, sites located on the fault trace will have $\phi = 0$ and y near 1.0, and will thus experience the maximum effect of both directivity and systematic fault-normal-to-fault-parallel differences in ground motion.

The impact of these effects on the spectra shown on Figure 3 was evaluated by considering the contributions of the different sources to the total hazard at return periods of 1,000 and 2,000 years. From Figure 6-12 of Geomatrix Consultants, Inc. (1999), the majority of the hazard for horizontal motions comes from the four nearby faults: the East, West, Stansbury, and East Cedar Mountains faults. For each fault, the parameters ϕ and y were conservatively set to the values associated with rupture at the closest point on the faults, with rupture initiation occurring at the base of the seismogenic crust. Thus, y was set equal to 1.0 for all faults and ϕ was set to 1.6°, 3.0°, 19.5°, and 54.9° for the East, West, Stansbury, and East Cedar Mountains faults, respectively. The appropriate adjustment factor for each fault was computed using the relationships presented in Somerville and others (1997) and the mean magnitude contributing to the hazard for each fault. The hazard curves for each fault were then scaled in the horizontal (ground motion) direction by these factors and then reinterpreted to obtain frequencies of exceedance at common ground motion levels. These were, in turn, summed to obtain a new composite hazard curve for these faults and the result added to the hazard from all other sources to obtain an adjusted total hazard for horizontal ground motions. An additional source of some conservatism in this process is the fact that the standard deviation in the ground motions should be slightly reduced because the inclusion of a systematic directivity effect should improve the ability of the attenuation relationships to predict the observed ground motion data. However, this effect has not been evaluated for dip-slip faults and has been ignored in this analysis.

The adjusted hazard curves were then interpolated to obtain spectral accelerations for return periods of 1,000 and 2,000 years. The resulting ratios of the adjusted to unadjusted spectral accelerations are:

Ratio of Near-Field Adjusted to Unadjusted Spectral Accelerations

Return Period	Spectral Period (sec)	Directivity only	Directivity plus Fault-Normal/ Average	Directivity plus Fault-Parallel/ Average
1,000 years	1.0	1.05	1.10	1.00
	2.0	1.10	1.27	1.02
	4.0	1.16	1.53	1.04
2,000 years	1.0	1.05	1.11	1.01
	2.0	1.13	1.25	1.03
	4.0	1.19	1.54	1.01

4.0 DESIGN GROUND MOTION RESPONSE SPECTRA

Design ground motion response spectra were developed by scaling the envelop of the response spectra shown on Figure 3 by the near-fault effects adjustment factors listed above. Ratios for intermediate frequencies were obtained by linear interpolation on log(period), with the ratio set to 1.0 for all periods less than 0.6 second (frequencies greater than 1.67 Hz). For vertical motions it was assumed that the near-fault effect for directivity only found for horizontal motions applies. The resulting response spectra are shown on Figures 4 and 5 and are tabulated in Table 1.

5.0 REFERENCES

Geomatrix Consultants, Inc., 1999, Fault evaluation study and seismic hazard assessment, Private Fuel Storage Facility, Skull Valley, Utah: report prepared for Stone & Webster Engineering Corporation, February, 3 vols.

Somerville, P.G., Smith, N.F., Graves, R.W., and Abrahamson, N.A., 1997, Modification of empirical strong ground motion attenuation relations to include the amplitude and duration effects of rupture directivity: Seismological Research Letters, v. 68, p. 199-222.

USNRC, 1997, Regulatory Guide 1.165 Identification and characterization of seismic sources and determination of safe shutdown earthquake ground motions: U.S. Nuclear Regulatory Commission, March.

TABLE 1

DESIGN GROUND MOTION RESPONSE SPECTRA

Skull Valley Private Fuel Storage Facility
Skull Valley, Utah

1,000-year Return Period Spectral Accelerations (g, 5% damping)				
Period (sec)	Horizontal		Period (sec)	Vertical
	Fault Normal	Fault Parallel		
PGA	0.404	0.404	PGA	0.391
0.03	0.404	0.404	0.02	0.391
0.05	0.500	0.500	0.05	0.761
0.075	0.631	0.631	0.075	0.932
0.1	0.792	0.792	0.1	1.001
0.15	0.995	0.995	0.15	0.952
0.2	1.086	1.086	0.2	0.791
0.3	1.060	1.060	0.3	0.547
0.4	0.964	0.964	0.4	0.419
0.5	0.868	0.868	0.5	0.333
0.75	0.615	0.591	0.75	0.211
1.0	0.425	0.389	1.0	0.138
1.5	0.265	0.225	1.5	0.0814
2.0	0.191	0.154	2.0	0.0579
3.0	0.120	0.0875	3.0	0.0362
4.0	0.0924	0.0627	4.0	0.0283
2,000-year Return Period Spectral Accelerations (g, 5% damping)				
Period (sec)	Horizontal		Period (sec)	Vertical
	Fault Normal	Fault Parallel		
PGA	0.528	0.528	PGA	0.533
0.03	0.528	0.528	0.02	0.533
0.05	0.662	0.662	0.05	1.030
0.075	0.835	0.835	0.075	1.268
0.1	1.046	1.046	0.1	1.369
0.15	1.317	1.317	0.15	1.296
0.2	1.437	1.437	0.2	1.104
0.3	1.406	1.406	0.3	0.780
0.4	1.284	1.284	0.4	0.594
0.5	1.166	1.166	0.5	0.476
0.75	0.851	0.814	0.75	0.306
1.0	0.605	0.547	1.0	0.203
1.5	0.379	0.323	1.5	0.123
2.0	0.272	0.223	2.0	0.0882
3.0	0.179	0.128	3.0	0.0557
4.0	0.138	0.0908	4.0	0.0440

