PROBABILISTIC SEISMIC HAZARD EVALUATION AND UNIFORM HAZARD SPECTRA

St. Lucie and Turkey Point Nuclear Power Plant Sites

FLORIDA

Report
prepared for the

Florida Power & Light Company Nuclear Licensing Department

December 1989

EBASCO

EBASCO SERVICES INCORPORATED
Greensboro, N.C.

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1.0 SUMMARY

Seismic hazards for the St. Lucie and Turkey Point sites were computed using the source zones and seismicity parameters established by each of the six EPRI Technical Evaluation Contractors (TEC), and the source zones and seismicity parameters identified by ESI for the Northern Caribbean. Hazard values calculated from each TEC model were then aggregated in accordance with the EPRI recommended procedure to generate the final hazard curves.

The mean and 15th, 50th, and 85th percentile hazard, in terms of annual probabilities of exceedance, for different peak ground accelerations at the St. Lucie site are shown in Table 1-1. Hazard curves for peak ground acceleration for the St. Lucie site are presented as constant percentile curves on Figure 1-1. On this figure the 15th, 50th, and 85th percentile curves represent the aggregated results of all TECs. The mean hazard curve is shown by a dashed line. Figure 1-2 shows 50th percentile uniform hazard spectrum plots at St. Lucie for annual exceedance probabilities of 1.0E-05, 1.0E-04, 2.0E-04, 1.0E-03 and 2.0E-03. Figure 1-3 is a uniform hazard spectrum plot at St. Lucie, showing mean spectra for annual exceedance probabilities of 1.0E-05, 1.0E-04, 2.0E-04, 1.0E-03 and 2.0E-03.

Seismic hazard results for the Turkey Point site are presented on Table 1-2. Figure 1-4 shows hazard curves for peak ground acceleration for the Turkey Point site. The 15th, 50th, and 85th percentile curves represent the aggregated results of all TECs. The mean hazard curve is shown by a dashed line. Figure 1-5 shows 50th percentile uniform hazard spectrum plots at Turkey Point for annual exceedance probabilities of 1.0E-05, 1.0E-04, 2.0E-04, 1.0E-03 and 2.0E-03. Figure 1-6 is a uniform hazard spectrum plot at Turkey Point, showing mean spectra for annual exceedance probabilities of 1.0E-05, 1.0E-04, 2.0E-04, 1.0E-03 and 2.0E-03.

The probabilistic seismic hazard at St. Lucie and Turkey Point Sites is very low. Most of the contribution to the St. Lucie and Turkey Point sites, in the case of each of the TEC source zones, is derived from the background source containing the sites.

In summary, the results of the probabilistic seismic hazard evaluation for Florida Power and Light's St. Lucie and Turkey Point sites, using the EPRI methodology, yield very low values for each site's seismic hazard. The results of seismic hazard computations are discussed in Section 7.

TABLE 1-1
St. Lucie
Annual Probability of Exceedance for Peak Ground Acceleration (PGA)

PGA (cm/sec^2)	PGA (g)	Mean	Percentiles 15	50	85
7.00	0.007	7.36E-04	1.82E-05	4.97E-04	1.60E-03
65.00	0.07	3.89E-05	7.80E-07	3.15E-05	6.84E-05
120.00	0.12	1.24E-05	2.00E-07	1.05E-05	2.29E-05
225.00	0.23	1.61E-06	1.40E-08	1.04E-06	2.75E-06
400.00	0.41	1.78E-07	5.82E-10	7.48E-08	3.08E-07
560.00	0.57	5.08E-08	1.97E-10	1.32E-08	8.60E-08
800.00	0.82	1.22E-08	1.91E-10	1.51E-09	1.41E-08

TABLE 1-2
Turkey Point
Annual Probability of Exceedance for Peak Ground Acceleration (PGA)

PGA (cm/sec^2)	PGA (g)	Mean	Percentiles 15	50	85
5.00	0.005	3.90E-03	1.02E-04	3.27E-04	1.34E-02
50.00	0.05	3.18E-05	7.89E-07	2.75E-05	5.61E-05
100.00	0.10	1.08E-05	1.87E-07	9.57E-06	2.02E-05
250.00	0.26	1.39E-06	1.29E-08	9.19E-07	2.58E-06
500.00	0.51	1.52E-07	7.26E-10	5.95E-08	2.85E-07
700.00	0.71	4.33E-08	3.91E-10	9.89E-09	7.16E-08
1000.00	1.02	1.04E-08	3.91E-10	1.17E-09	1.21E-08

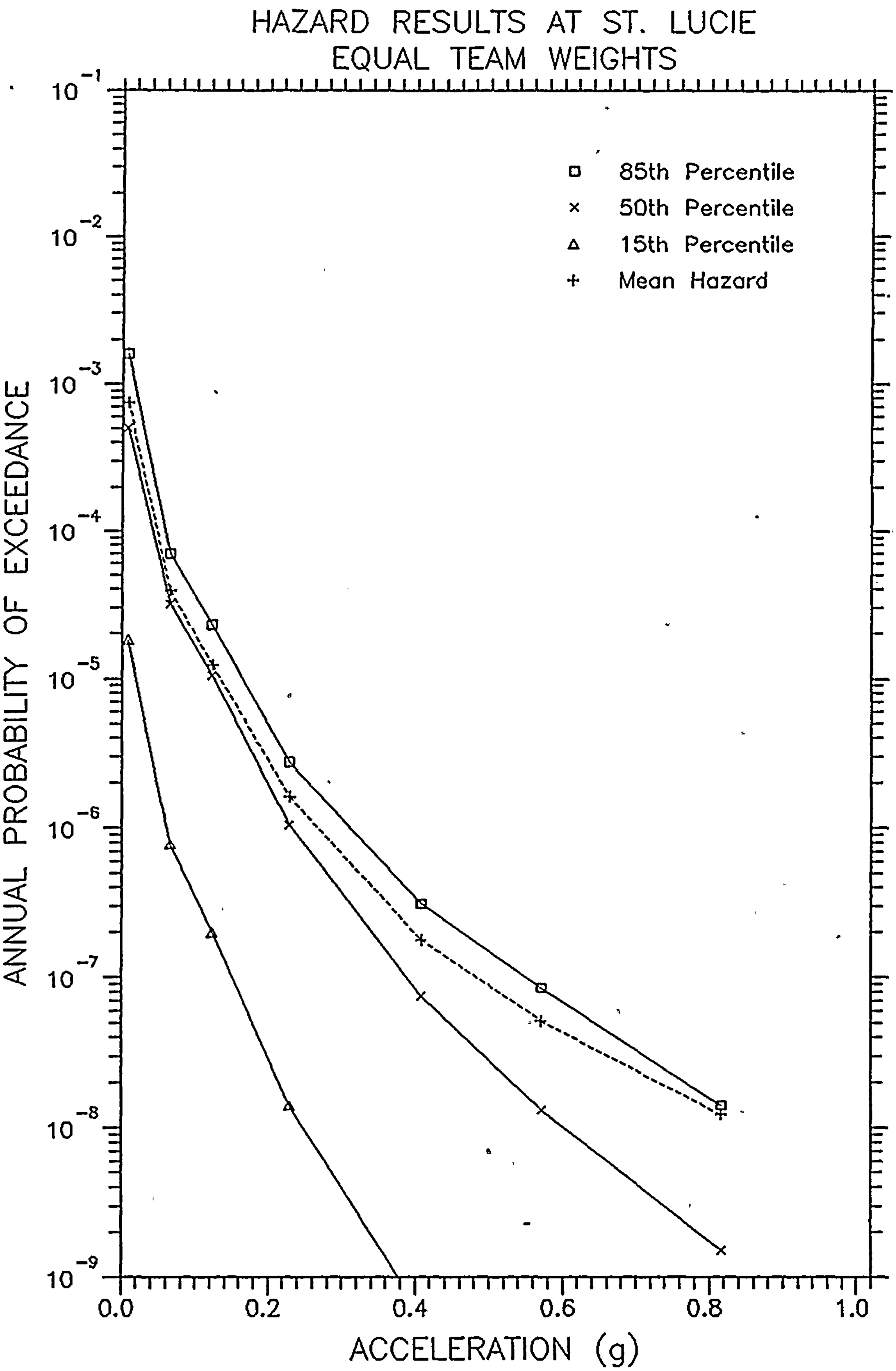

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FIGURE 1-1

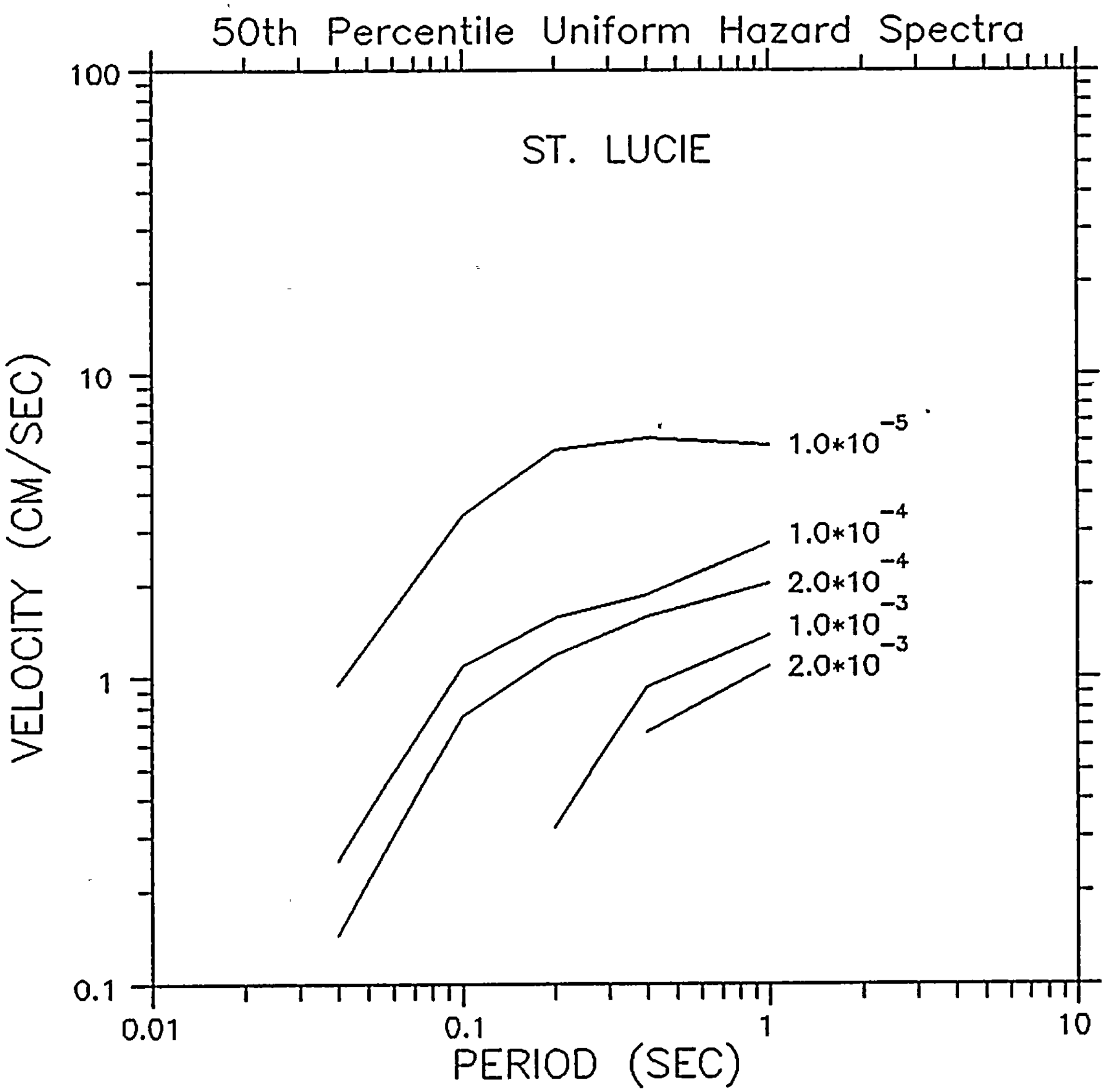

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FIGURE 1-2

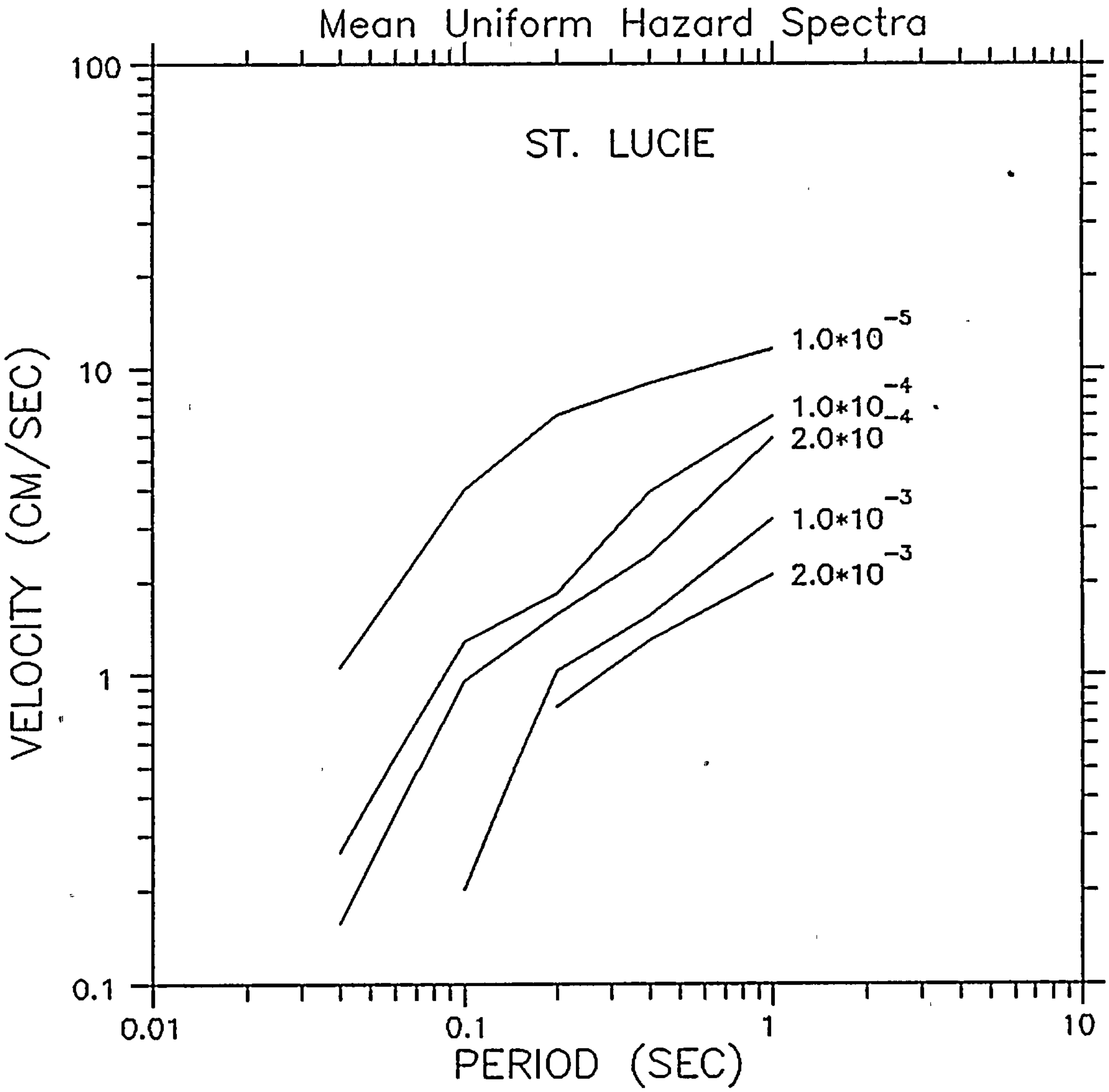

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FIGURE 1-3

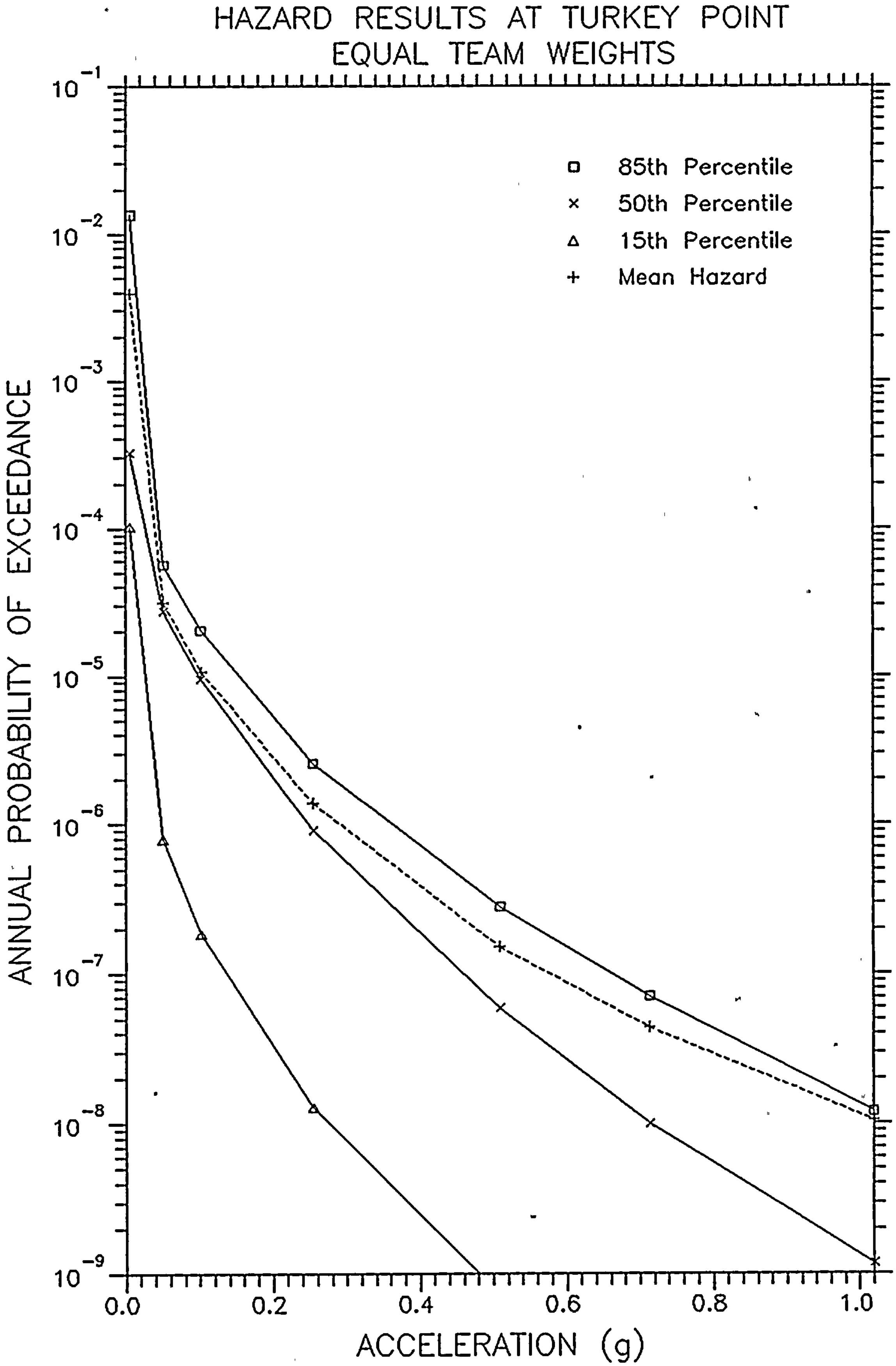

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FIGURE 1-4

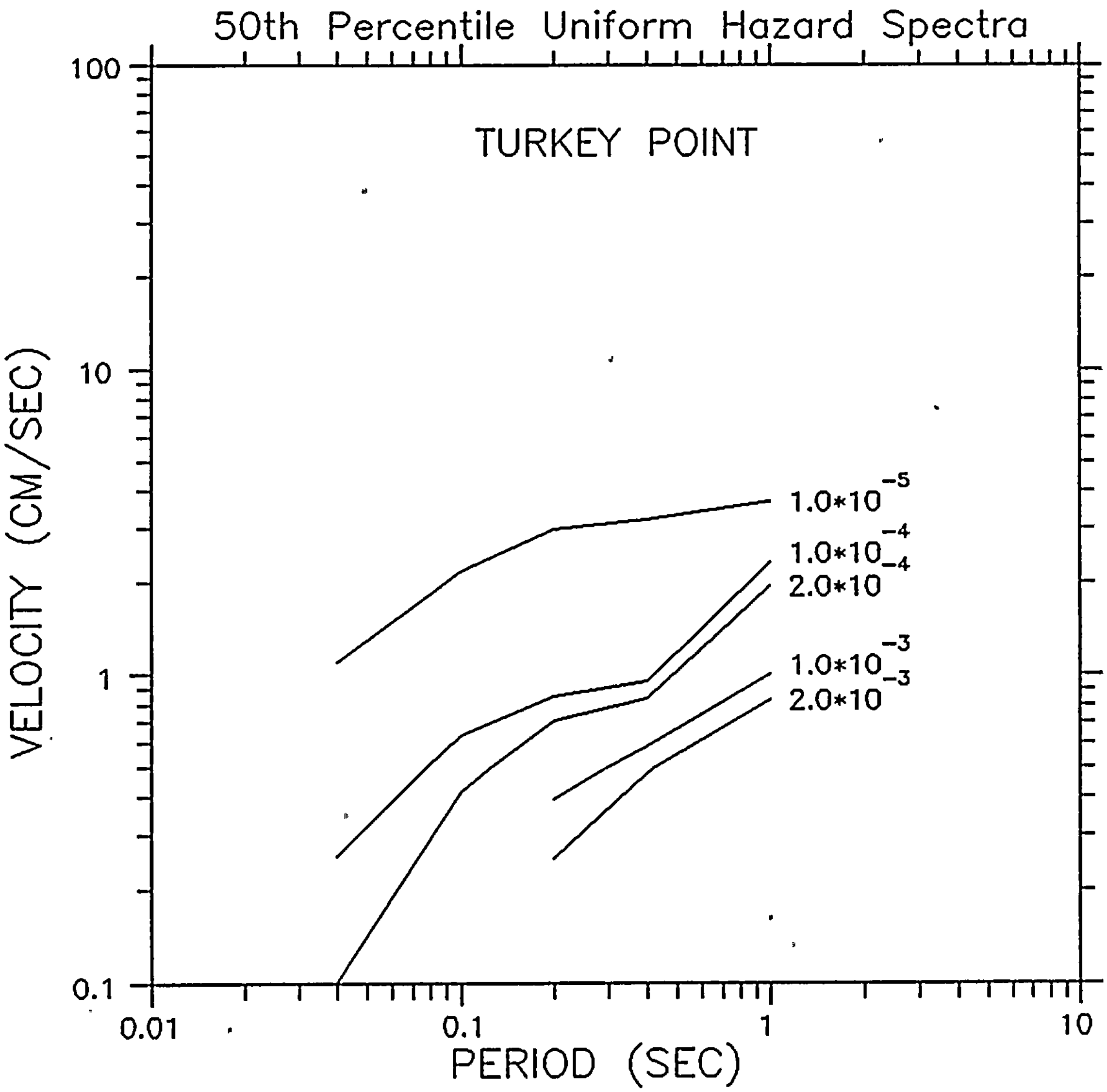

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FIGURE 1-5

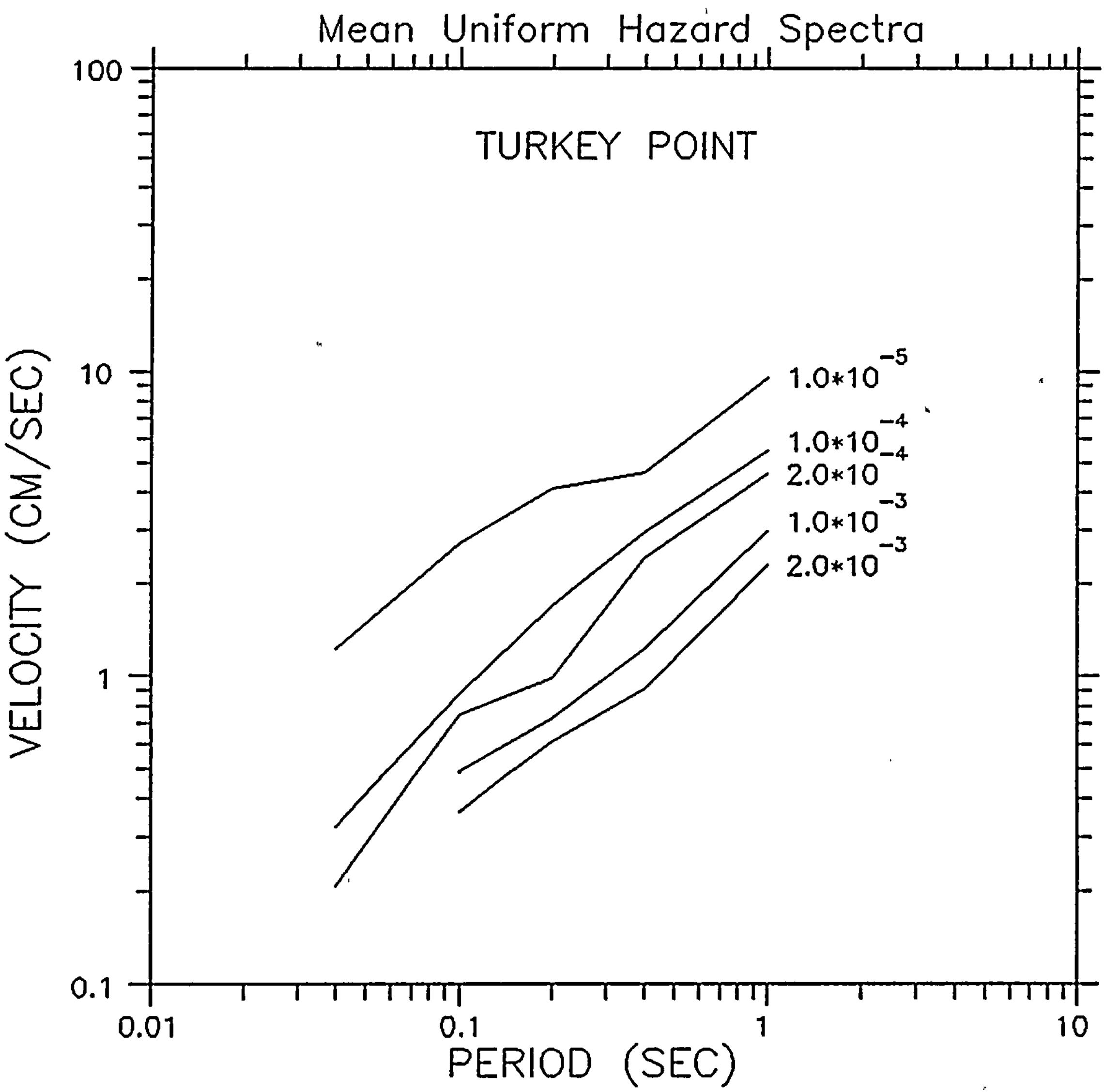

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FIGURE 1-6

2.0 INTRODUCTION

The earth's crust is comprised of a series of plates which are in motion relative to each other. Along present day plate boundaries, such as the vicinity of U.S. west coast, strain accumulates at relatively high rates. Consequently, the mean return period for large earthquakes in these areas is on the order of tens or in some cases hundreds of years. By contrast, deformation in the interior areas of plates, such as the Eastern United States, occurs at much slower rates, resulting in lower levels of seismicity. In these regions, the return period between moderate to large seismic events may be on the order of thousands or perhaps even tens of thousands of years.

A review of historical seismicity occurring in the Eastern U.S. reveals that the overall level of Eastern U.S. seismicity is relatively low, consistent with its setting. However, at some locations, such as New Madrid, Missouri and Charleston, South Carolina the levels of historical and/or instrumental seismicity are relatively high.

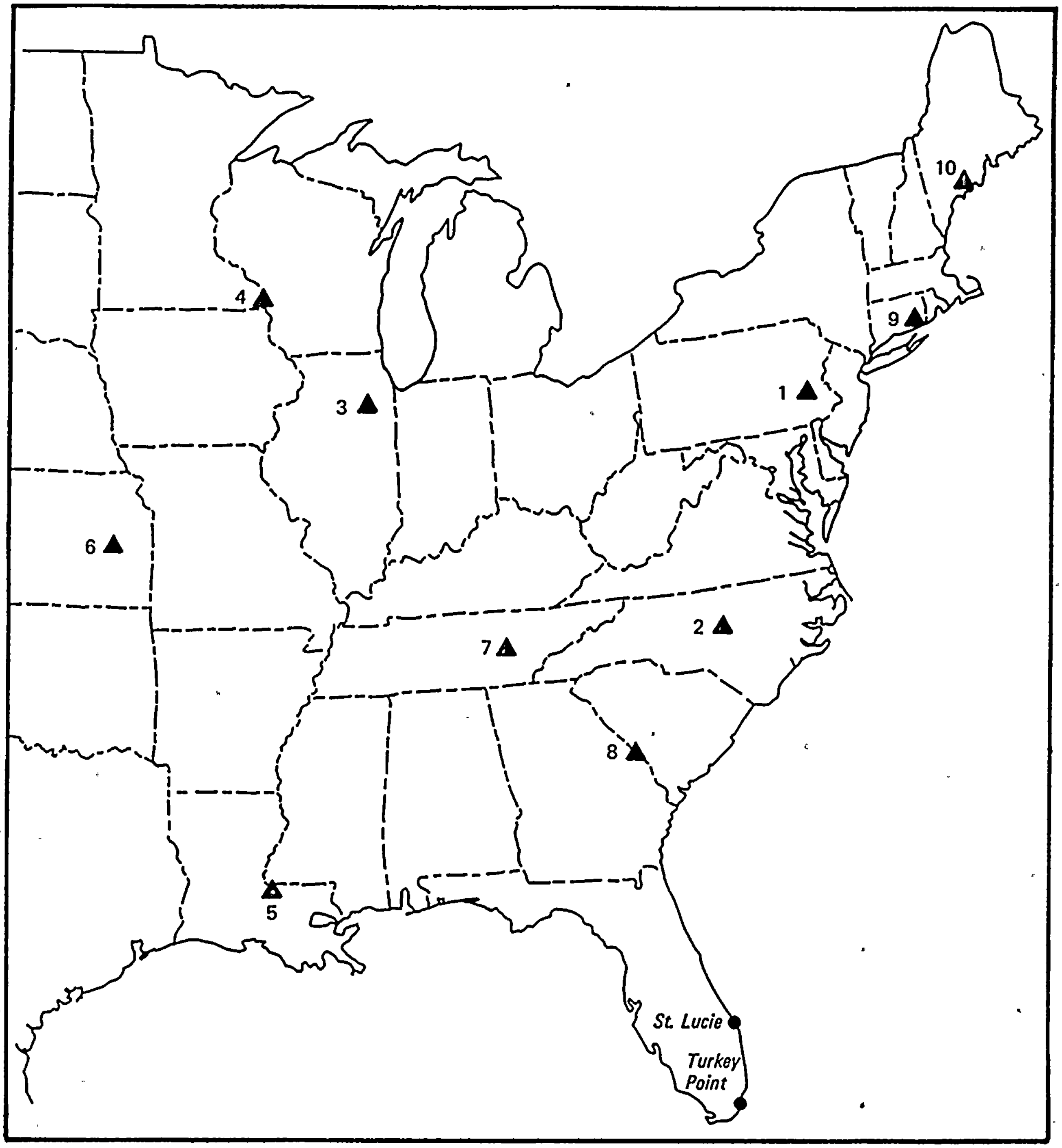
The 1811-12 New Madrid earthquakes and the 1886 Charleston earthquake stand out as the most significant events to occur in the Eastern U.S. during historical times. Consequently the cause of these earthquakes and the potential for similar large events occurring elsewhere in the region must be addressed during the development of seismic design criteria for critical facilities. To date the criteria used by the NRC in establishing seismic design values for nuclear facilities in the Eastern United States as outlined in Appendix A to 10 CFR Part 100 require that seismicity be correlated with a tectonic structure or in the absence of such a seismogenic structure be correlated with a specific tectonic province. Based in part on the opinions expressed by the AEC and the U.S.G.S. in the late 1960's and early 1970's, the NRC has taken the position that seismicity occurring in the New Madrid and Charleston areas are related to tectonic structures unique to the epicentral areas of the 1811-1812 and 1886 events, and for the purposes of seismic design, the occurrence of similar large earthquakes outside these areas is not considered credible.

Since the early 1970's, multidisciplinary investigations of the tectonics and seismicity of the Eastern U.S. have been carried out with the goal of understanding the cause of Eastern seismicity, thus leading to a better comprehension of the seismic hazard in the region. Based on these studies various models have been put forward to explain Eastern U.S. seismicity. As a result of these recent studies, the faults most likely associated with the historical and instrumental seismicity recorded in the New Madrid area have been identified. However, to date no geologic structure has been conclusively identified as the source of the seismicity in the Charleston, S.C. area. Furthermore, these studies have failed to unequivocably define the causative mechanism(s) of this seismicity. Consequently, in 1982, the U.S.G.S. clarified their earlier position on this issue and concluded that based on available data there appear to be other areas of the Eastern U.S. that are characterized by tectonic features similar to those identified in the Charleston region, thus inferring that the potential for events similar to the 1886 Charleston earthquake may exist outside the Charleston, South Carolina area.

As a result of the unresolved questions regarding the cause and source of seismicity in the region of the United States east of 105°W longitude (Eastern U.S.), the U.S. Nuclear Regulatory Commission (NRC) is actively pursuing the use of probabilistic methods, as alternatives to the deterministic methods used in the past, to determine the adequacy of the seismic design of nuclear facilities in the Eastern U.S. The methodology takes into account the uncertainties in source geometry, seismicity parameters and ground motion for large earthquakes that could occur in the Eastern U.S. As part of the NRC-funded investigations, the Lawrence Livermore National Laboratory (LLNL) initially conducted probabilistic seismic hazard evaluations for ten "sample sites" whose locations are shown on Figure 2-1. Recently it published an eight volume report on seismic hazard characterization of 69 nuclear plant sites east of the Rocky Mountains, and presented comparisons to previous results for ten test sites (Bernreuter et al., 1989). A parallel probabilistic seismic hazard study, based on an intensive data collection and evaluation effort, was implemented by the Electric Power Research Institute (EPRI) (1986-87) with the assistance of six Technical Evaluation Contractors (TEC). Both the NRC-funded

LLNL studies, and the EPRI investigations, funded by a group of nuclear power plant owners in the Eastern U.S., utilize comprehensive seismic and tectonic data bases and recent advances in the probabilistic methodologies to perform a state-of-the-art seismic hazard evaluation for sites located in the Eastern U.S.

In light of these recent advances in probabilistic seismic risk assessment, the Florida Power and Light Company (FP&L), Nuclear Licensing Department requested that Ebasco Services Incorporated (ESI) perform a state-of-the-art seismic hazard evaluation for its St. Lucie and Turkey Point nuclear power plant sites and generate the associated uniform hazard spectra for comparison purposes. The evaluation was performed under the Quality Assurance requirements of 10 CFR 50 Appendix B, and used the methodology, computer programs, and the tectonic and seismic input parameters developed as a result of the EPRI investigations. In addition, the scope of the ESI investigation included an evaluation of the contribution to seismic hazard at the St. Lucie and Turkey Point sites from the possible occurrence of large magnitude earthquakes in the Northern Caribbean.



Key to Site Index Numbers

Sites considered by LLNL to fall in the Southeastern Region of the U.S.

1. Limerick *
2. Shearon Harris *
3. Braidwood
4. La Crosse
5. River Bend
6. Wolf Creek
7. Watts Bar *
8. Vogtle *
9. Millstone
10. Maine Yankee

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Location of the LLNL Sample Sites and St. Lucie and Turkey Point

FIGURE 2-1

3.0 REVIEW OF EPRI SEISMIC HAZARD INVESTIGATIONS

As noted the Electric Power Research Institute (EPRI) implemented a probabilistic seismic hazard evaluation in parallel to the NRC funded studies. The main objectives of the EPRI program were to:

1) compile from existing sources a data base consisting of geological, tectonic, geophysical, and seismological information suitable for evaluating the physical significance and applicability of causative models for earthquake generation in the Eastern U.S.

2) develop interpretative seismic source zones for moderate and large earthquakes in the Eastern U.S.

3) develop seismicity parameters for the zones

4) estimate the probabilities of activity for each zone

5) assess the uncertainty in the seismicity parameters for each zone.

The resulting information could be used to assess the seismic hazard for facilities in the eastern U.S..

To accomplish these objectives, EPRI enlisted the services of six Technical Evaluation Contractors (TEC) to work in parallel to compile a data base and perform tectonic evaluations leading to the interpretation of seismic source zones and their associated seismicity parameters. Data and information compiled by the six TEC were catalogued by the Data Management Contractor and discussed at workshops coordinated by the Seismic Hazards Methodology Contractor.

Workshops were the key method of exchanging information and interpretations among the TEC. Although consensus interpretations were not required, a common understanding of competing interpretations and their technical bases were sought. The seismic hazards methodology contractor coordinated and managed the tectonic interpretation workshops. Guidance and assistance in characterizing uncertainty and assigning weights to the alternative interpretations and their parameter values were provided to the TEC in the several workshops that were held at regular intervals throughout the study. The topics covered by the various workshops included:

1) Inventory of tectonic models and assessment of data needs to perform tectonic evaluations,
2) Review of data sets and initial tectonic models evaluations,
3) Review of tectonic model evaluations
4) Tectonic framework interpretation
5) Review of tectonic framework and seismic source interpretation
6) Methodology for seismicity parameter evaluation
7) Review of seismicity parameters.

The results of the EPRI study were published in a series of documents comprised of workshop proceedings, reports on the seismic hazard methodology, and reports on the tectonic framework and seismic source zones of the Eastern U.S. by the six TEC. (EPRI, 1986 and 1987).

4.0 THE EPRI COMPUTER PROGRAMS FOR SEISMIC HAZARD ANALYSIS

The EPRI computer programs for seismic hazard analysis follow the general methodology outlined by Cornell (1968) and were derived primarily from the McGuire (1976) seismic risk program. However, the EPRI Programs differ from the McGuire Program in four main aspects:

1) In the EPRI Study, seismic sources are subdivided into one-degree cells. The "a" and "b" values can be specified separately for each cell, thus allowing the user to specify spatial variability in the seismicity properties of a source,

2) The EPRI Programs allow the user to specify uncertainties on the seismic source configuration, the seismicity parameters, the upper-bound magnitudes, and the attenuation functions. The effects of these uncertainties are kept separate so as to obtain uncertainties as well as mean values in the final hazard estimates,

3) The EPRI Programs also aggregate the results obtained from the application of the interpretations of the different TECs, and

4) The EPRI Programs perform simultaneously hazard analyses on several measures of ground motion, such as Peak Ground Acceleration (PGA), Pseudo-Spectral Relative Velocity (PSRV) for 5% damping at 1, 2.5, 5, 10 and 25 hz.

The computer programs used to perform the seismic hazard computations are collectively referred to as the EQHAZARD package. EQHAZARD consists of four modules:

EQPARAM: Performs analysis of the historical earthquake catalog, and calculates recurrence parameters that are allowed to vary spatially within specified seismic source geometries.

EQHAZ: Calculates the seismic hazard contribution at a given site (geographic position) for each source in the vicinity, and for multiple alternative interpretations of source parameters and multiple ground motion attenuation functions.

EQPOST: Computes the total seismic hazard at a site for each set of alternative interpretations of seismic sources and source combinations.

EQAG: Aggregates the total seismic hazard at a site due to multiple interpretations.

A detailed description of the EPRI Seismic Hazard Methodology for the Central and Eastern U.S. is given in volumes 1, 2 and 3 (EPRI, 1986 and 1987).

5.0 INPUT DATA

The methodology developed by the EPRI for the computation of seismic hazard was applied to the St. Lucie and Turkey Point nuclear power plant sites.

A probabilistic seismic hazard analysis consists of estimating the annual probabilities that various levels of earthquake ground motions will be exceeded at a site. In the hazard computation, the following input data are needed: 1) a description of earthquake source zones and an estimation of the probability of activity of each zone, singly or in combination with other sources, 2) maximum magnitude distribution and seismicity parameter distribution for each source zone, along with their associated probabilities, for each of the six TEC, and 3) an estimation of the attenuation of ground motion between these sources and the site under investigation.

5.1 Seismic Source Zones

Seismic source interpretations for the EPRI program were made independently by the six TEC teams, and collectively these sources represent the current state of scientific knowledge on the subject. In addition, a formal subjective probability assessment approach was developed to permit each team to express its confidence that a seismic source is the true explanation of earthquake activity, thus enabling uncertainty to be understood and quantified. Uncertainty was considered in terms of the state of scientific knowledge of earthquake causes and characteristics, and in terms of limitations imposed by an incomplete data base. The method also allows specification of dependencies among sources. For example, if two sources represent different structures which cannot be activated at the same time, this aspect of the source behavior becomes part of the source representation. If there are uncertainties in the boundary of a source, it can also be accommodated by using a set of possible alternative boundaries. A subjective probability is assigned to each alternate source geometry representing the likelihood that it is the correct source configuration.

The seismic source zones that were used in the seismic hazard evaluation for the St. Lucie and Turkey Point Sites are grouped by TEC and listed in Table 5-1. The location and extent of these seismic source zones are shown on Figures 5-1 through 5-6. The probability of activity of these sources, their interdependencies, the maximum magnitude distribution, and the choices of smoothing options given by the six TEC for calculation of seismicity parameters are given in the EQHAZARD Primer (EPRI, 1989).

Some of the Caribbean sources of high seismicity are closer to the sites than the Charleston or New Madrid sources. This is especially true for the Turkey Point site. Consequently, we investigated the tectonics of the Northern Caribbean region to delineate seismic source zones (Figure 5-7) and develop associated seismicity parameters for that region (Appendix B). These data were then used to evaluate the hazard at the sites from earthquakes in the Northern Caribbean.

5.2 Seismicity Parameters

Seismicity parameters were developed for each source configuration separately. To model the statistical occurrence of future earthquakes within a source, EPRI utilized two approaches: one that specifies spatially uniform activity within a source, and the other that allows for spatial variation of activity within a source. The flexibility of the second approach offers the advantage of representing variations in earthquake occurrence over a large region.

5.3 Attenuation Equations

EPRI adopted the following standard form of the attenuation equation to characterize ground motion from a given earthquake magnitude m_{Lg} and hypocentral distance R in kilometer.

$$\ln y = a + b\, m_{Lg} + c \ln R + d\, R$$

where a, b, c, and d are coefficients derived by theoretical or empirical methods. The equation predicts the mean of the natural logarithm of y, the ground motion parameter (spectral velocity in cm/sec, or acceleration in cm/sec^2).