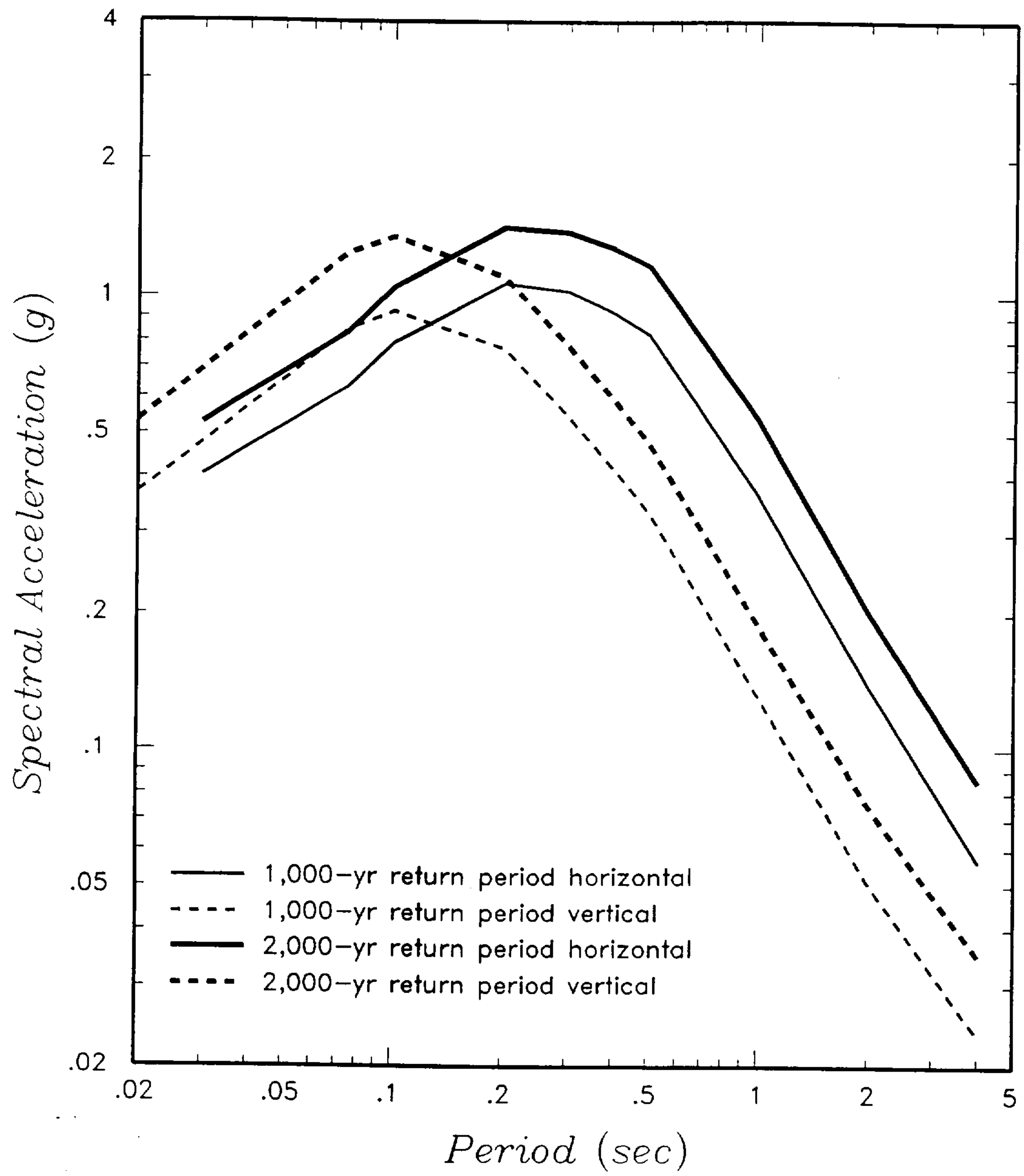
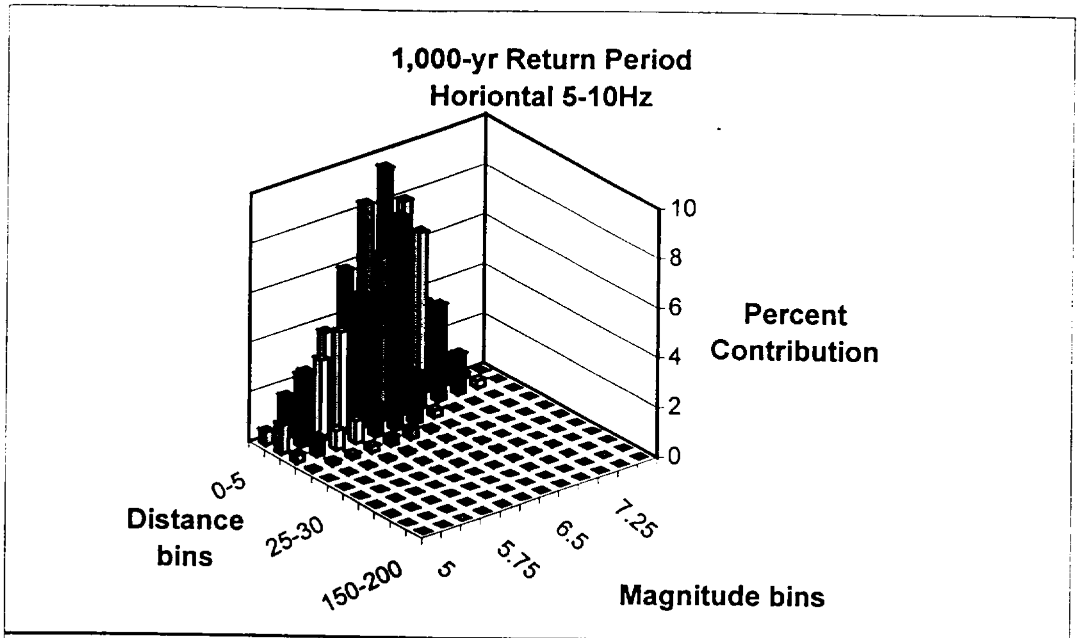
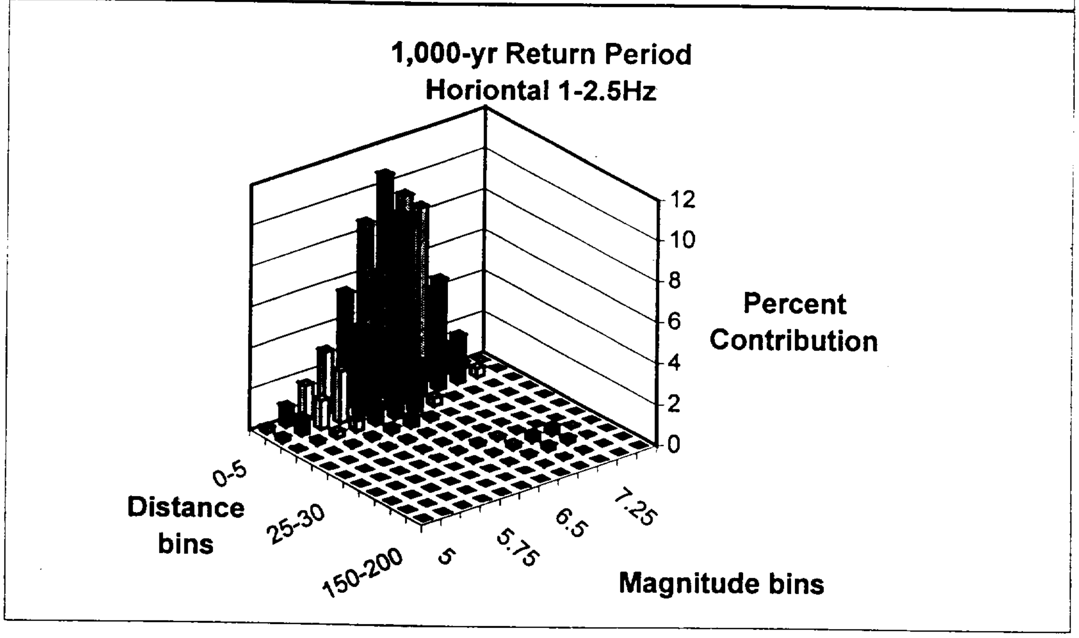