The uncertainty in ground motion is incorporated in the seismic hazard analysis by considering multiple attenuation models. Weights may be assigned to each model by experts, based on the credibility that is given to the hypothesis that it is the "true" ground motion.

In the EPRI/SOG hazard computations for nuclear power plant sites in the eastern U.S. the following three attenuation models were used.

1) The attenuation functions derived by McGuire et al. (1988), using a ω-squared model with stress drop of 100 bars.
   weight: 0.50

2) The attenuation functions computed by Boore and Atkinson (1987), using a ω-squared model with stress drop of 100 bars.
   weight: 0.25

3) Nuttli (1986) attenuation model combined with the Newmark and Hall (1982) response spectral shape.
   weight: 0.25

The first two of these models are based on a random-vibration method, which utilizes a source scaling model, a random-process representation of acceleration, and a simplified representation of propagation effects. The coefficients in the above empirical attenuation equation are summarized in Table 5-2.

A standard error of 0.50 in ln y was assumed for all models in the hazard computations. A focal depth of 10 km for earthquakes in each source zone was assumed in the risk computation.

Table 5-1
Computerized Data Base Label No. of Source Zones

TEC Name	TEC Label No. (Used on TEC Maps)	Source Name	Data Base Label No. (Used on Computer Files)
Bechtel Group	13	Mesozoic Basins	01300
	30	New Madrid	03000
	31	Reelfoot Rift	03100
	H	Charleston Area	05200
	N-3	Charleston Faults	05900
	BZ-0	New Madrid Region	00100
	BZ-1	Gulf Coast Background	00600
	BZ-4	Atlantic Coast Background	02000
Dames & Moore	20	Southern Coastal Margin	02000
	21	New Madrid	02100
	22	Reelfoot Rift	02200
	22-21B	Reelfoot Rift-New Madrid	91500
	52	Charleston Rift	05200
	53	Southern Appalachian Default	05300
	54	Charleston Seismic Zone	05400
	65	Dunbarton Triassic Basin	06500
Law Engineering	04a	Reelfoot Rift(A)	00401
	04b	Reelfoot Rift(B)	00402
	22	Reactivated Eastern Seaboard	02200
	08	Mesozoic Basins	00816
	18	Reelfoot Rift Faults	01800
	35	Charleston	03500
	108	Brunswick Background.	04300
	126	Southern Coastal Block	06001
	M-37	Mafic Pluton	03837
	M-38	Mafic Pluton	03838
	M-39	Mafic Pluton	03839
	M-40	Mafic Pluton	03840
	M-41	Mafic Pluton	03841
	M-42	Mafic Pluton	03842
	M-43	Mafic Pluton	03843
	M-44	Mafic Pluton	03844
	M-45	Mafic Pluton	03845
	M-48	Mafic Pluton	03848
	M-49	Mafic Pluton	03849
	M-50	Mafic Pluton	03850

Table 5-1 - continued

Table 5-1 (Continued)
Computerized Data Base Label No. of Source Zones

TEC Name	TEC Label No. (Used on TEC Maps)	Source Name	Data Base Label No. (Used on Computer Files)
Rondout Associates	1	New Madrid	00100
	2	New Madrid Rift	00200
	24	Charleston	02400
	26	South Carolina	02600
	49-05	Appalachian Basement Background	04905
	51	Gulf Coast to Bahamas Background	05100
Weston Geophysical	25	Charleston	02500
	26	South Carolina	02600
	31	New Madrid	03100
	32	Reelfoot Rift	03200
	104	Southern Coastal Plain Background	05400
	107	Gulf Coast Background	05700
	Z032-Z031	Combination (C-11)	91100
	Z104-Z022	Combination (C-20)	92000
	Z104-Z025	Combination (C-21)	92100
	Z104-Z026	Combination (C-22)	92200
	Z104-Z022 -Z026	Combination (C-23)	92300
	Z104-Z022 -Z025	Combination (C-24)	92400
	Z104-Z028BCDE -Z022 -Z025	Combination (C-27)	92700
	Z104-Z028BCDE -Z022 -Z026	Combination (C-28)	92800
Woodward-Clyde	1	Continental Shelf Edge	00100
	29	SC Gravity Saddle (extended)	02900
	29A	SC Gravity Saddle #2	0290A
	30	Charleston NOTA	03000
	40	Central Reelfoot Rift	04000
	41	Combination (C-8)	90800
	44	New Madrid Loading Zone	04400

TABLE 5-2

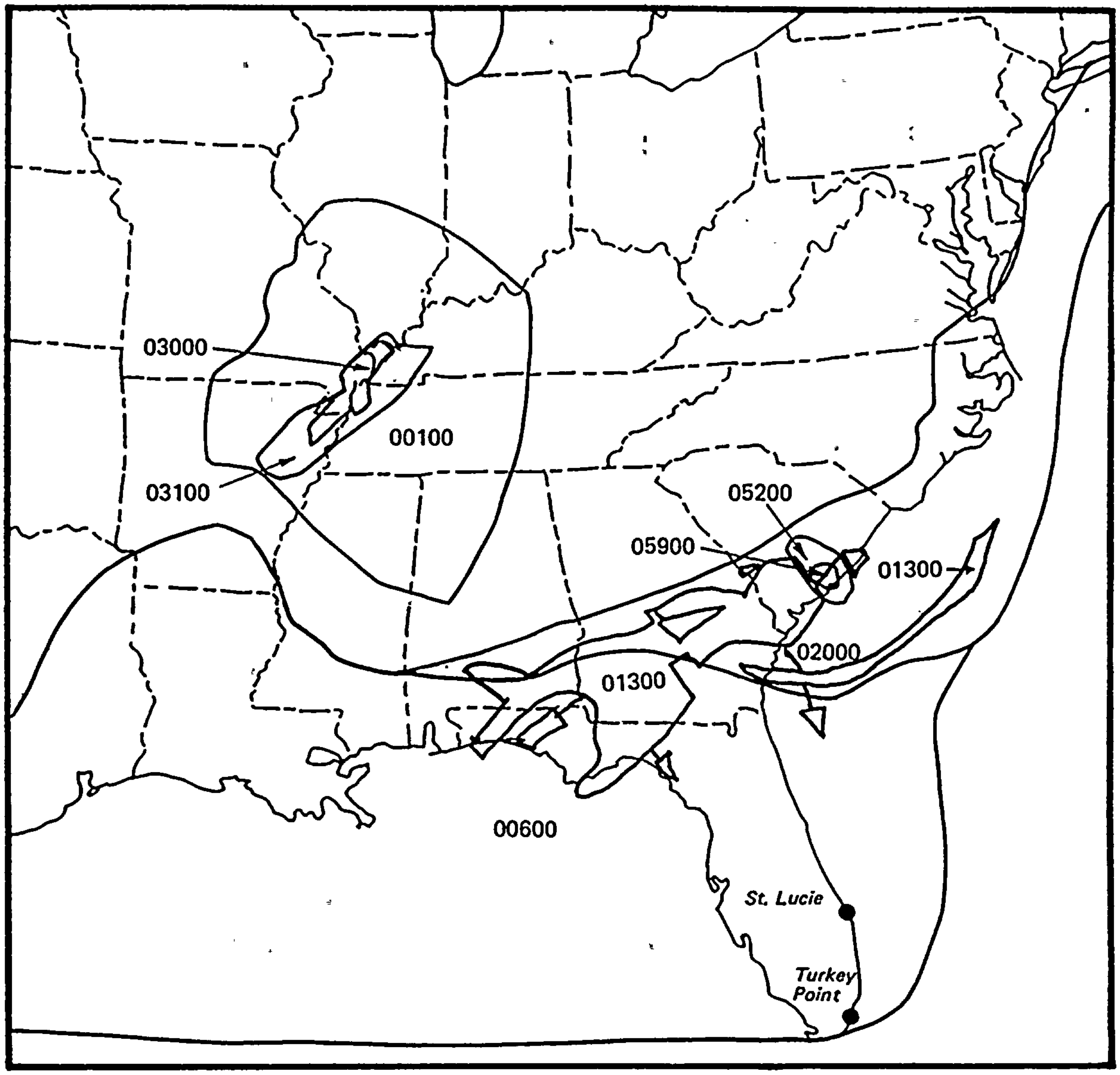
Attenuation Equations for Hazard Computations

$$\ln y = a + b\, m_{Lg} + c \ln R + d\, R$$

Model	Weight	y[1]	a	b	c	d
McGuire et al. (1988)	0.5	Acceleration	2.55	1.00	-1.00	-0.0046
		PSV(25 Hz)	-1.63	0.98	-1.00	-0.0053
		PSV(10 Hz)	-1.55	1.05	-1.00	-0.0039
		PSV(5 Hz)	-2.11	1.20	-1.00	-0.0031
		PSV(2.5 Hz)	-3.81	1.49	-1.00	-0.0024
		PSV(1 Hz)	-7.95	2.14	-1.00	-0.0018
Boore and Atkinson (1987)	0.25	All frequencies and acceleration	Complicated functional form (Eq. 12 and 13, and Table 3 in Boore and Atkinson, 1987).			
Nuttli (1986), Newmark-Hall Amplification Factors	0.25	Acceleration	1.38	1.15	-0.83	-0.0028
		PSV(25 Hz)[2]	-3.53	1.15	-0.83	-0.0028
		PSV(10 Hz)[2]	-2.13	1.15	-0.83	-0.0028
		PSV(5 Hz)[2]	-1.32	1.15	-0.83	-0.0028
		PSV(2.5 Hz)[2]	-0.62	1.15	-0.83	-0.0028
		PSV(1 Hz)[2]	0.29	1.15	-0.83	-0.0028

[1] Peak acceleration in cm/sec/sec, PSV - pseudo relative velocity at 5% damping in cm/sec, and R in kilometers.

[2] For a given m_{Lg} and R, ln y is the smaller of $a + b\, m_{Lg} + c \ln R + d\, R$ and $-8.3 + 2.3\, m_{Lg} - 0.83 \ln R - 0.0012\, R$.



Source Zone		Source Zone Contributing to Hazard	
Number	Name	St. Lucie	Turkey Point
01300	Mesozoic Basins	01300	
03000	New Madrid		
03100	Reelfoot Rift		
05200	Charleston Area	05200	
05900	Charleston Faults		
00100	New Madrid Background		
00600	Site Background	00600	00600
02000	Adjacent Background	02000	02000

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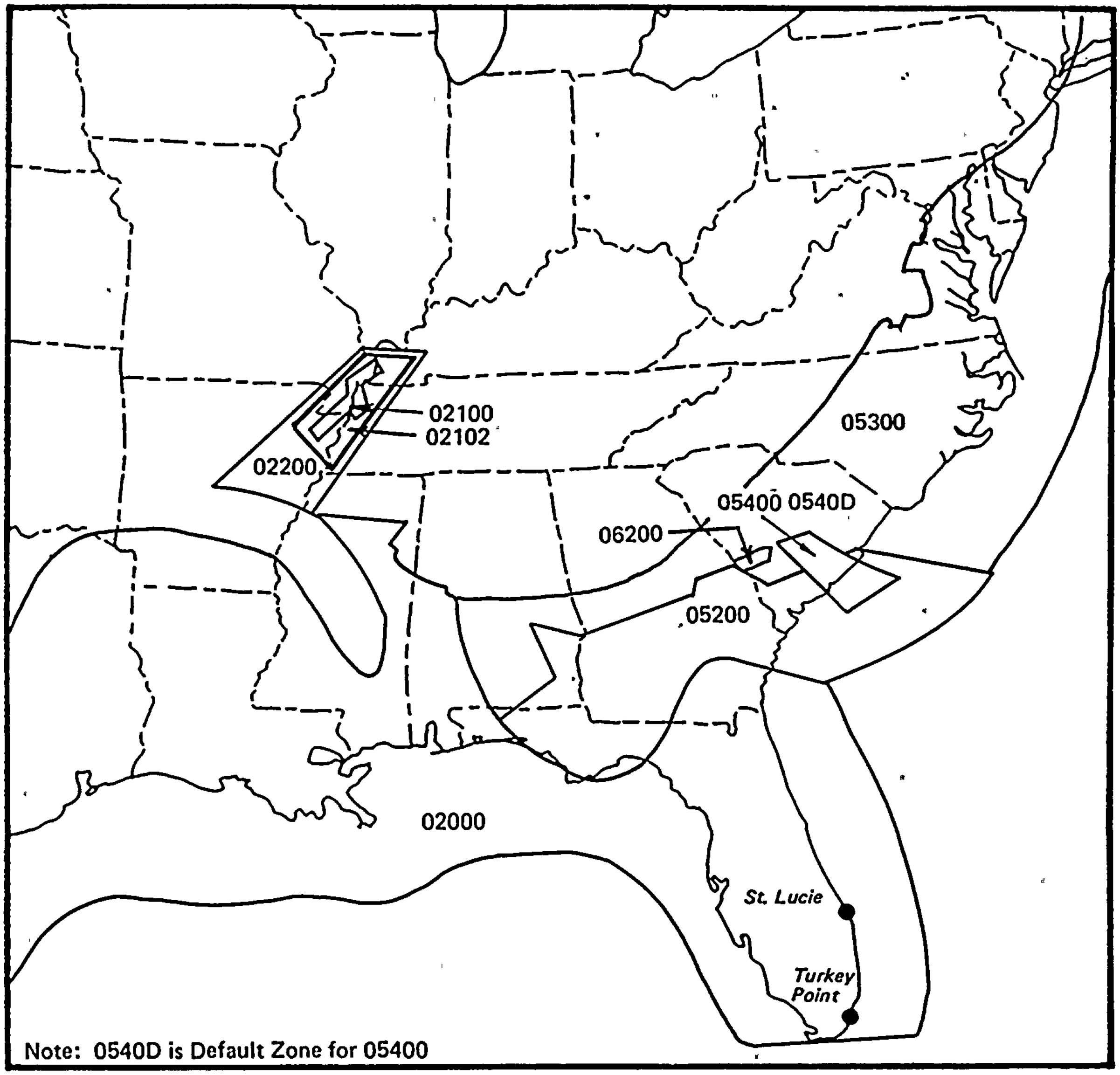
Seismic Source Zones Considered for the Florida Power and Light Company (Bechtel Group Inc. Model)

FIGURE 5-1



Source Zone		Source Zone Contributing to Hazard	
Number	Name	St. Lucie	Turkey Point
02000	Southern Coastal Margin	02000	02000
02100	New Madrid		
02200	Reelfoot Rift		
05200	Charleston Rift	05200	<u>05200</u>
05300	Southern Appalachian Default	05300	<u>05300</u>
05400	Charleston Seismic Zone	05400	<u>05400</u>
0540D	Charleston Default Zone	0540D	<u>0540D</u>
06200	Dunbarton Triassic Basin		

NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

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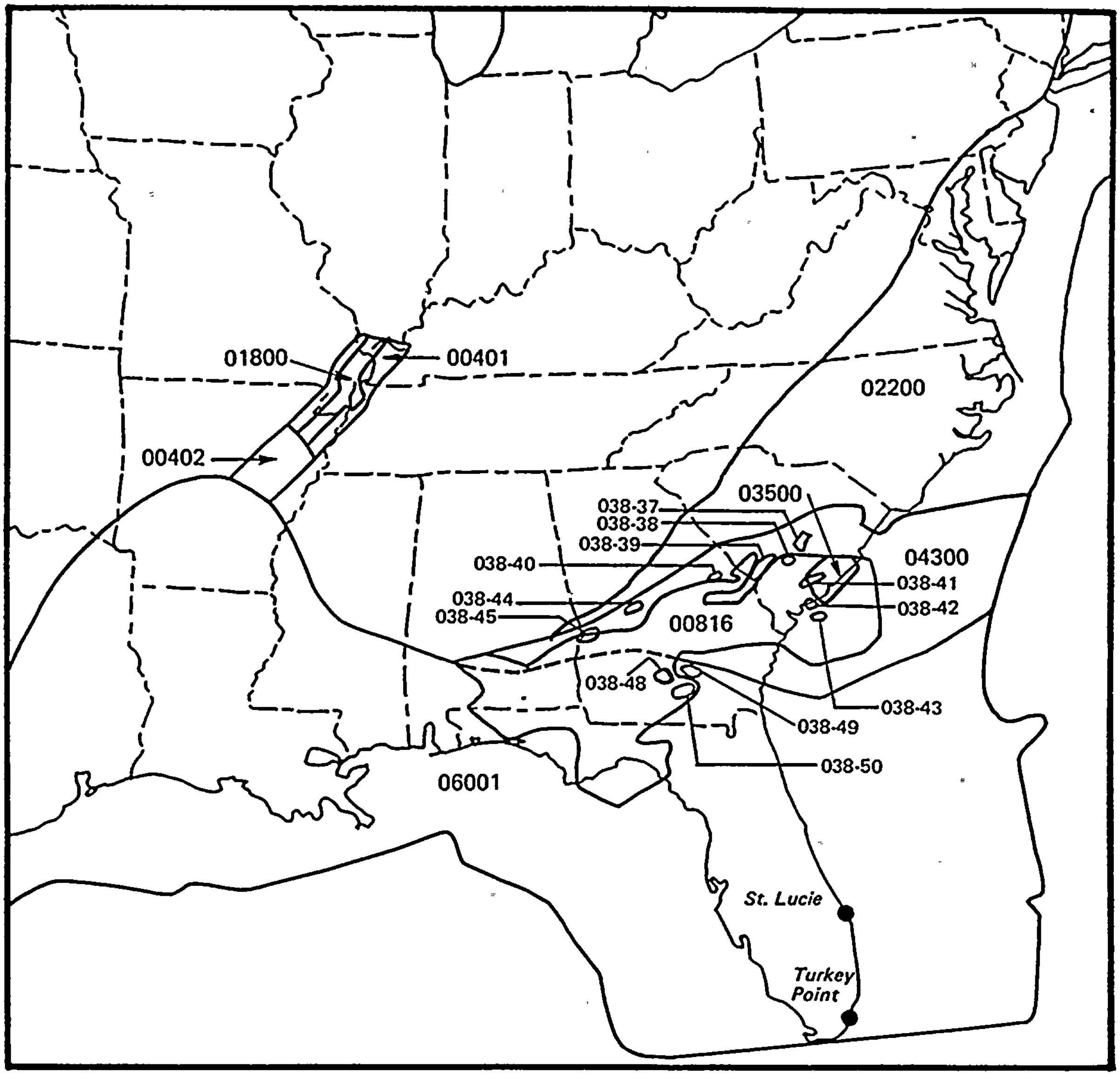
Seismic Source Zones Considered for the Florida Power and Light Company (Dames and Moore Model)

FIGURE 5-2



Source Zone Number	Source Zone Name	Source Zone Contributing to Hazard: St. Lucie	Source Zone Contributing to Hazard: Turkey Point
00401	Reelfoot Rift (A)		
00402	Reelfoot Rift (B)		
00816	Mesozoic Basins	00816	00816
01800	Reelfoot Rift Faults		
02200	Reactivated Eastern Seaboard	02200	02200
03500	Charleston		
04300	Brunswick	04300	04300
06001	Southern Coastal Block	06001	06001
03837 to 03845	Mafic Plutons	03842 03848	03842 03848
03848 to 03850	Mafic Plutons	03849 03850	

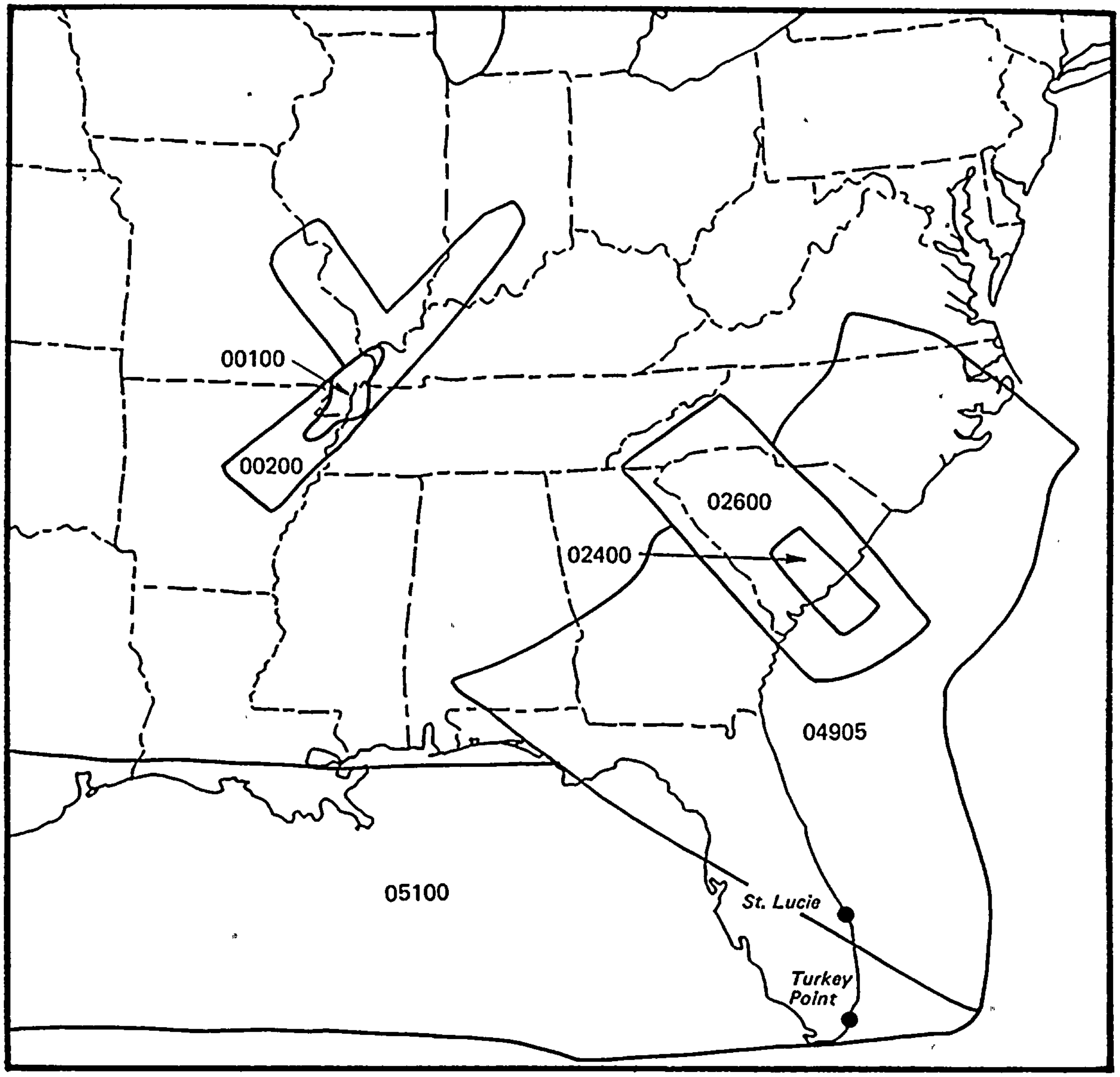
NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

Florida Power and Light Company

EBASCO SERVICES INCORPORATED

Seismic Source Zones Considered for the Florida Power and Light Company (Law Engineering Company Model)

FIGURE 5-3



Source Zone Number	Name	Source Zone Contributing to Hazard: St. Lucie	Turkey Point
00100	New Madrid		
00200	New Madrid Rift		
02400	Charleston	02400	02400
02600	South Carolina	02600	02600
04905	Appalachian Basement Background	04905	04905
05100	Gulf Coast to Bahamas Background	05100	05100

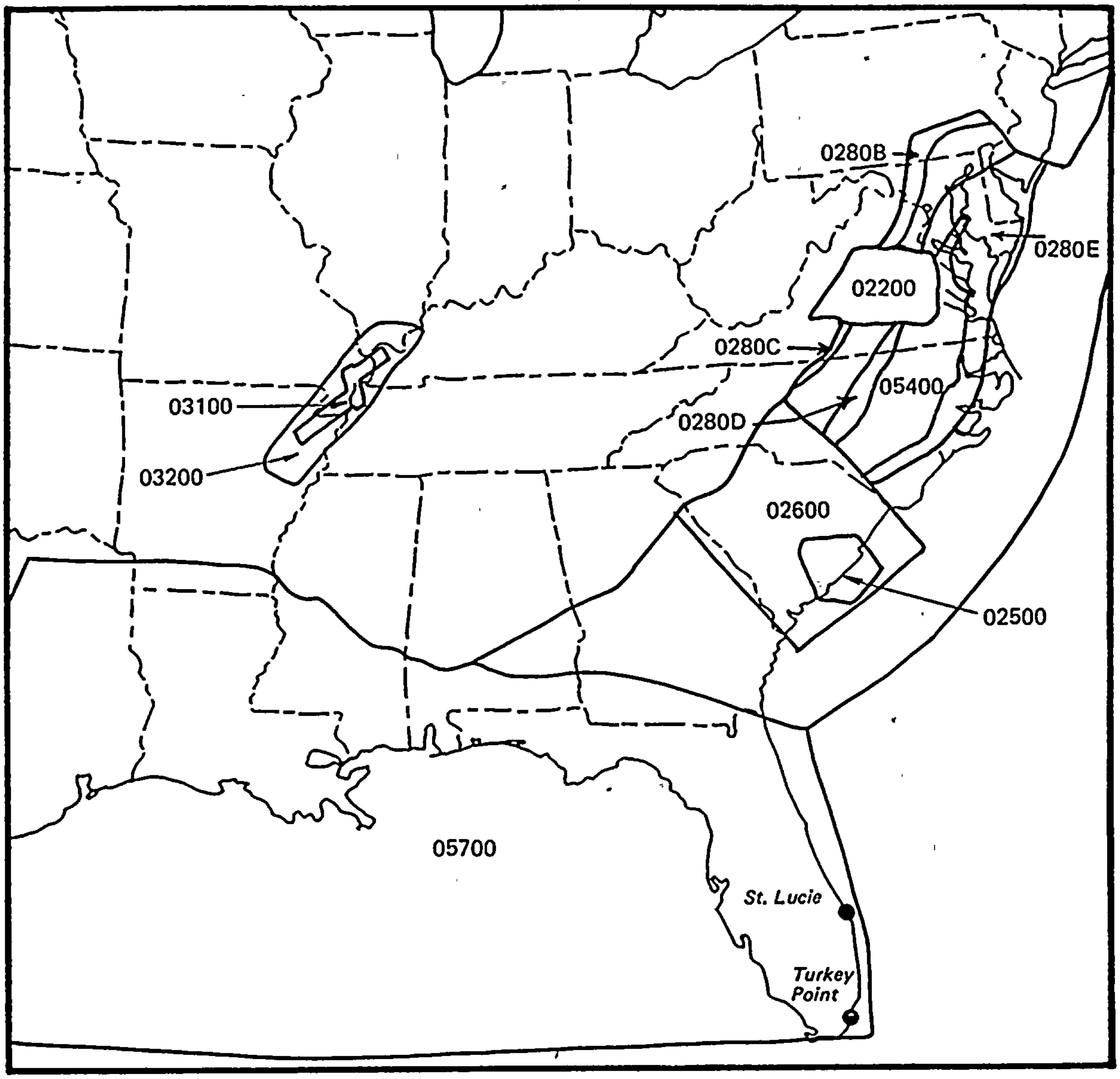
NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

Florida Power and Light Company

EBASCO SERVICES INCORPORATED

Seismic Source Zones Considered for the Florida Power and Light Company (Rondout Associates Model)

FIGURE 5-4



Source Zone Number	Source Zone Name	Source Zone Contributing to Hazard: St. Lucie	Source Zone Contributing to Hazard: Turkey Point
02500	Charleston	02500	02500
02600	South Carolina	02600	02600
03100	New Madrid		
03200	Reelfoot Rift		
05400	Southern Coastal Plain	05400	05400
05700	Gulf Coast Background	05700	05700
91100*	Combination 11		
92000* to 92400*	Combinations 920 to 924	92000 to 92400	92000 to 92400
92700*	Combination 927	92700	92700
92800*	Combination 928	92800	92800

*Geometry of Combination Sources Given in Table 1.

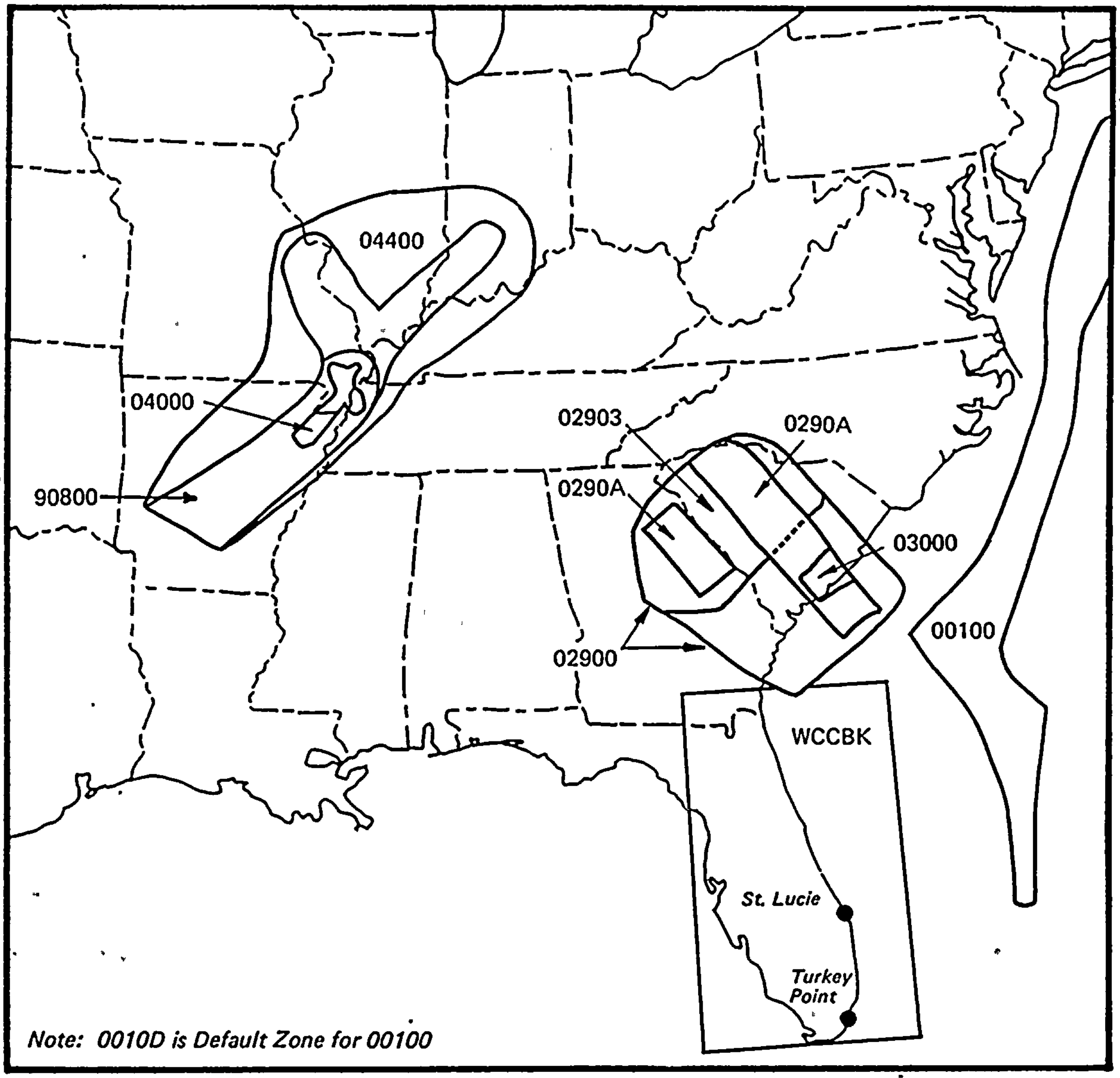
NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

Florida Power and Light Company

EBASCO SERVICES INCORPORATED

Seismic Source Zones Considered for the Florida Power and Light Company (Weston Geophysical Corp. Model)

FIGURE 5-5



Source Zone		Source Zone Contributing to Hazard	
Number	Name	St. Lucie	Turkey Point
00100	Continental Shelf Edge		
02900	South Carolina, Gravity Saddle (extended)	02900	02900
0290A	South Carolina, Gravity Saddle No. 2	0290A	0290A
03000	Charleston NOTA		
04000	Central Reelfoot Rift		
90800	Reelfoot Rift		
04400	New Madrid Loading Zone		
WCCBK	Background	WCCBK	WCCBK

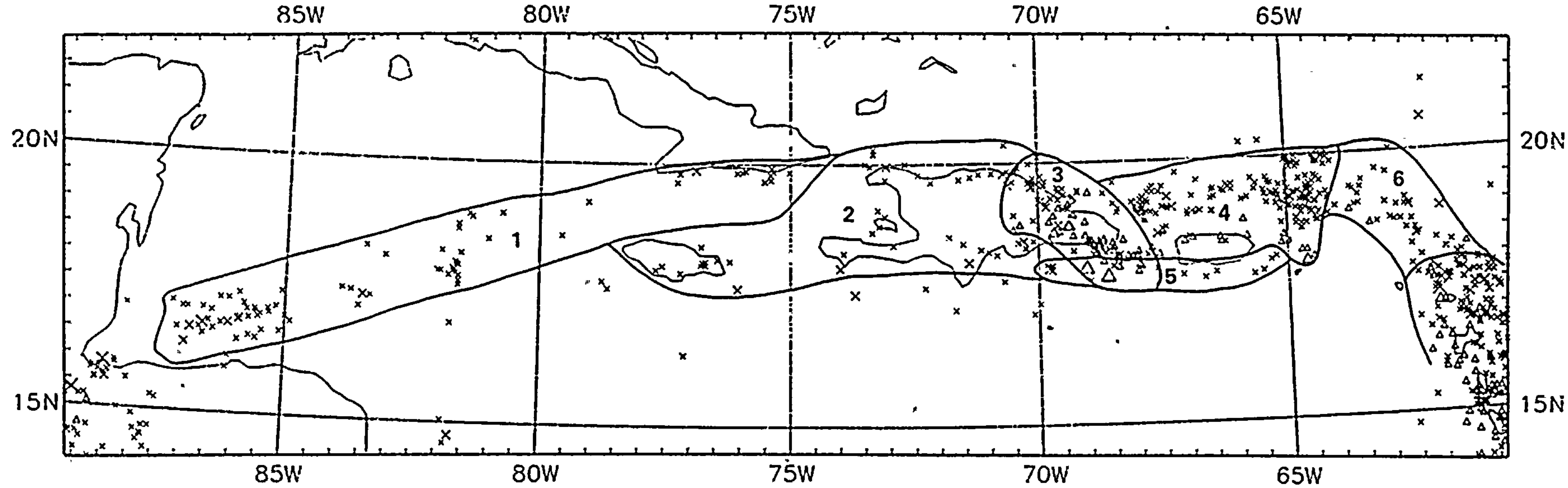
NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

Florida Power and Light Company

EBASCO SERVICES INCORPORATED

Seismic Source Zones Considered for the Florida Power and Light Company (Woodward Clyde Consultants Model)

FIGURE 5-6



Source Zone		Source Zone Contributing to Hazard	
Number	Name	St. Lucie	Turkey Point
1 CB001	Cayman Trough	1	1.
2 CB002	Jamaica–Western Hispaniola	2	2
3 CB003	Eastern Hispaniola		
4 CB004	Puerto Rico Trench		
5 CB005	Muertos Trench		
6 CB006	Greater Antilles– Lesser Antilles Transition		

NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

Florida Power and Light Company

EBASCO SERVICES INCORPORATED

Seismic Source Zones Considered for the Florida Power and Light Company in the Northern Caribbean

FIGURE 5-7

6.0 HAZARD COMPUTATION

Using the EPRI software package, seismic hazards were computed for the St. Lucie and Turkey Point sites using the seismic source zones and seismicity parameters established by each of the six EPRI Technical Evaluation Contractors (TEC), and the seismic source zones and seismicity parameters identified by Ebasco Services Incorporated for the Northern Caribbean.

The EQHAZ program assesses the independent contribution of each of the selected sources at a particular site. The Law Engineering team assigned a maximum magnitude less than 5.0 to zones 04300 and 06001. In the present study, these magnitudes were upgraded to 5.01. Also, the components of source zone 01300 of the Bechtel model that are located south of latitude 34°N were included in the computations.

The source zones that contributed more than 1.0E-10 to the seismic hazard at each of the two plant sites are listed on Table 6-1, and are also identified on Figures 5-1 through 5-6. The contributions of some of the distant sources were small in the computation of hazard for the peak ground acceleration, and PSV at 25 and 10 hz, but were not negligible for PSV at frequencies 5 hz and less. These sources are underlined in Table 6-1.

Two of the Northern Caribbean sources, Cayman Trough and Jamaica-Western Hispaniola, contributed to the seismic hazard at Turkey Point, but contributed to the hazard at St. Lucie only for PSV values at frequencies 5 hz and less. Also contributions of New Madrid area sources to the seismic hazard at both plant sites for each of the six TEC were negligible.

The scenarios and weights for the source zones that contributed to seismic hazard at St. Lucie and Turkey Point sites are given in Table 6-2 and 6-3, respectively. The seismic hazard values that were calculated from each TEC model were then aggregated to generate the final hazard curves. The following operations were performed, using the

EQPOST program module, on hazard estimates of all combinations of all scenarios, by assigning equal weights to each contractor's risk computation:

1. Compute overall fractiles using equal team weights (no conditioning),
2. Compute median fractiles for each earth science team (sensitivity to earth science teams), and
3. Compute median fractiles for each attenuation function (sensitivity to attenuation functions).

TABLE 6-1
Contributing Source Zones*

TEC Team	St. Lucie	Turkey Point
Bechtel	01300, 05200, 00600, 02000, CB001, CB002	00600, 02000, CB001, CB002
Dames and Moore	02000, 05200, 05300, 05400, CB001, CB002	02000, 05200, 05300, 05400, CB001, CB002
Law Engineering	00816, 02200, 04300, 06001, 03842, 03848 03849, 03850, CB001, CB002	00816, 02200, 04300, 06001, 03842, 03848 CB001, CB002
Rondout Associates	02400, 02600, 04905, 05100, CB001, CB002	02400, 02600, 04905, 05100, CB001, CB002
Weston Geophysical Corporation	02500, 02600, 05400, 05700, 92000, 92100, 92200, 92300, 92400, 92700, 92800, CB001, CB002	02500, 02600, 05400, 05700, 92000, 92100, 92200, 92300, 92400, 92700, 92800, CB001, CB002
Woodward Clyde Consultants	02900, 0290A, WCCBK CB001, CB002	02900, 0290A, WCCBK CB001, CB002

*Notes: Source Zone numbers correspond to those on Table 4-1
CB001 and CB002 are northern Caribbean Seismic Sources described in Appendix B (see also Section 8.0)

The contributions of the underlined sources to the peak ground acceleration, PSV at 25 and 10 hz were small.

TABLE 6-2
Scenarios for Contributing Source Zones[1]
St. Lucie (frequencies greater than 5hz)

TEC Team	Scenario[2]	Weight[3]
Bechtel	00600 + 02000 + 01300 + 05200	0.05
	00600 + 02000 + 01300	0.05
	00600 + 02000 + 05200	0.45
	00600 + 02000	0.45
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + 05400	0.28
	02000 + 05400 + 05200	0.46
	02000 + 05400 + 05300	0.26
Background	02000	1.0
Law Engineering	04300 + 06001 + 02200	0.27
	04300 + 06001 + 00816	0.27
	04300 + 06001	0.46
Background	04300	0.42
	06001	0.49
Rondout Associates	02400 + 02600 + 04905 + 05100	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + 92000	0.001
	05700 + 02500 + 92100	0.012
	05700 + 02600 + 92200	0.069
	05700 + 02600 + 92300	0.312
	05700 + 02500 + 92400	0.368
	05700 + 02500 + 92700	0.126
	05700 + 02600 + 92800	0.100
	05700 + 05400	0.012
Background	05700	1.0
Woodward Clyde Consultants	WCCBK	0.573
	WCCBK + 02900	0.122
	WCCBK + 0290A	0.305
Background	WCCBK	1.0

Table 6-2 - continued

TABLE 6-2 (continued)
Scenarios for Contributing Source Zones[1]
St. Lucie (frequencies 5hz and less)

TEC Team	Scenario[2]	Weight[3]
Bechtel	00600 + 02000 + 01300 + 05200 + CB001 + CB002	0.05
	00600 + 02000 + 01300 + CB001 + CB002	0.05
	00600 + 02000 + 05200 + CB001 + CB002	0.45
	00600 + 02000 + CB001 + CB002	0.45
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + 05400 + CB001 + CB002	0.28
	02000 + 05400 + 05200 + CB001 + CB002	0.46
	02000 + 05400 + 05300 + CB001 + CB002	0.26
Background	02000	1.0
Law Engineering	04300 + 06001 + 02200 + CB001 + CB002	0.2700
	04300 + 06001 + 00816 + 03842 + 03848 + 03849 + 03850 + CB001 + CB002	0.1161
	04300 + 06001 + 00816 + CB001 + CB002	0.1539
	04300 + 06001 + 03842 + 03848 + 03849 + 03850 + CB001 + CB002	0.1978
	04300 + 06001 + CB001 + CB002	0.2622
Background	04300	0.42
	06001	0.49
Rondout Associates	02400 + 02600 + 04905 + 05100 + CB001 + CB002	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + 92000 + CB001 + CB002	0.001
	05700 + 02500 + 92100 + CB001 + CB002	0.012
	05700 + 02600 + 92200 + CB001 + CB002	0.069
	05700 + 02600 + 92300 + CB001 + CB002	0.312
	05700 + 02500 + 92400 + CB001 + CB002	0.368
	05700 + 02500 + 92700 + CB001 + CB002	0.126
	05700 + 02600 + 92800 + CB001 + CB002	0.100
	05700 + 05400 + CB001 + CB002	0.012
Background	05700	1.0

Table 6-2 - continued

TABLE 6-2 (continued)
Scenarios for Contributing Source Zones[1]
St. Lucie (frequencies 5hz and less)

TEC Team	Scenario[2]	Weight[3]
Woodward Clyde Consultants	WCCBK + CB001 + CB002	0.573
	WCCBK + 02900 + CB001 + CB002	0.122
	WCCBK + 0290A + CB001 + CB002	0.305
Background	WCCBK	1.0

Notes: 1 Source Zone numbers correspond to those on Table 1 and on Figures 2 through 7.

2 Each TEC scenario is made up of the allowable source zone combinations whose total weights, or probability of activity add up to 1.0.