Fig 1

GEOMATRIX	EQUAL HAZARD RESPONSE SPECTRA (5% DAMPING) FOR THE SKULL VALLEY SITE Private Fuel Storage Facility	Project No. 4790 Figure 1





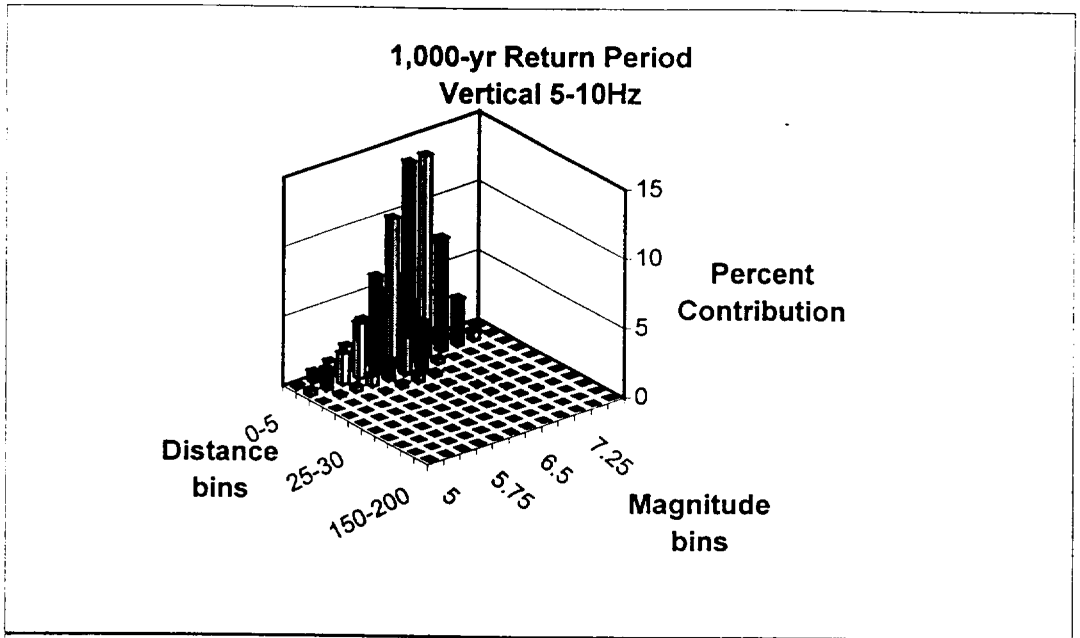
GEOMATRIX

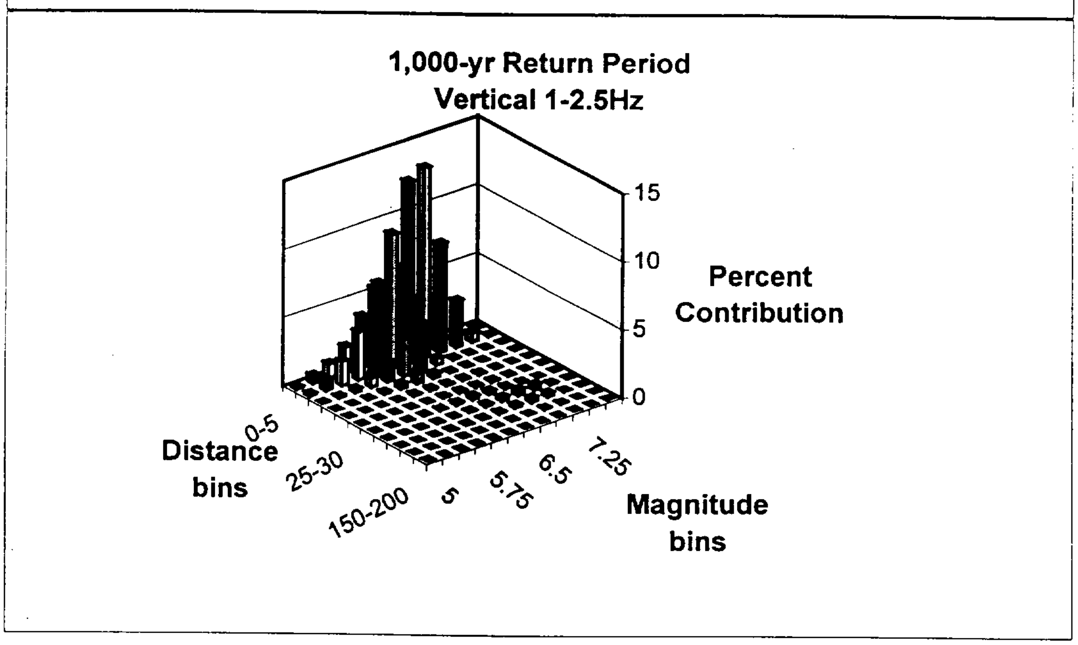
PERCENT CONTRIBUTIONS OF EVENTS FOR SPECIFIED MAGNITUDE AND DISTANCE BINS TO THE HAZARD

Private Fuel Storage Facility

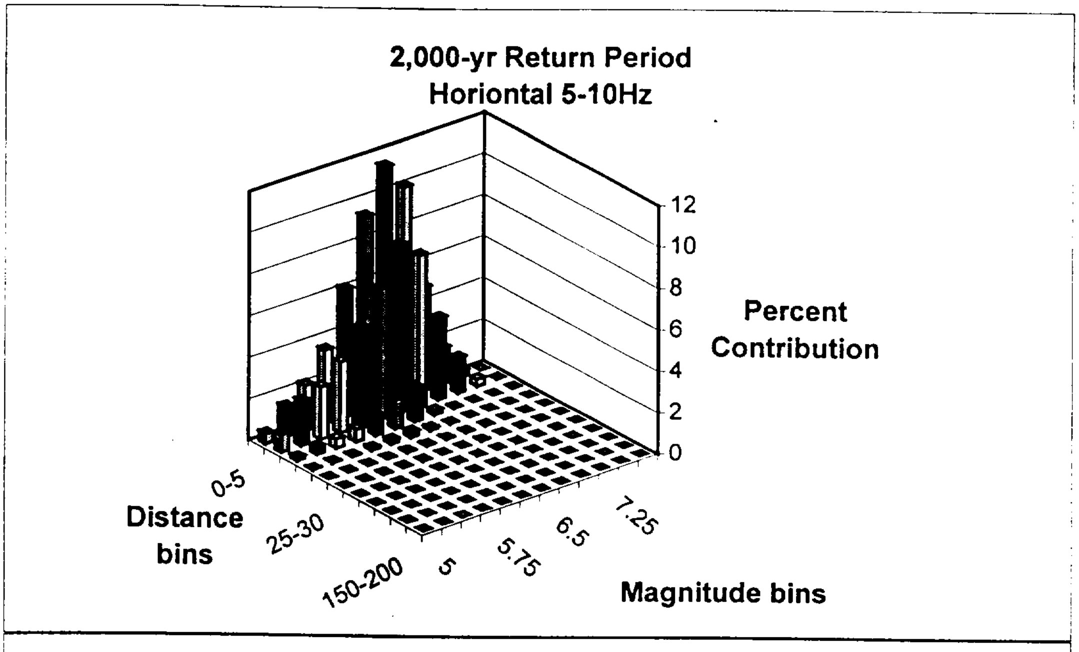
Project No. 4790

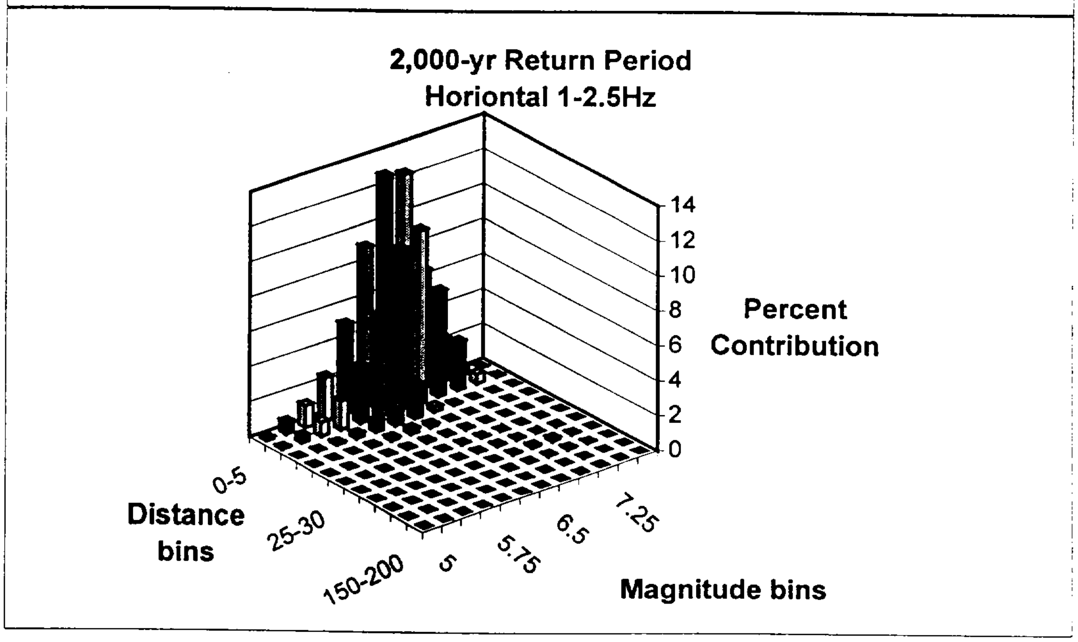
Figure 2





GEOMATRIX	PERCENT CONTRIBUTIONS OF EVENTS FOR SPECIFIED MAGNITUDE AND DISTANCE BINS TO THE HAZARD Skull Valley, Utah — Page 2 of 4	Project No. 4790 Figure 2





GEOMATRIX

PERCENT CONTRIBUTIONS OF EVENTS FOR SPECIFIED MAGNITUDE AND DISTANCE BINS TO THE HAZARD

Private Fuel Storage Facility

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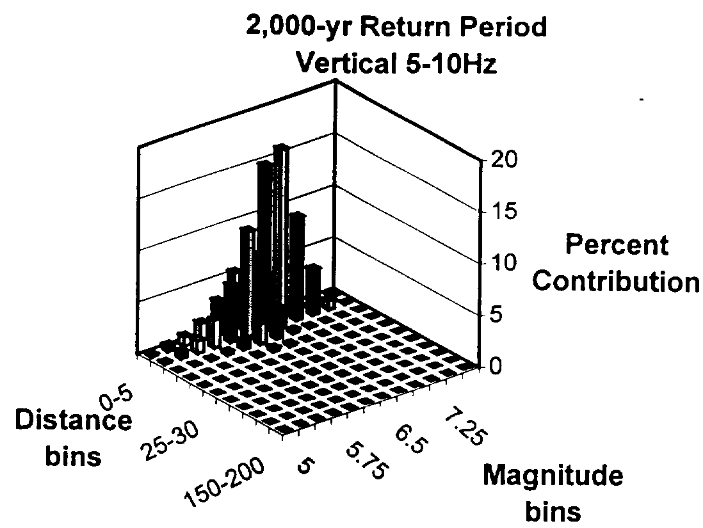