3 Weight is defined as the fractional probability of activity.

TABLE 6-3
Scenarios for Contributing Source Zones[1]
Turkey Point (frequencies greater than 5hz)

TEC Team	Scenario[2]	Weight[3]
Bechtel	00600 + 02000 + CB001 + CB002	1.0
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + CB001 + CB002	1.0
Law Engineering	04300 + 06001 + 02200 + CB001 + CB002	0.27
	04300 + 06001 + 00816 + CB001 + CB002	0.27
	04300 + 06001 + CB001 + CB002	0.46
Background	04300	0.42
	06001	0.49
Rondout Associates	04905 + 05100 + CB001 + CB002	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + CB001 + CB002	1.0
Background	05700	1.0
Woodward Clyde Consultants	WCCBK + CB001 + CB002	1.0
Background	WCCBK	1.0

Table 6-3 - continued

TABLE 6-3 (continued)
Scenarios for Contributing Source Zones[1]
Turkey Point (frequencies 5hz and less)

TEC Team	Scenario[2]	Weight[3]
Bechtel	00600 + 02000 + CB001 + CB002	1.0
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + 05400 + CB001 + CB002	0.28
	02000 + 05400 + 05200 + CB001 + CB002	0.46
	02000 + 05400 + 05300 + CB001 + CB002	0.26
Law Engineering	04300 + 06001 + 02200 + CB001 + CB002	0.2700
	04300 + 06001 + 00816 + 03842 + 03848 + CB001 + CB002	0.1161
	04300 + 06001 + 00816 + CB001 + CB002	0.1539
	04300 + 06001 + 03842 + 03848 + CB001 + CB002	0.1978
	04300 + 06001 + CB001 + CB002	0.2622
Background	04300	0.42
	06001	0.49
Rondout Associates	02400 + 02600 + 04905 + 05100 + CB001 + CB002	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + 92000 + CB001 + CB002	0.001
	05700 + 02500 + 92100 + CB001 + CB002	0.012
	05700 + 02600 + 92200 + CB001 + CB002	0.069
	05700 + 02600 + 92300 + CB001 + CB002	0.312
	05700 + 02500 + 92400 + CB001 + CB002	0.368
	05700 + 02500 + 92700 + CB001 + CB002	0.126
	05700 + 02600 + 92800 + CB001 + CB002	0.100
	05700 + 05400 + CB001 + CB002	0.012
Background	05700	1.0

Table 6-3 - continued

TABLE 6-3 (continued)
Scenarios for Contributing Source Zones[1]
Turkey Point (frequencies 5hz and less)

TEC Team	Scenario[2]	Weight[3]
Woodward Clyde Consultants	WCCBK + CB001 + CB002	0.573
	WCCBK + 02900 + CB001 + CB002	0.122
	WCCBK + 0290A + CB001 + CB002	0.305
Background	WCCBK	1.0

Notes: 1 Source Zone numbers correspond to those on Table 1 and on Figures 2 through 7.

2 Each TEC scenario is made up of the allowable source zone combinations whose total weights, or probability of activity add up to 1.0.

3 Weight is defined as the fractional probability of activity.

7.0 HAZARD RESULTS

This section presents the results of hazard computation at St. Lucie and Turkey Point sites. Six ground motion measures, viz., peak ground acceleration (PGA), pseudo relative velocity for 5% damping at 25, 10, 5, 2.5 and 1 hz, were considered.

7.1 St. Lucie

7.1.1 Peak Ground Acceleration (PGA)

The mean, and 15th, 50th and 85th percentile annual probability of exceedance for peak ground acceleration (PGA), aggregated over all six earth science teams with equal weights, are presented in Table 1-1. Hazard curves based on the results shown in Table 1-1 are plotted in Figure 1-1. The mean hazard curve is higher than the 50th percentile curve.

The 50th and 85th percentile annual probability of exceedance and corresponding return periods are presented in Tables 7-1 and 7-2, respectively.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-1, which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The Woodward Clyde Consultants, Bechtel, Weston Geophysical, and Rondout Associates models yield higher hazard curves. The hazard curves for these four teams are close to each other.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-2 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. Hazard curves for the three attenuation functions are reasonably close to each other. McGuire and Toro's (1988) attenuation functions

yield the highest hazard, and Boore and Atkinson's (1987) attenuation functions, the lowest.

7.1.2 Pseudo Relative Velocity at 25 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 25 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-3. The mean hazard curve is higher than the 50th percentile curve.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-4, which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The Woodward Clyde Consultants, Bechtel, Weston Geophysical, and Rondout Associates models yield higher hazard curves. The hazard curves for these four teams are close to each other.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-5 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. Hazard curves for the Boore and Atkinson's (1987) attenuation functions are very close to the curve for Nuttli (1986)-Newmark and Hall (1982) and are higher than the curve for McGuire and Toro's (1988).

7.1.3 Pseudo Relative Velocity at 10 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 10 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-6. The mean hazard curve is higher than the 50th percentile curve.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-7,

which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The hazard curves for Woodward Clyde Consultants and Bechtel models are close to each other and higher than the remaining. The curves for Weston Geophysical and Rondout Associates models are close to each other.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-8 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. McGuire and Toro's (1988) attenuation functions yield the highest hazard, and Boore and Atkinson's (1987) attenuation functions, the lowest.

7.1.4 Pseudo Relative Velocity at 5 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 5 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-9. The mean hazard curve is higher than the 50th percentile curve and crosses over the 85th percentile curve at a velocity of about 20 cm/sec.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-10, which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The Woodward Clyde Consultants, Bechtel, Weston Geophysical, and Rondout Associates models yield higher hazard curves. The hazard curves for these four teams are close to each other.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-11 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. McGuire and Toro's (1988) attenuation functions

yield the highest hazard, and Boore and Atkinson's (1987) attenuation functions, the lowest.

7.1.5 Pseudo Relative Velocity at 2.5 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 2.5 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-12. The mean hazard curve is higher than the 50th percentile curve and crosses over the 85th percentile curve at a velocity of about 15 cm/sec.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-13, which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The hazard curves for Woodward Clyde Consultants and Bechtel models are close to each other and higher than the remaining. The curves for Weston Geophysical and Rondout Associates models are close.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-14 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. McGuire and Toro's (1988) attenuation functions yield the highest hazard, and Boore and Atkinson's (1987) attenuation functions, the lowest.

7.1.6 Pseudo Relative Velocity at 1 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 1 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-15. The mean hazard curve is much higher than the 50th percentile curve and crosses over the 85th percentile curve at a

velocity of about 20 cm/sec.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-16, which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The Woodward Clyde Consultants and Bechtel models yield higher hazard curves.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-17 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. McGuire and Toro's (1988) attenuation functions yield the highest hazard, and Boore and Atkinson's (1987) attenuation functions, the lowest.

7.1.7 Uniform Hazard Spectra

Uniform hazard spectra are plots of pseudo relative velocity (for example, for 5% damping) as a function of period (or frequency) for a specified annual probability of exceedance. Hazard curves shown in Figures 7-3, 7-6, 7-9, 7-12 and 7-15 were used to derive constant percentile and mean uniform hazard spectra for annual exceedance probabilities of 1.0E-05, 1.0E-04, 2.0E-04, 1.0E-03 and 2.0E-03. The 15th, 50th and 85th percentile uniform hazard spectra at various risk levels are shown on Figures 7-18 through 7-22. The 50th percentile and mean uniform hazard spectra at various risk levels are shown on Figures 1-2 and 1-3, respectively.

7.2 Turkey Point

7.2.1 Peak Ground Acceleration (PGA)

The mean, and 15th, 50th and 85th percentile annual probability of exceedance for peak

ground acceleration (PGA), aggregated over all six earth science teams with equal weights, are presented in Table 1-2. Hazard curves based on the results shown in Table 1-2 are plotted in Figure 1-2. The mean hazard curve is higher than the 50th percentile curve.

The 50th and 85th percentile annual probability of exceedance and corresponding return periods are presented in Tables 7-2 and 7-3, respectively.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-23, which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The hazard curves for Woodward Clyde Consultants and Bechtel models are close to each other and higher than the remaining. The curves for Weston Geophysical and Rondout Associates models are close to each other.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-24 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. McGuire and Toro's (1988) attenuation functions yield the highest hazard, and Boore and Atkinson's (1987) attenuation functions, the lowest.

7.2.2 Pseudo Relative Velocity at 25 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 25 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-25. The mean hazard curve is higher than the 50th percentile curve.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-26, which includes the mean, and 15th, 50th and 85th percentile annual probability of

exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The Woodward Clyde Consultants, Bechtel, Weston Geophysical, and Rondout Associates models yield higher hazard curves. The hazard curves for these four teams are close to each other.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-27 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. Hazard curves for the Boore and Atkinson's (1987) attenuation functions are very close to the curve for Nuttli (1986)-Newmark and Hall (1982) and are higher than the curve for McGuire and Toro's (1988).

7.2.3 Pseudo Relative Velocity at 10 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 10 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-28. The mean hazard curve is higher than the 50th percentile curve.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-29, which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The hazard curves for Woodward Clyde Consultants and Bechtel models are close to each other and higher than the remaining. The curves for Weston Geophysical and Rondout Associates models are close.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-30 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. McGuire and Toro's (1988) attenuation functions yield the highest hazard, and Boore and Atkinson's (1987) attenuation functions, the lowest.

7.2.4 Pseudo Relative Velocity at 5 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 5 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-31. The mean hazard curve is higher than the 50th percentile curve and crosses over the 85th percentile curve at a velocity of about 14 cm/sec.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-32, which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The Woodward Clyde Consultants, Bechtel, Weston Geophysical, and Rondout Associates models yield higher hazard curves. The hazard curves for these four teams are close to each other.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-33 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. McGuire and Toro's (1988) attenuation functions yield the highest hazard, and Boore and Atkinson's (1987) attenuation functions, the lowest.

7.2.5 Pseudo Relative Velocity at 2.5 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 2.5 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-34. The mean hazard curve is much higher than the 50th percentile curve and crosses over the 85th percentile curve at a velocity of about 10 cm/sec.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-35,

which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The use of Law Engineering model yields the lowest hazard. The hazard curves for Woodward Clyde Consultants and Bechtel models are close to each other and higher than the remaining. The curves for Weston Geophysical and Rondout Associates models are close.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-36 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. McGuire and Toro's (1988) attenuation functions yield the highest hazard, and Boore and Atkinson's (1987) attenuation functions, the lowest.

7.2.6 Pseudo Relative Velocity at 1 hz

Hazard curves showing mean, and 15th, 50th and 85th percentile annual probability of exceedance for pseudo relative velocity at 1 hz, aggregated over all six earth science teams with equal weights, are presented in Figure 7-37. The mean hazard curve is much higher than the 50th percentile curve and crosses over the 85th percentile curve at a velocity of about 10 cm/sec.

Sensitivity of hazard results to different earth science teams is displayed in Figure 7-38, which includes the mean, and 15th, 50th and 85th percentile annual probability of exceedance curves along with 50th percentile curves for each of the six teams. The Woodward Clyde Consultants and Bechtel models yield higher hazard curves.

Sensitivity of hazard results to different attenuation relations is shown in Figure 7-39 by plotting 50th percentile annual probability of exceedance curves derived by considering each attenuation relation separately. McGuire and Toro's (1988) attenuation functions yield the highest hazard curve.

7.2.7 Uniform Hazard Spectra

Hazard curves shown in Figures 7-25, 7-28, 7-31, 7-34 and 7-37 were used to derive constant percentile and mean uniform hazard spectra for annual exceedance probabilities of 1.0E-05, 1.0E-04, 2.0E-04, 1.0E-03 and 2.0E-03. The 15th, 50th and 85th percentile uniform hazard spectra at various risk levels are shown on Figures 7-40 through 7-44. The 50th percentile and mean uniform hazard spectra at various risk levels are shown on Figures 1-5 and 1-6, respectively.

TABLE 7-1
Peak Ground Acceleration (PGA)
Annual Probability of Exceedance and Return Periods

Seismic Hazard Results
Summary for St. Lucie Site
50th Percentile

Acceleration (g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
0.007	4.97E-04	2,012
0.07	3.15E-05	31,746
0.12	1.05E-05	95,238
0.23	1.04E-06	961,538
0.41	7.48E-08	13,368,984
0.57	1.32E-08	75,757,576
0.82	1.51E-09	662,251,655

TABLE 7-2
Peak Ground Acceleration (PGA)
Annual Probability of Exceedance and Return Periods

Seismic Hazard Results
Summary for St. Lucie Site
85th Percentile

Acceleration (g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
0.007	1.60E-03	625
0.07	6.84E-05	14,620
0.12	2.29E-05	43,668
0.23	2.75E-06	363,636
0.41	3.08E-07	3,246,753
0.57	8.60E-08	11,627,907
0.82	1.41E-08	70,921,986

TABLE 7-3
Peak Ground Acceleration (PGA)
Annual Probability of Exceedance and Return Periods

Seismic Hazard Results
Summary for Turkey Point Site
50th Percentile

Acceleration (g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
0.005	3.27E-04	3,058
0.05	2.75E-05	36,364
0.10	9.57E-06	104,493
0.26	9.19E-07	1,088,139
0.51	5.95E-08	16,806,723
0.71	9.89E-09	101,112,234
1.02	1.17E-09	854,700,854

TABLE 7-4
Peak Ground Acceleration (PGA)
Annual Probability of Exceedance and Return Periods

Seismic Hazard Results
Summary for Turkey Point Site
85th Percentile

Acceleration (g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
0.005	1.34E-02	75
0.05	5.61E-05	17,825
0.10	2.02E-05	49,505
0.26	2.58E-06	387,597
0.51	2.85E-07	3,508,772
0.71	7.16E-08	13,966,480
1.02	1.21E-08	82,644,628