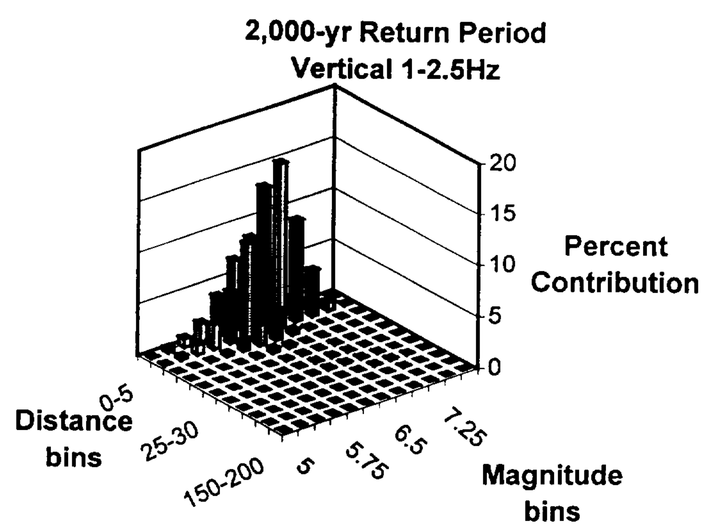

GEOMATRIX

PERCENT CONTRIBUTIONS OF EVENTS FOR SPECIFIED MAGNITUDE AND DISTANCE BINS TO THE HAZARD
Skull Valley, Utah

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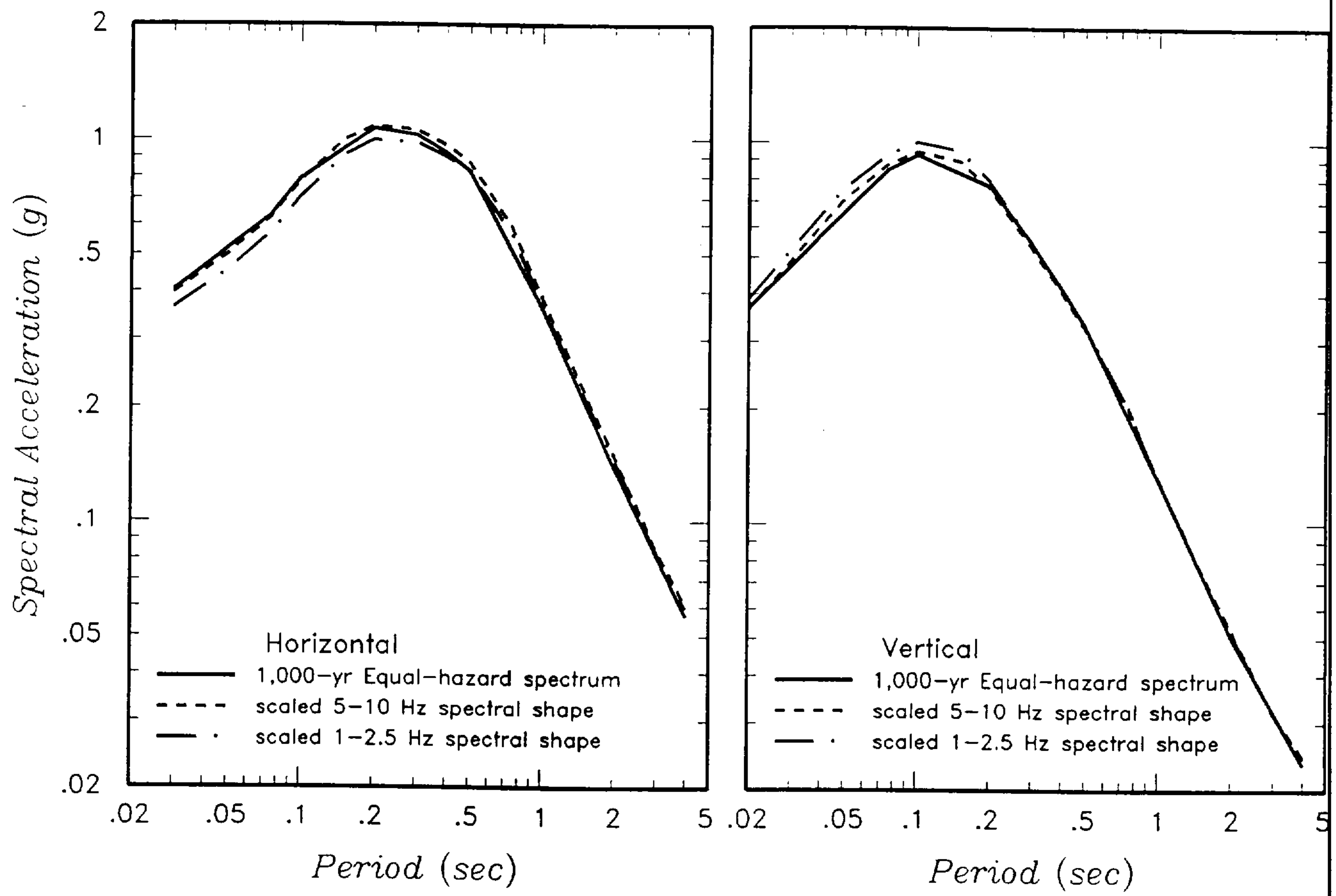
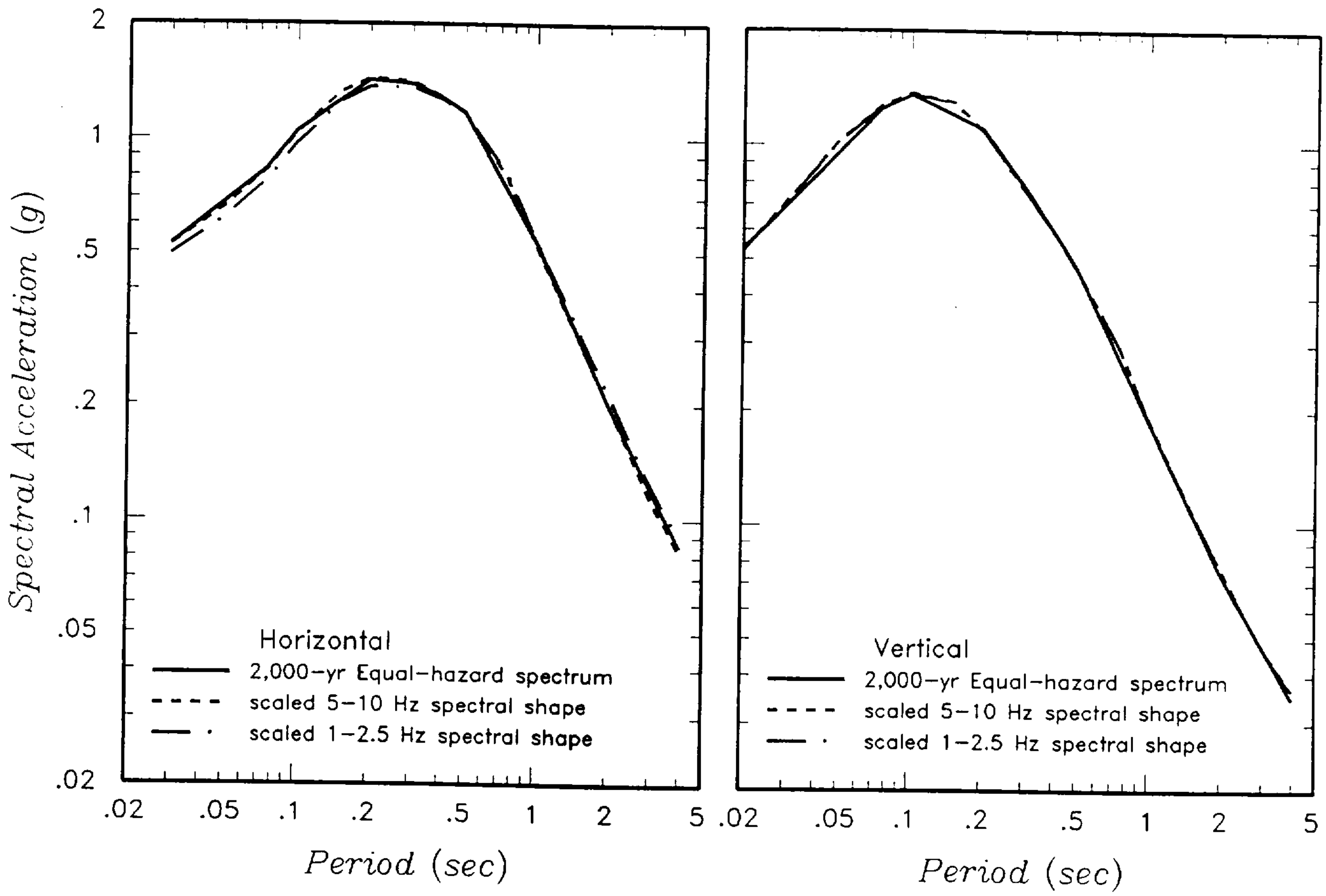