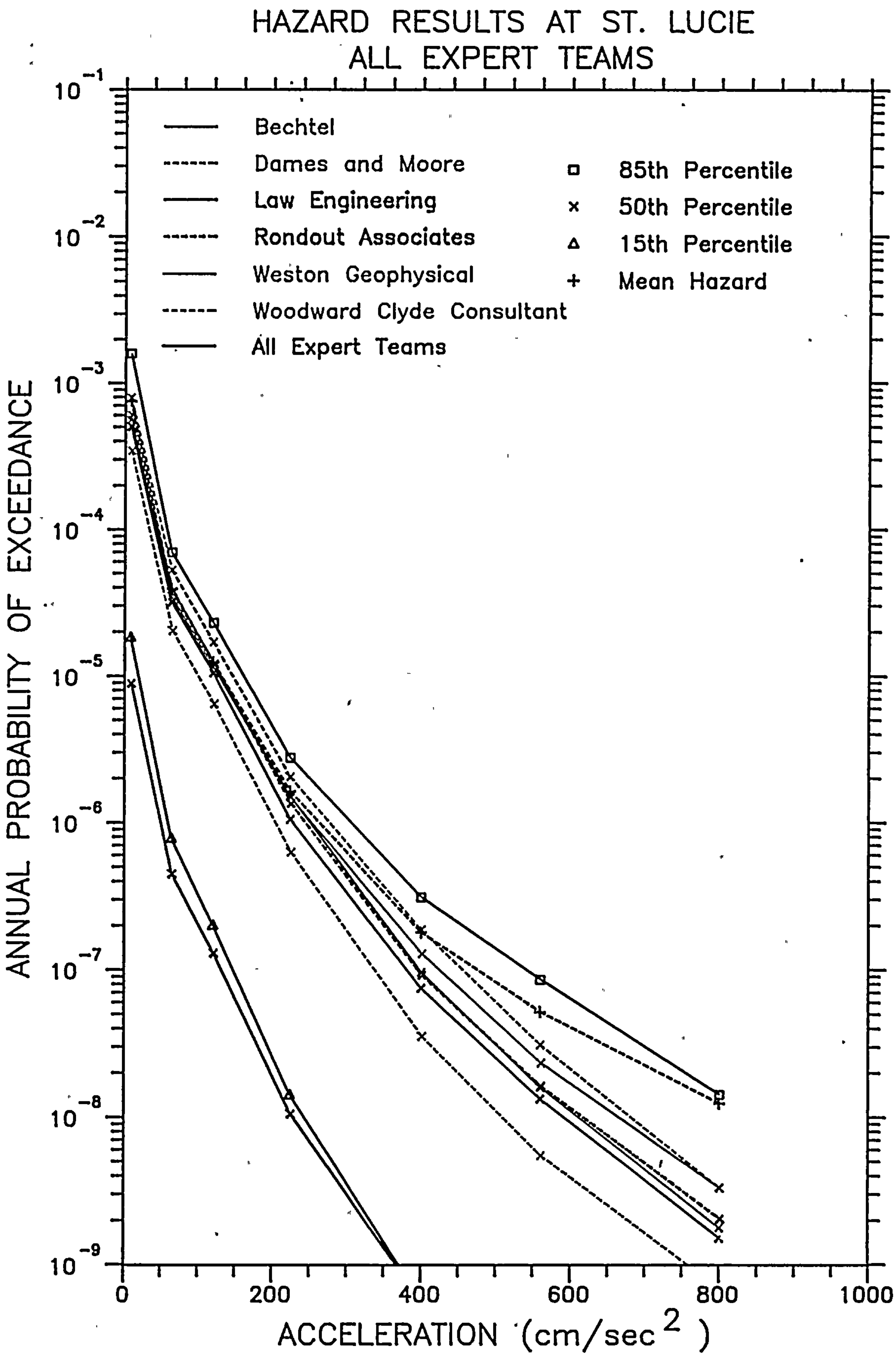


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FIGURE 7-1

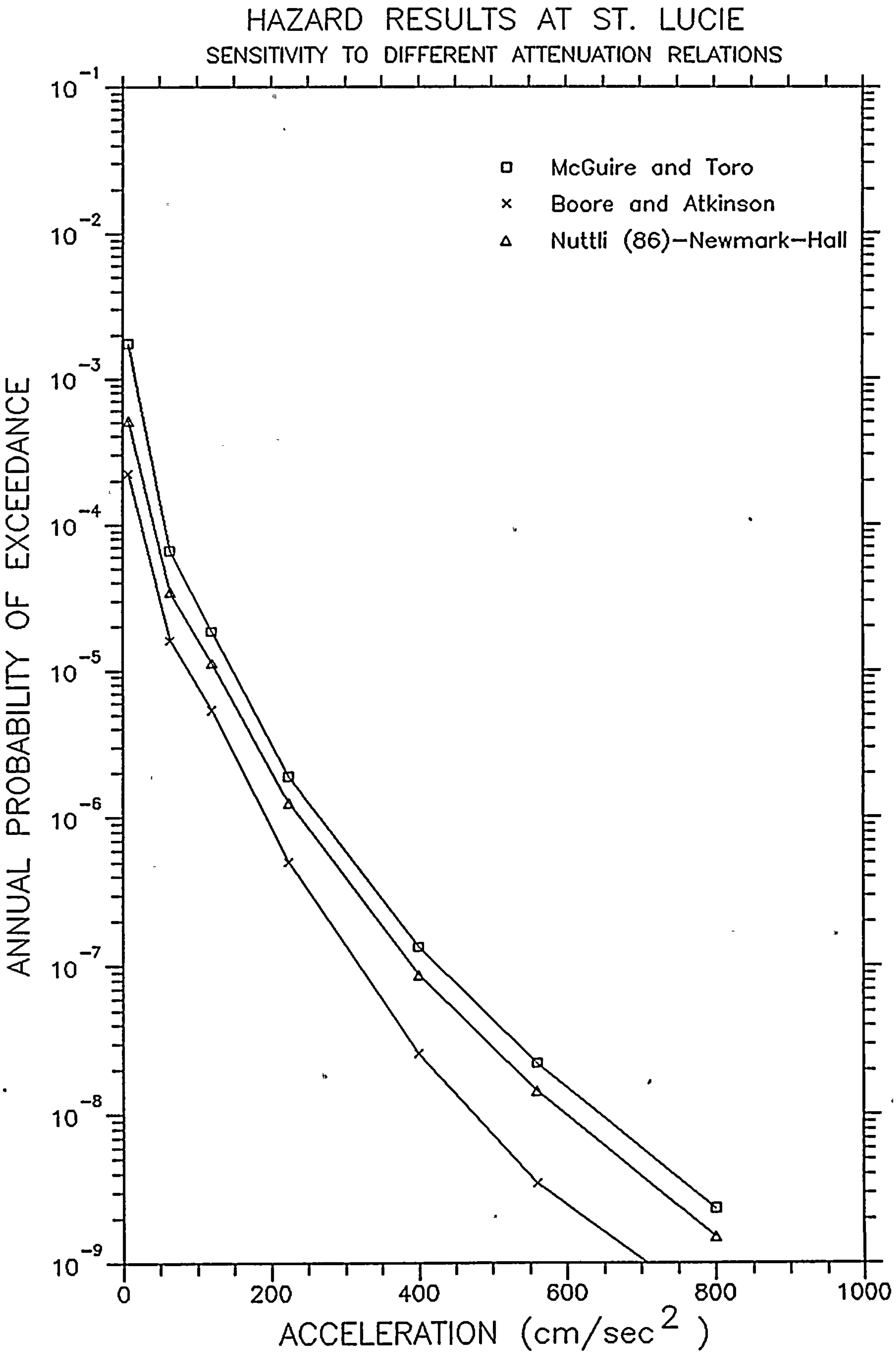

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FIGURE 7-2

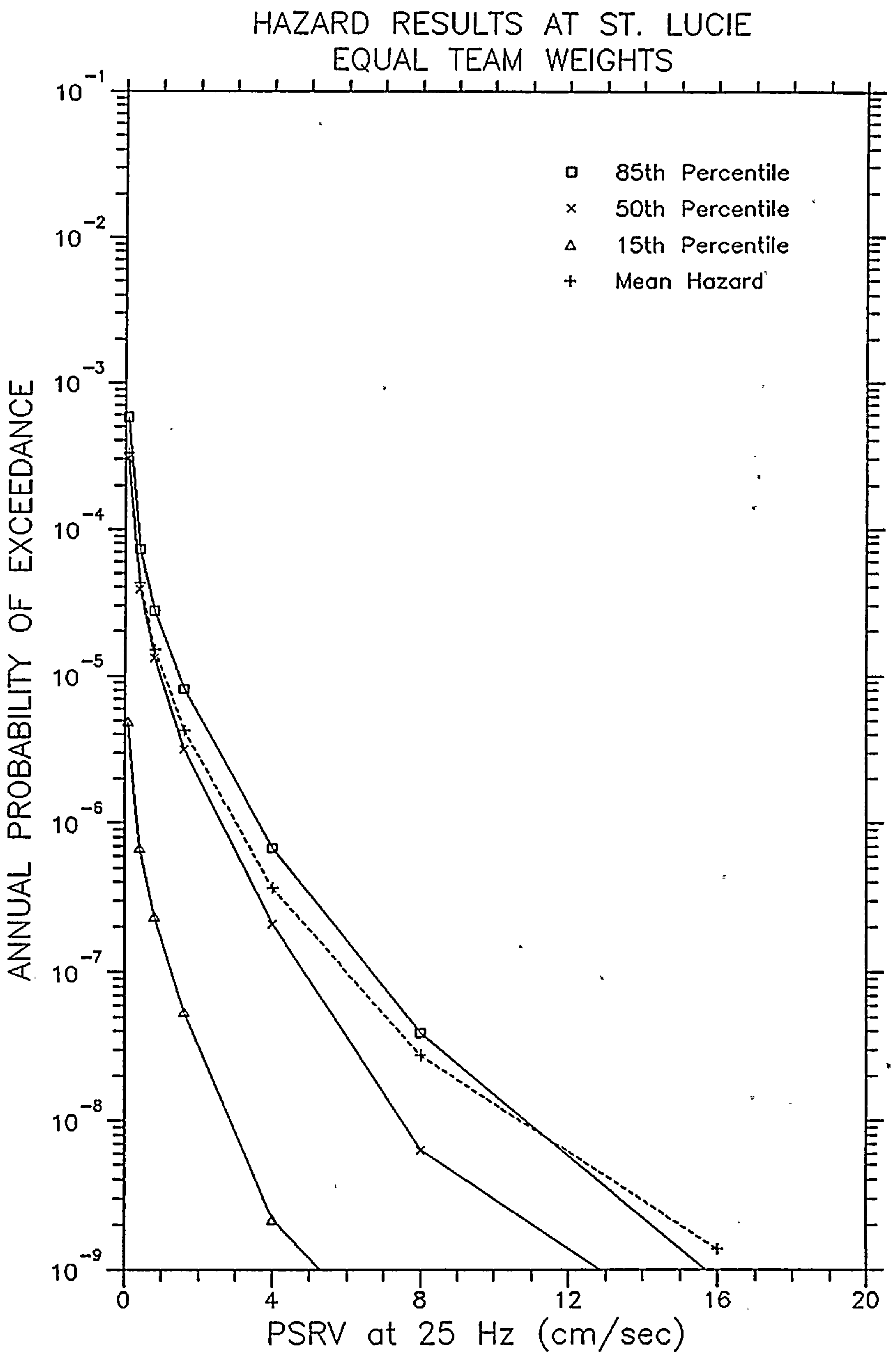

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FIGURE 7-3

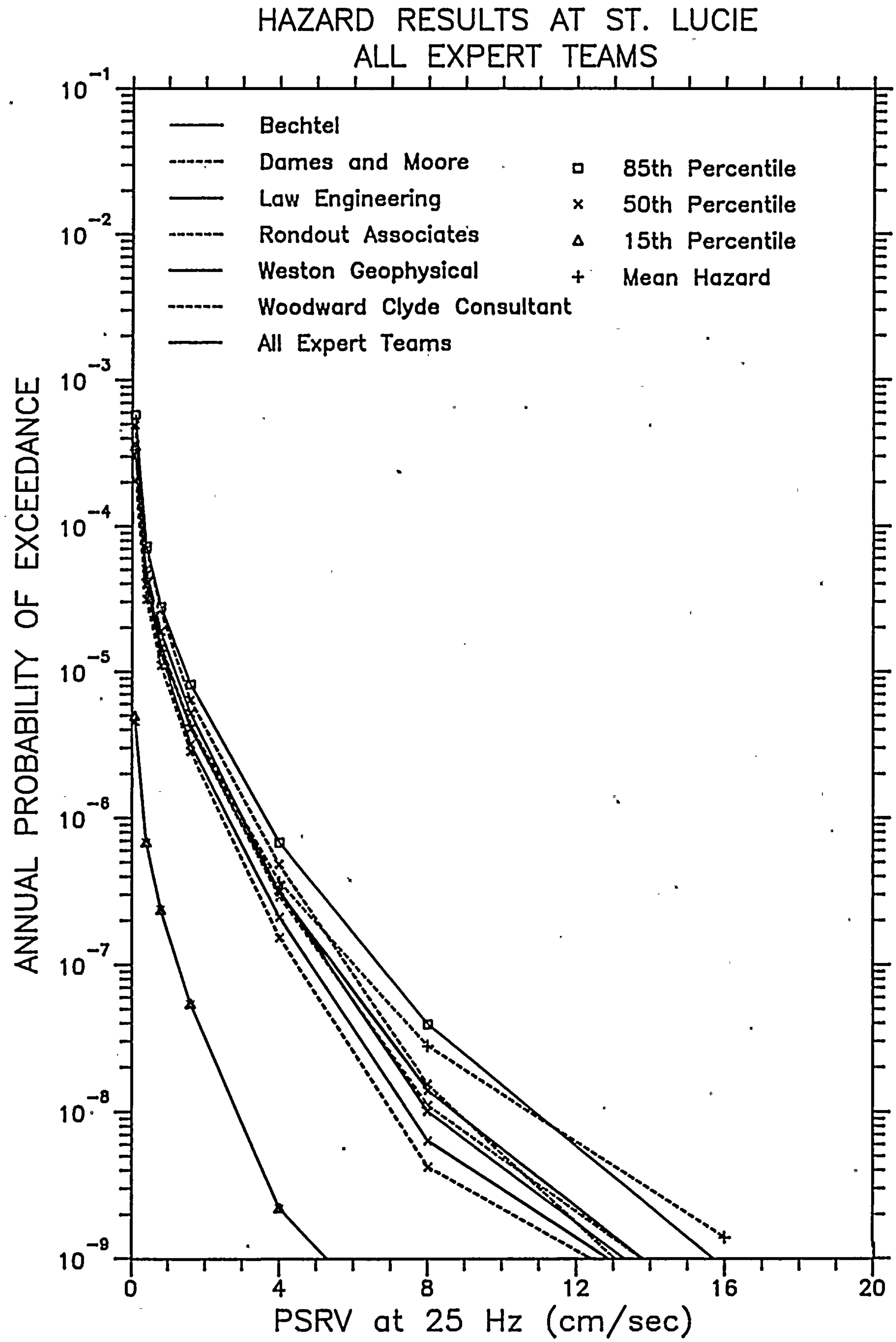

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FIGURE 7-4

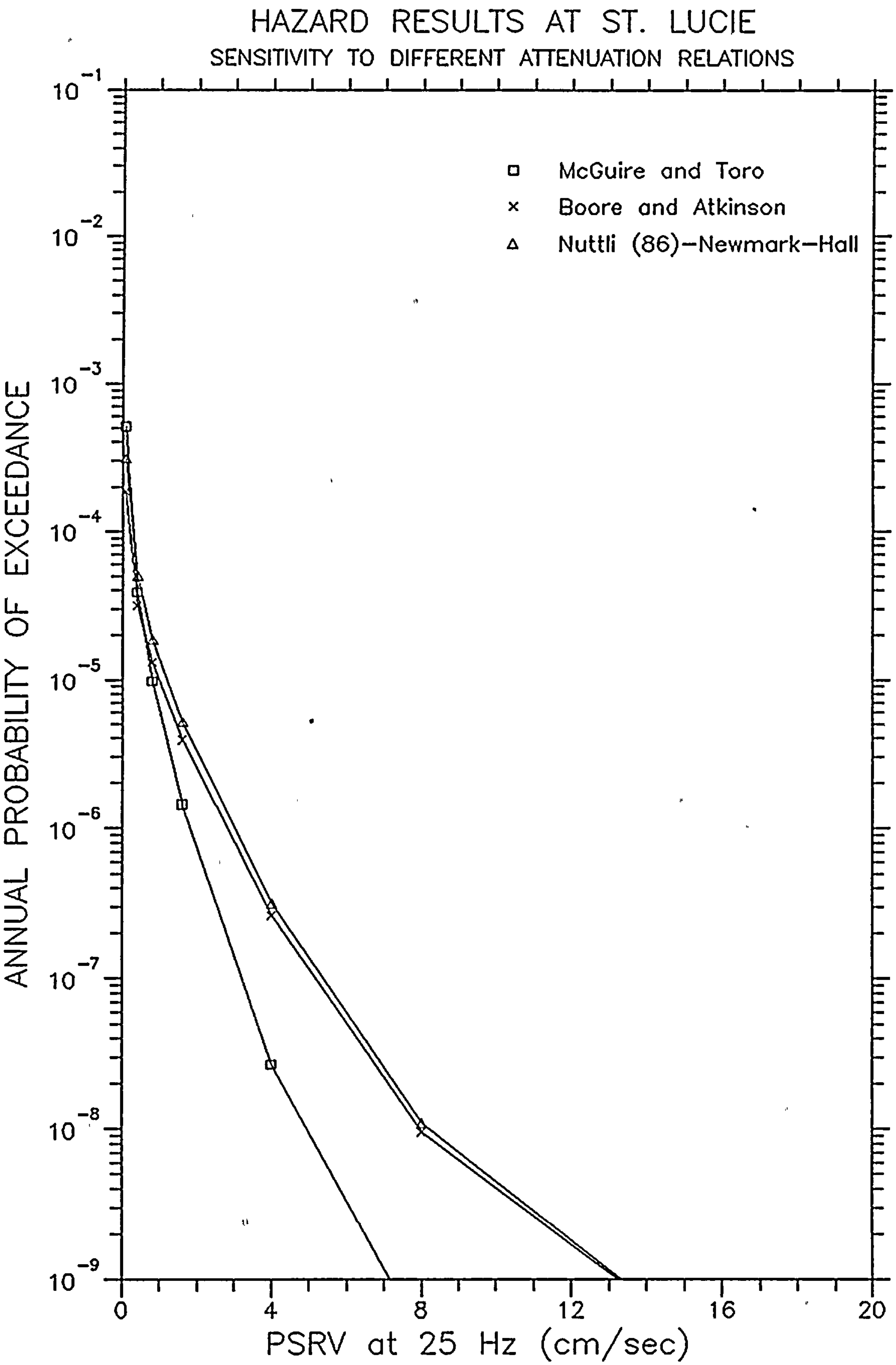

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FIGURE 7-5

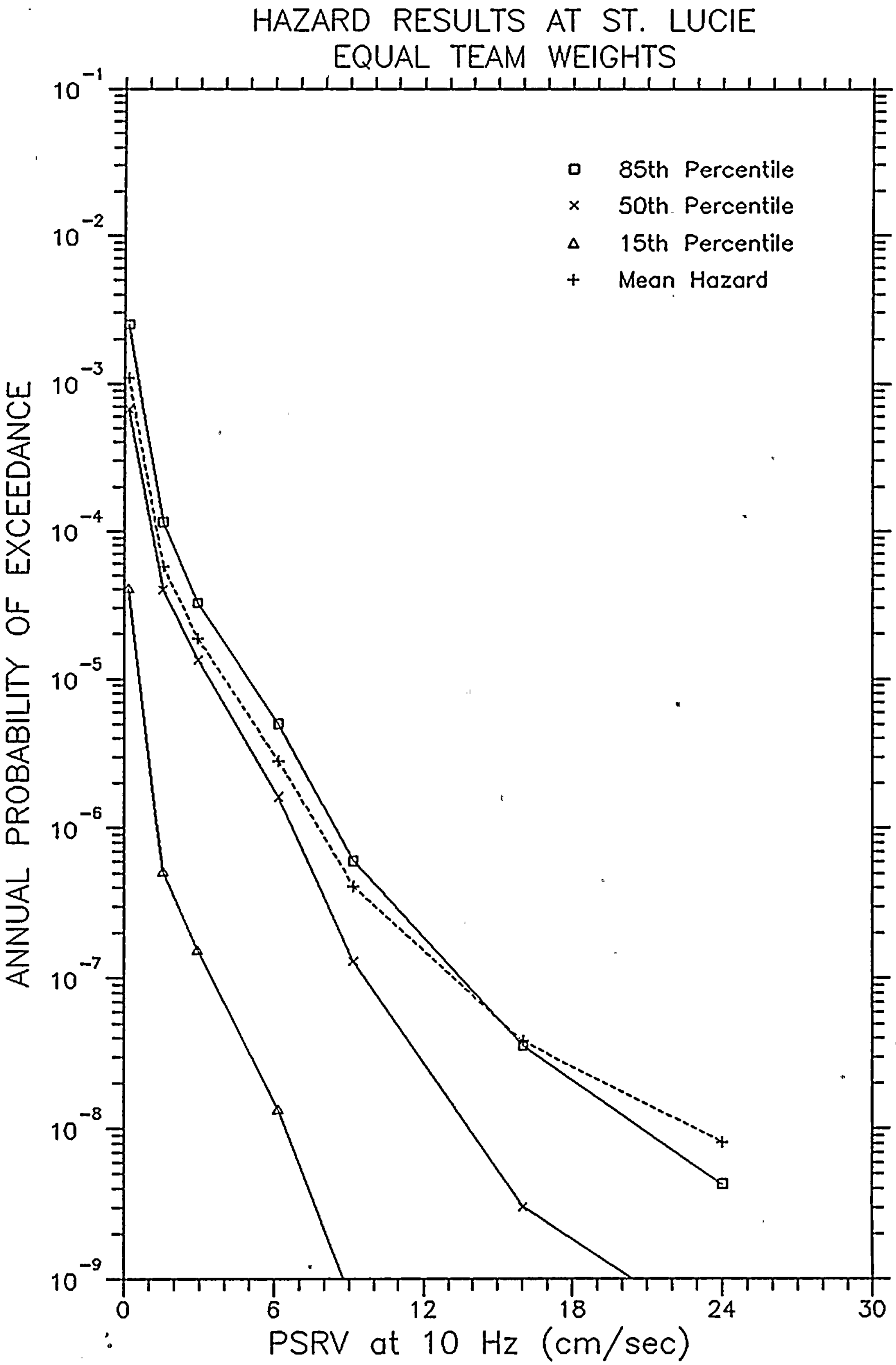

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FIGURE 7-6

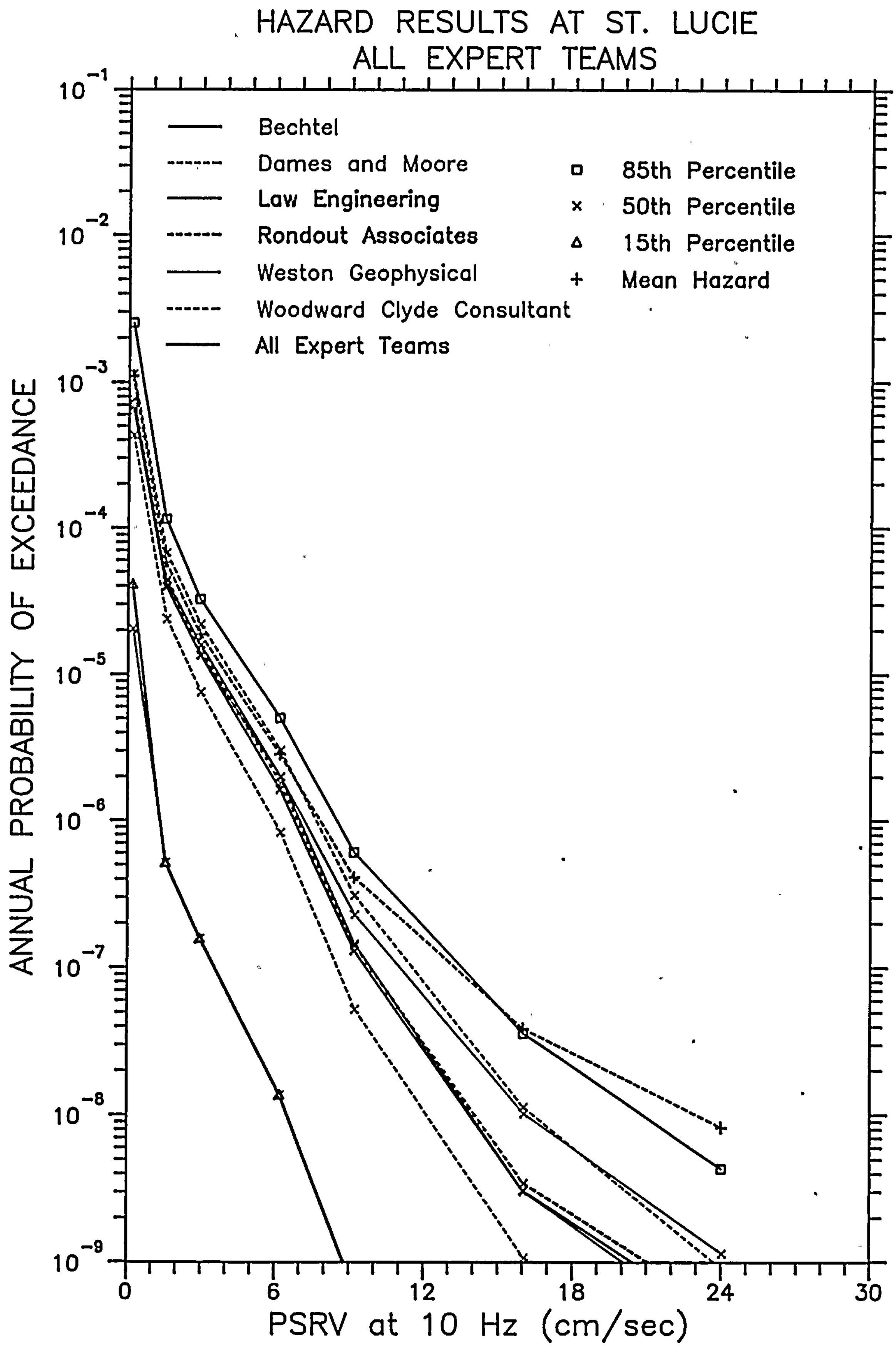