Fig 3

GEOMATRIX	COMPARISON OF EQUAL-HAZARD RESPONSE SPECTRA AND SCALED SPECTRAL SHAPES Private Fuel Storage Facility — Page 1 of 2	Project No. 4790 Figure 3



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GEOMATRIX	COMPARISON OF EQUAL-HAZARD RESPONSE SPECTRA AND SCALED SPECTRAL SHAPES Skull Valley, Utah — Page 2 of 2	Project No. 4790 Figure 3

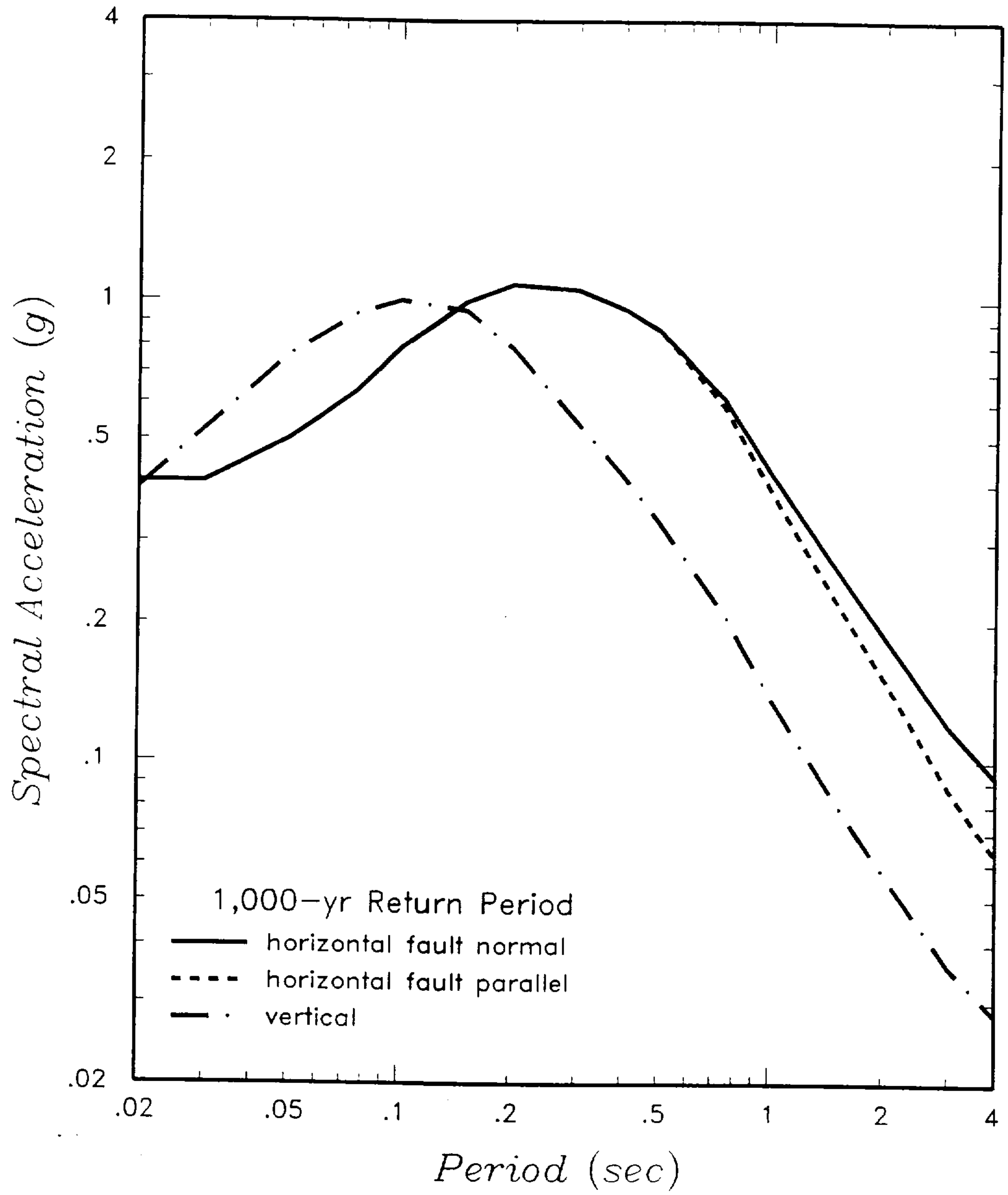

Fig 4

GEOMATRIX	DESIGN GROUND MOTION RESPONSE SPECTRA (5% DAMPING) BASED ON 1,000-YEAR RETURN PERIOD HAZARD Private Fuel Storage Facility	Project No. 4790 Figure 4

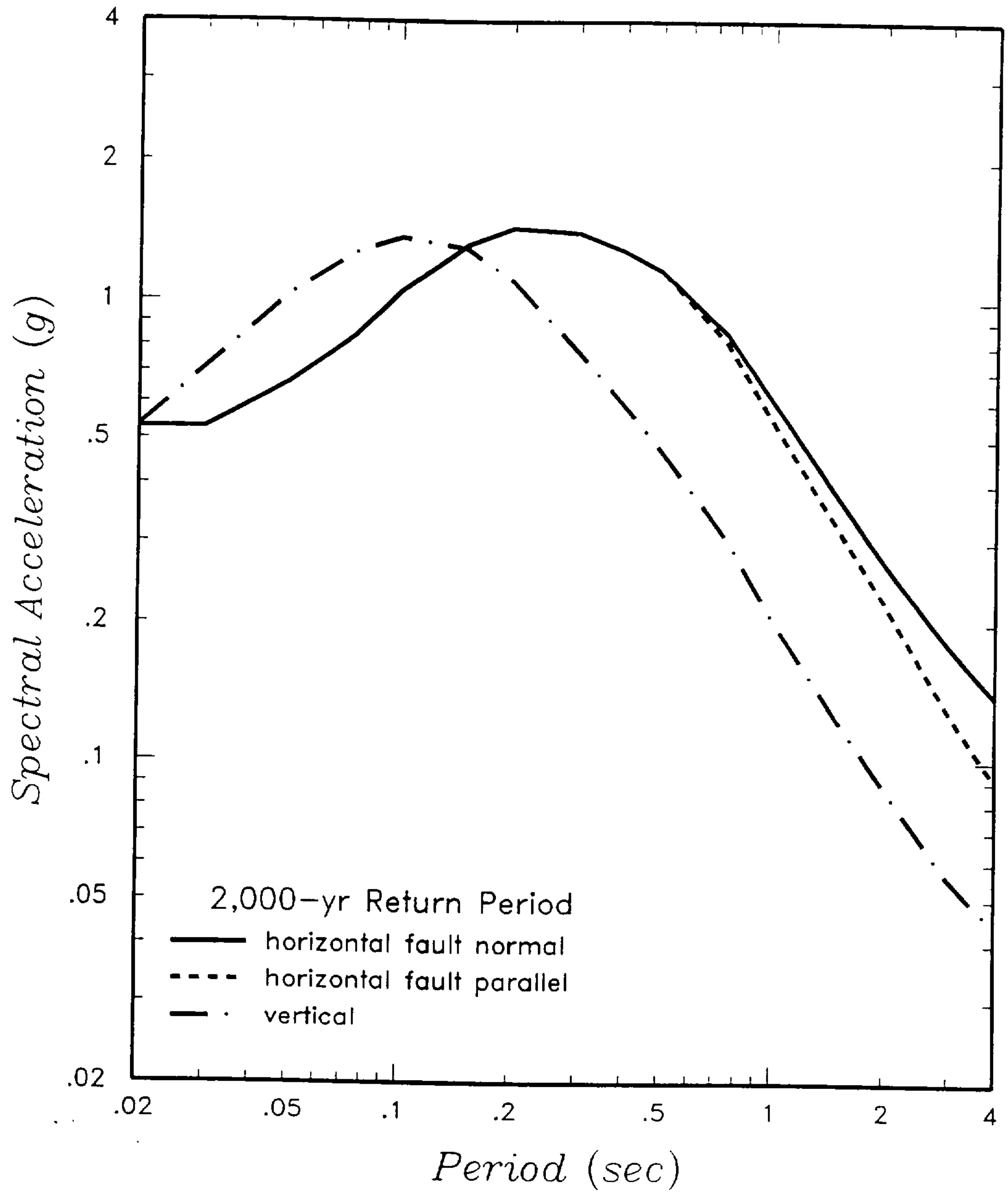

Fig 5

GEOMATRIX	DESIGN GROUND MOTION RESPONSE SPECTRA (5% DAMPING) BASED ON 2,000-YEAR RETURN PERIOD HAZARD Skull Valley, Utah	Project No. 4790 Figure **5**