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FIGURE 7-7

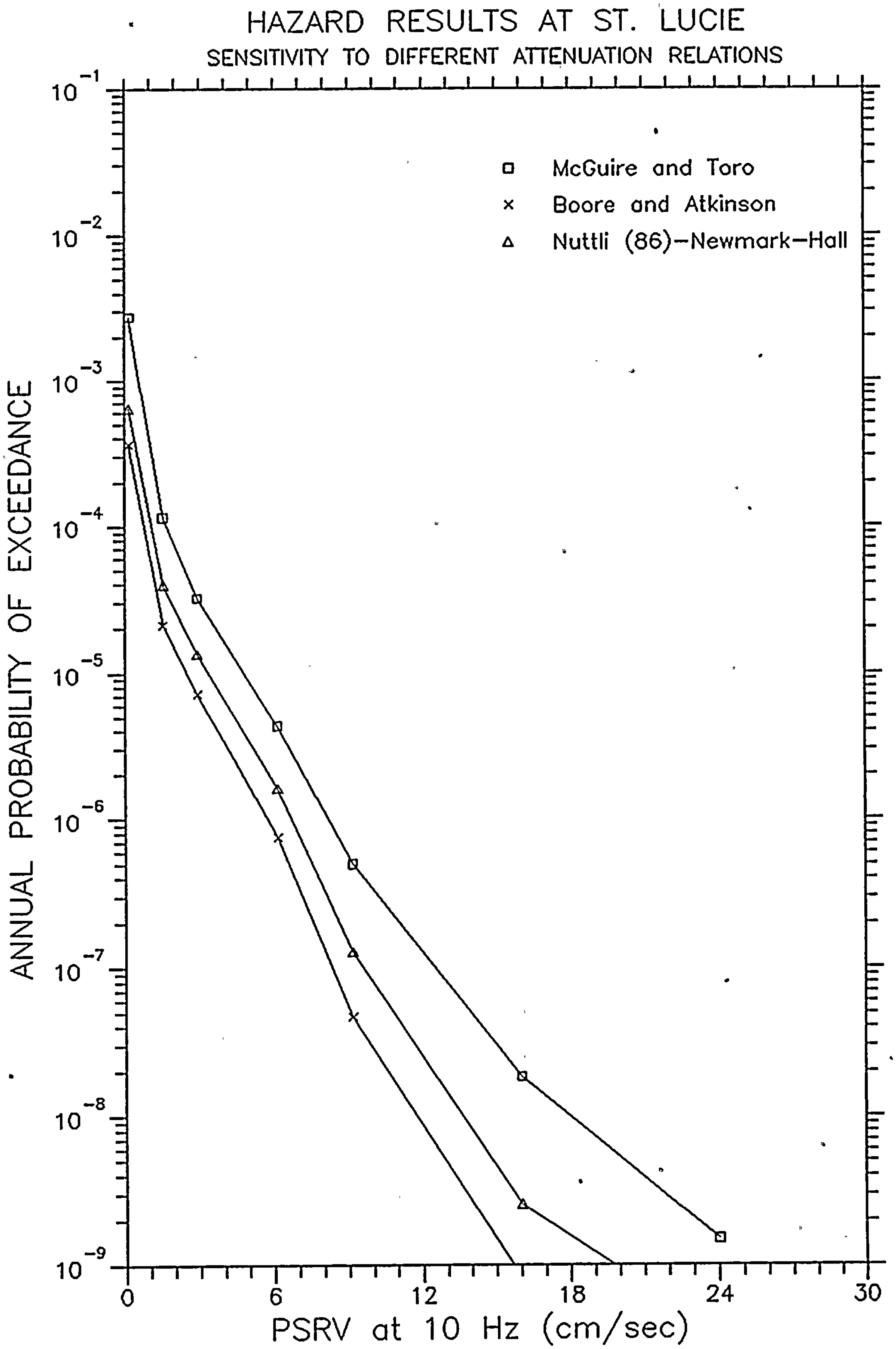

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FIGURE 7-8

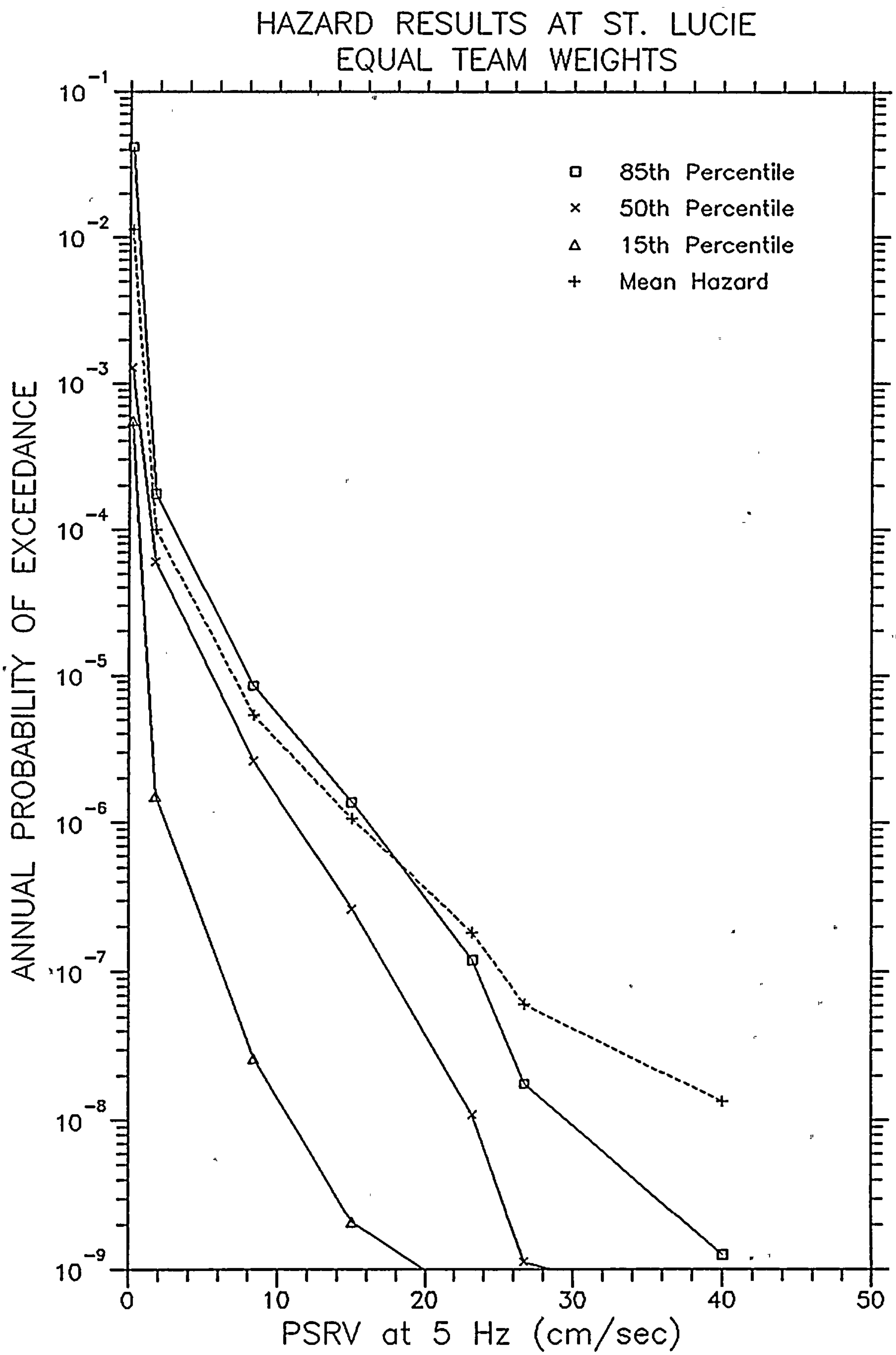

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FIGURE 7-9

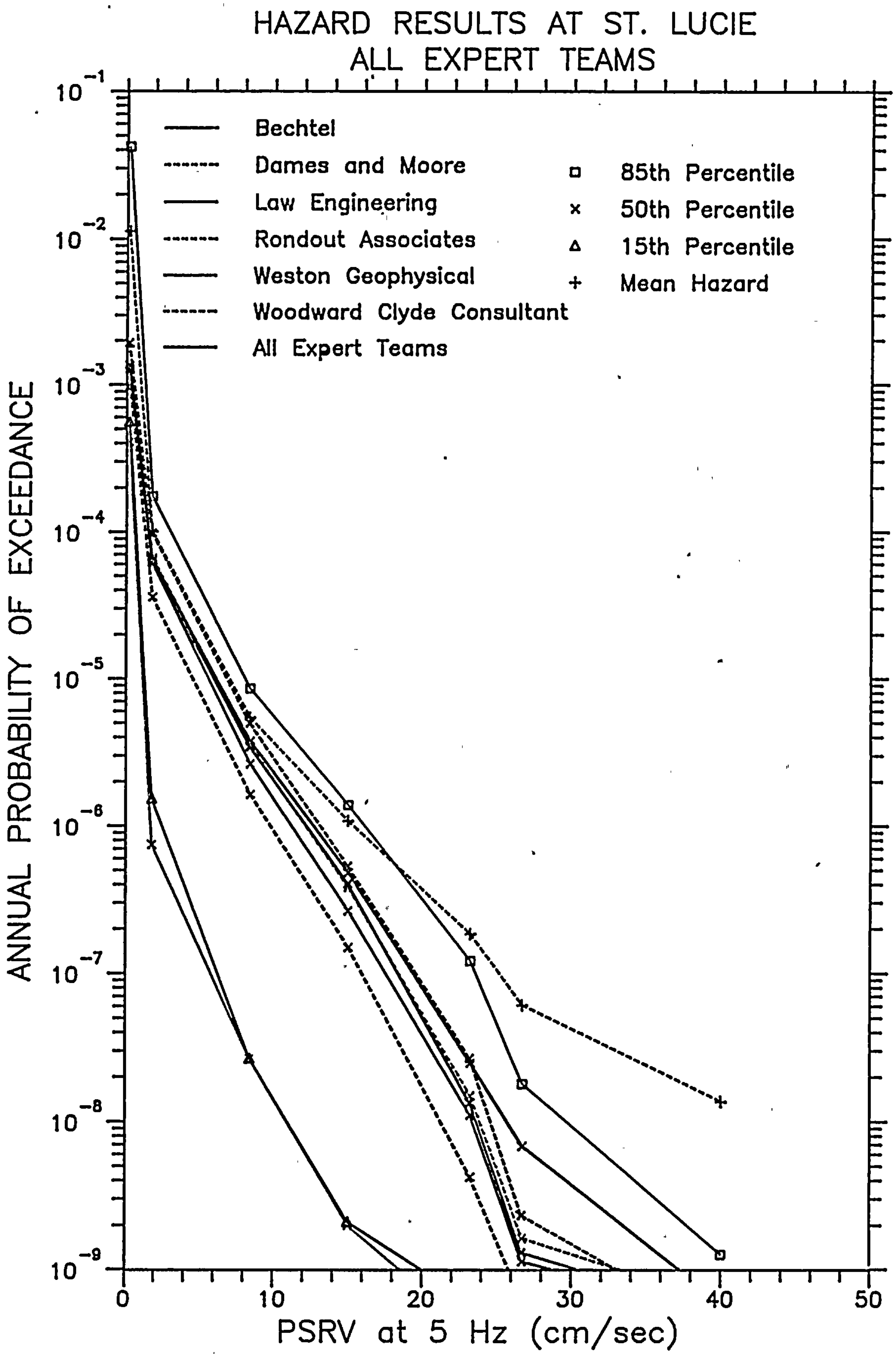

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FIGURE 7-10

HAZARD RESULTS AT ST. LUCIE

SENSITIVITY TO DIFFERENT ATTENUATION RELATIONS

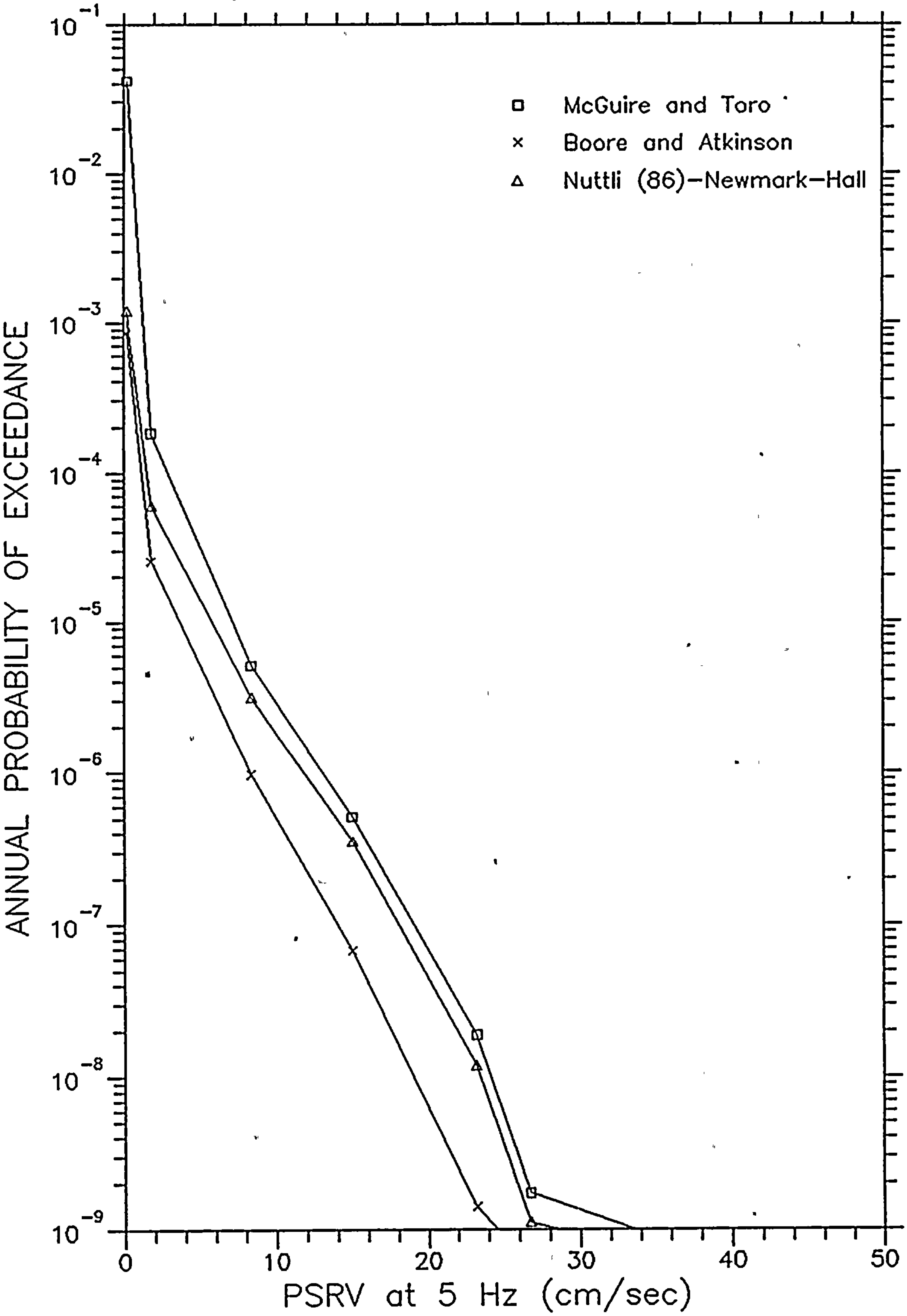

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FIGURE 7-11

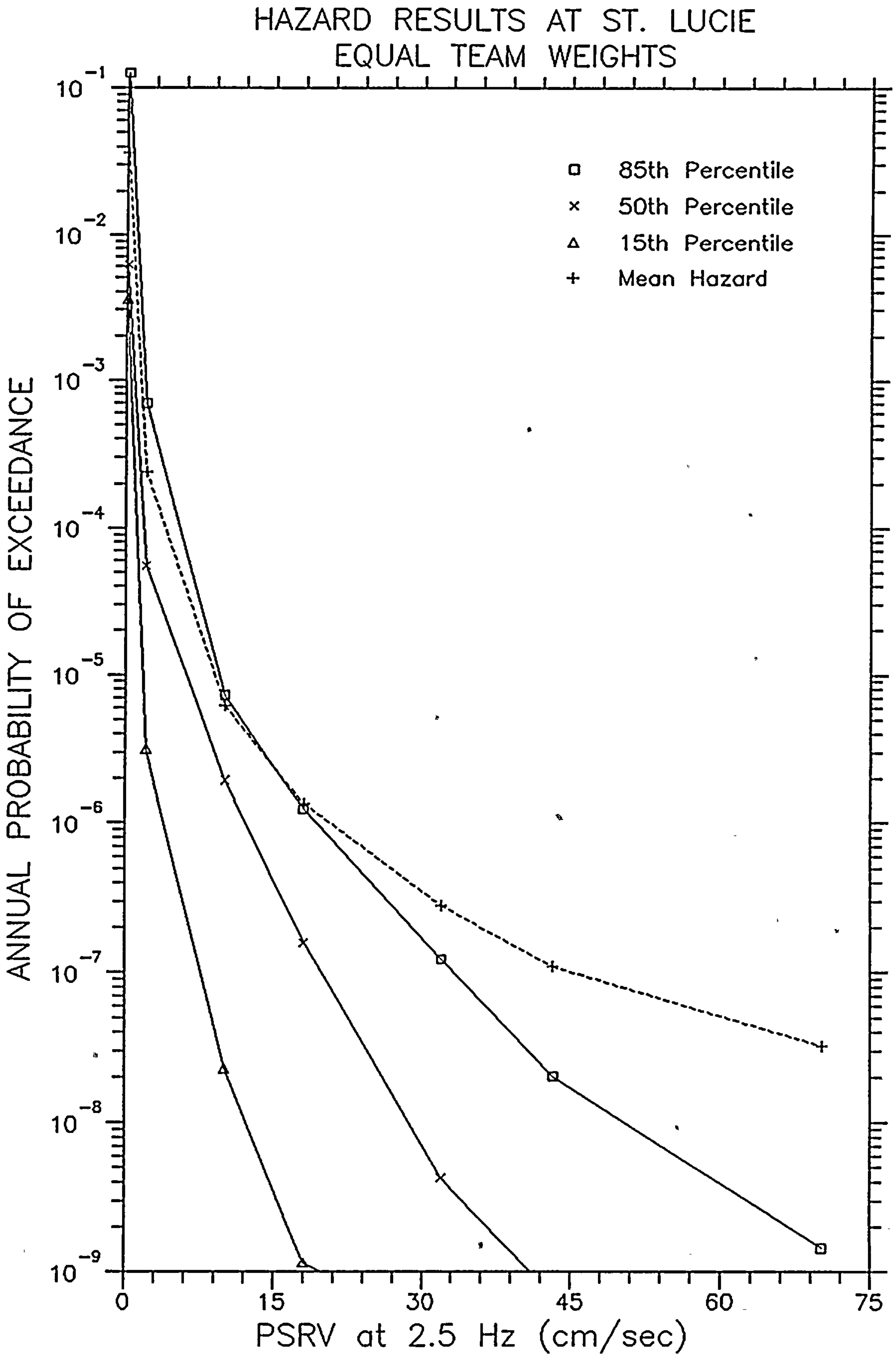

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FIGURE 7-12

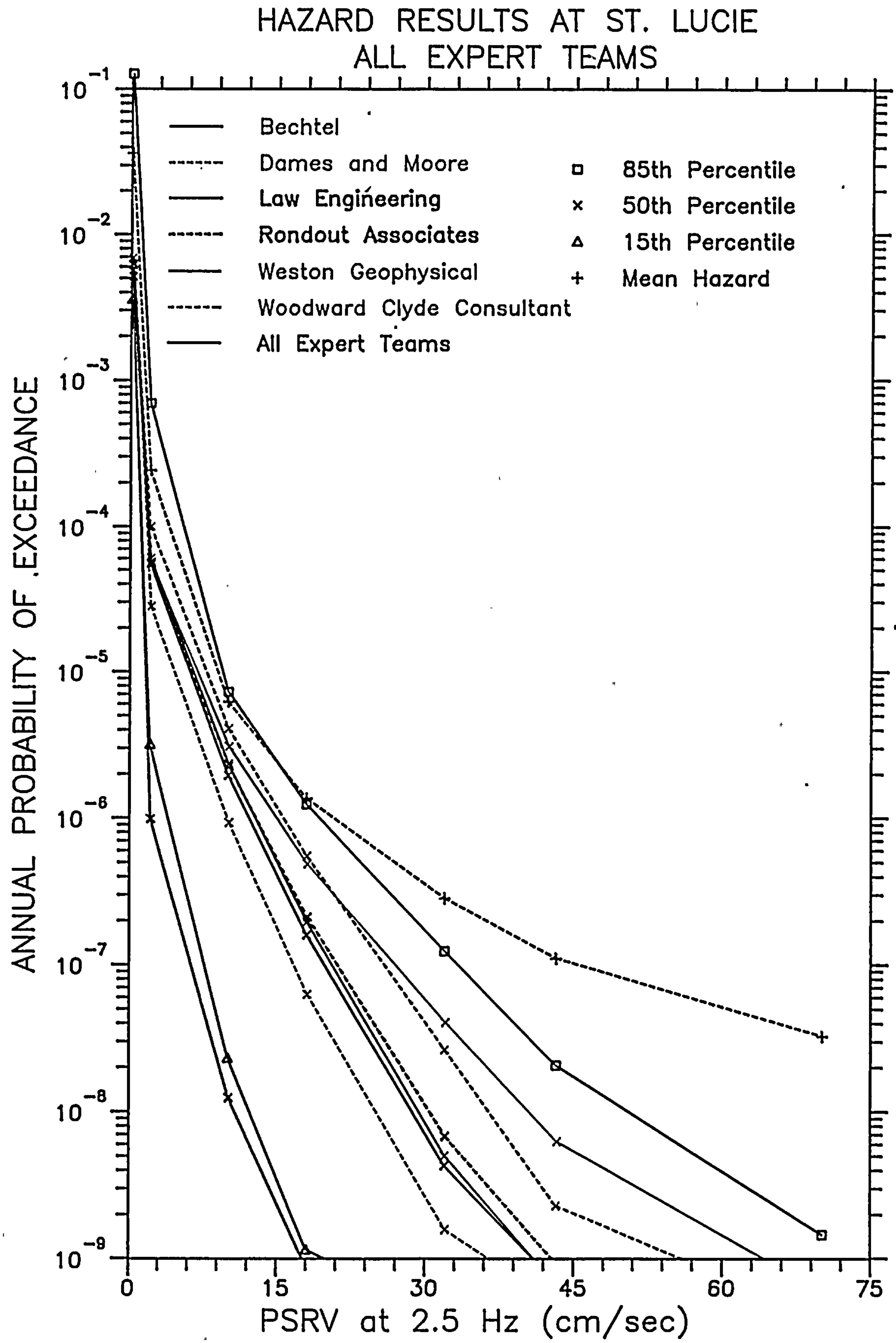

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FIGURE 7-13

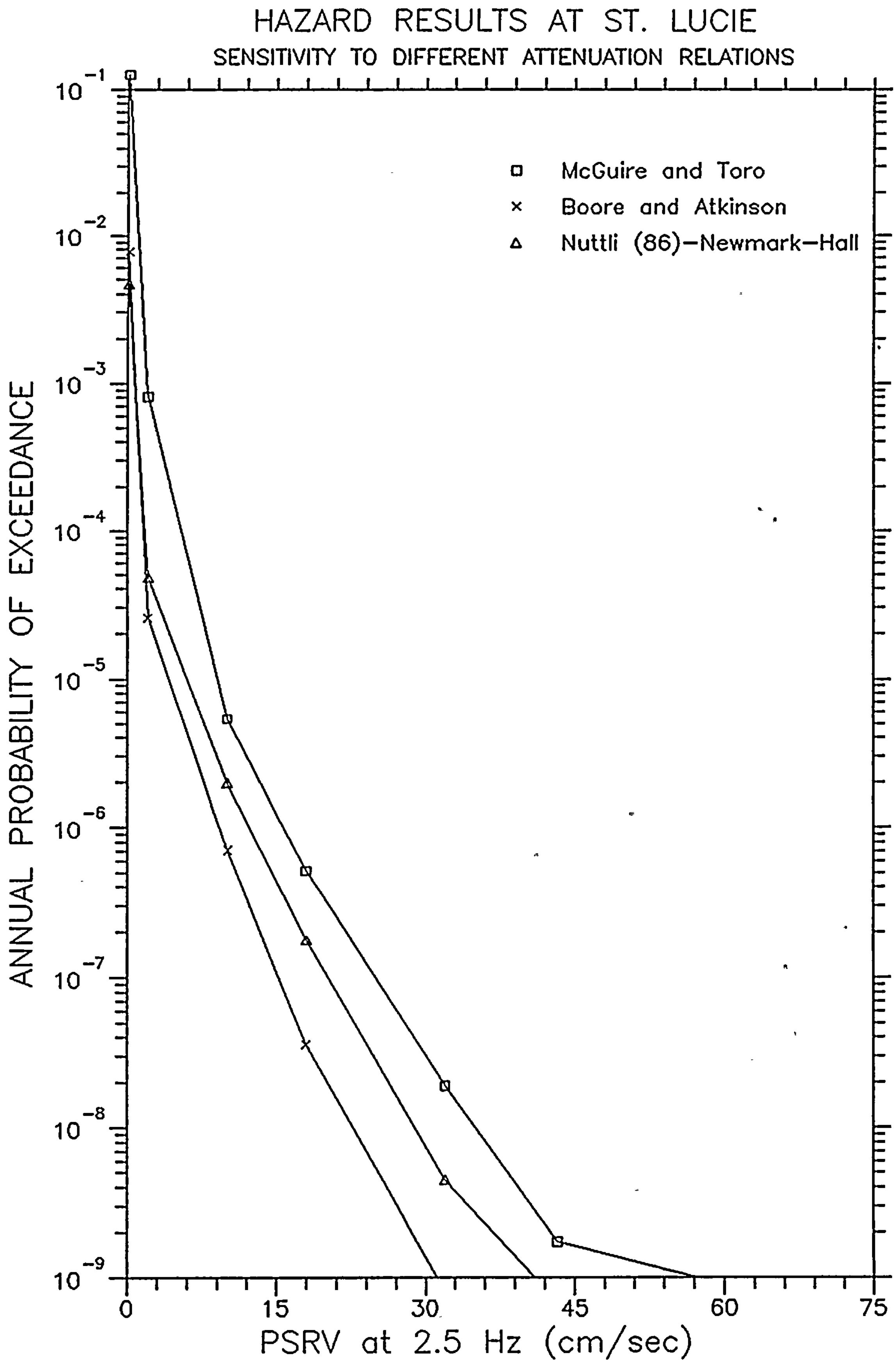

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FIGURE 7-14

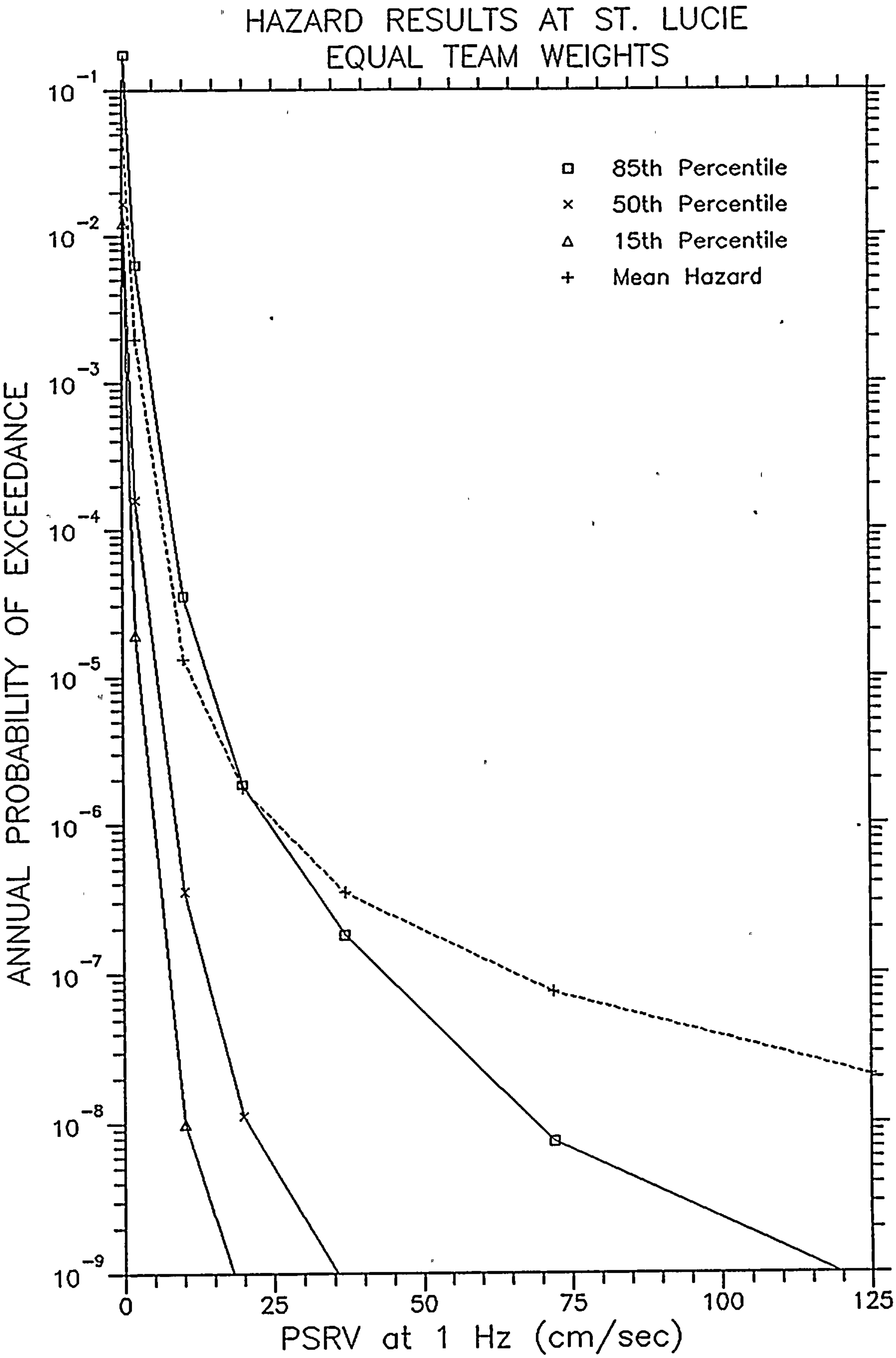

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FIGURE 7-15

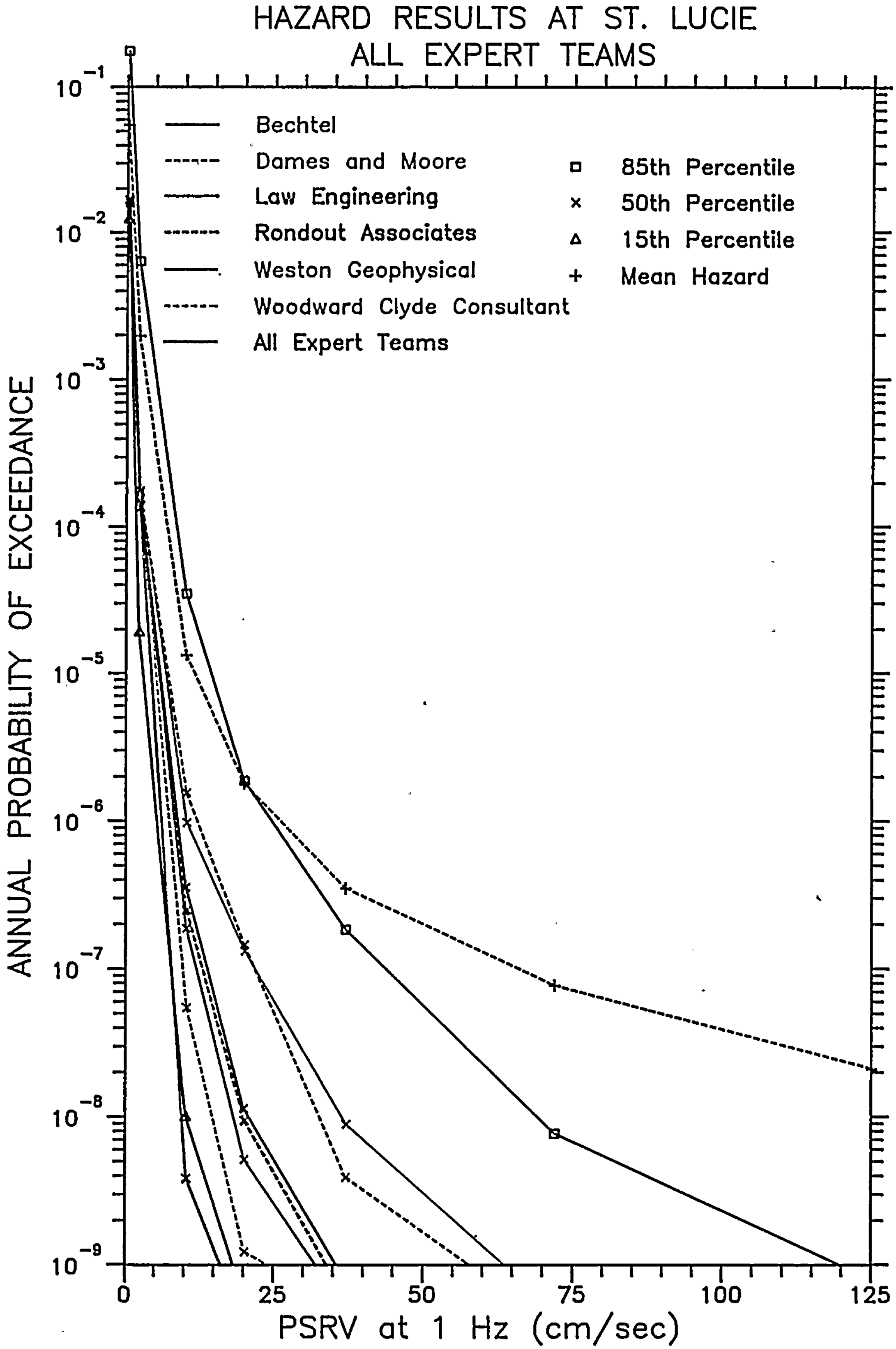

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FIGURE 7-16

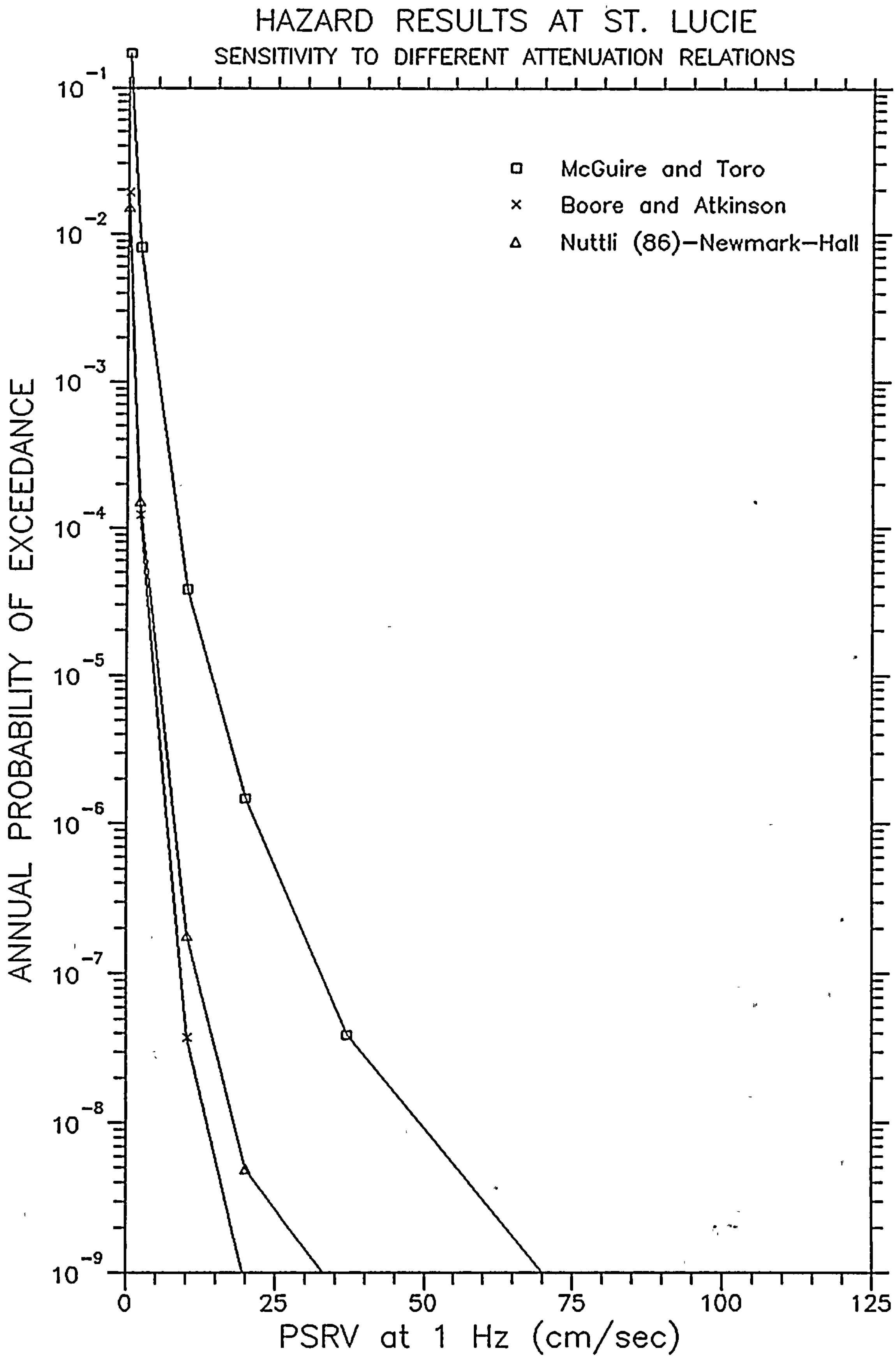

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FIGURE 7-17

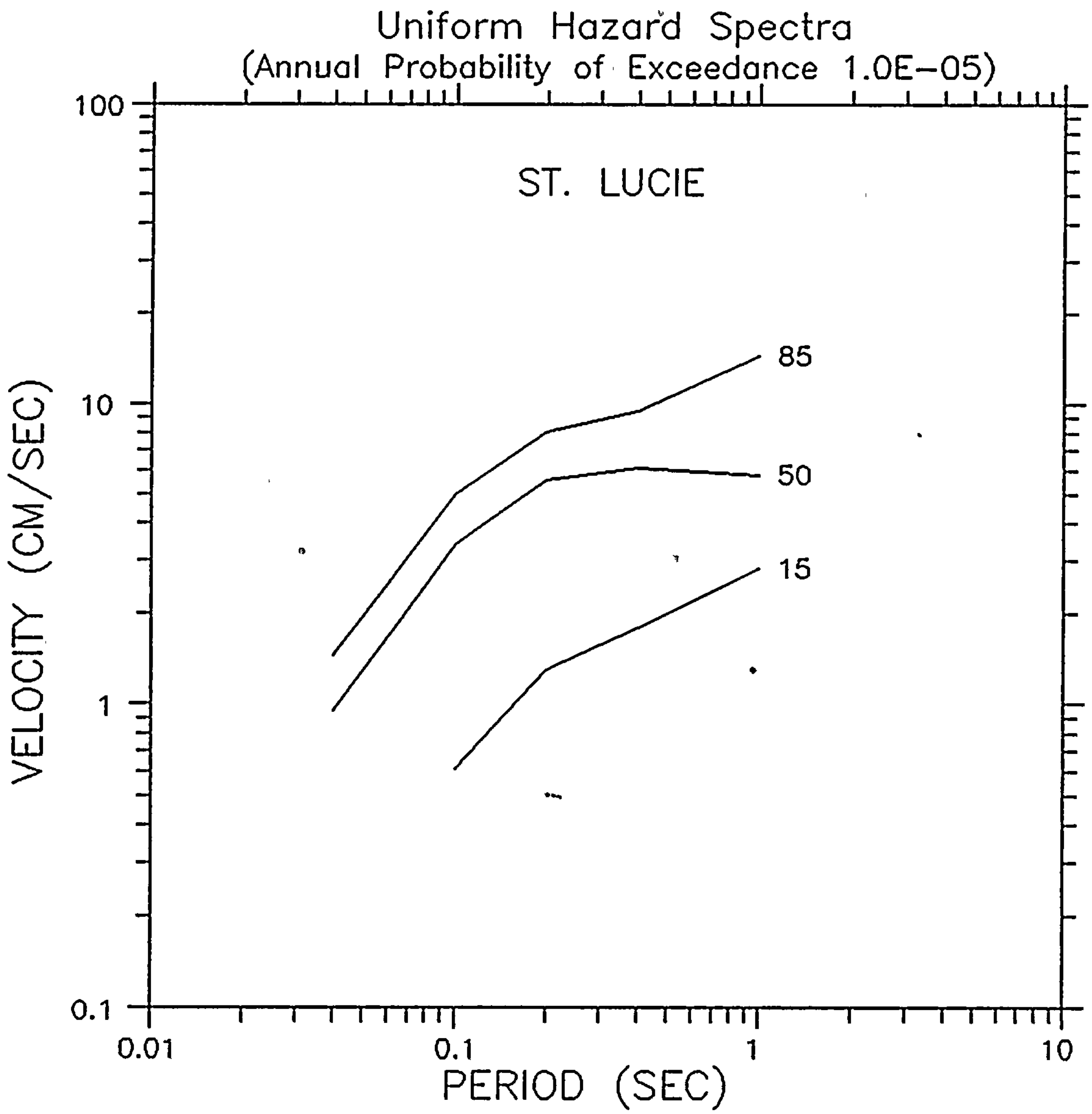

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FIGURE 7-18

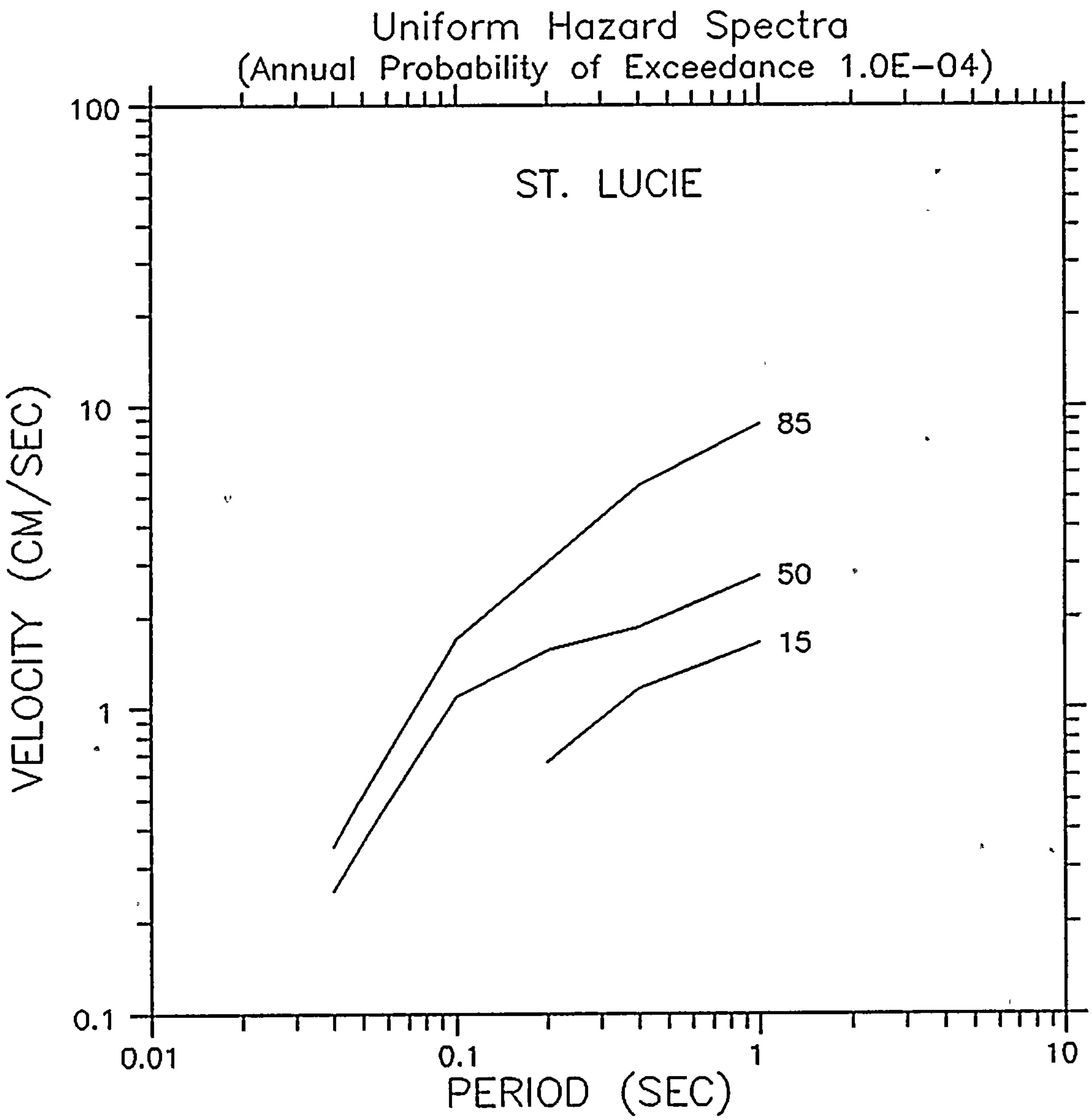

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FIGURE 7-19

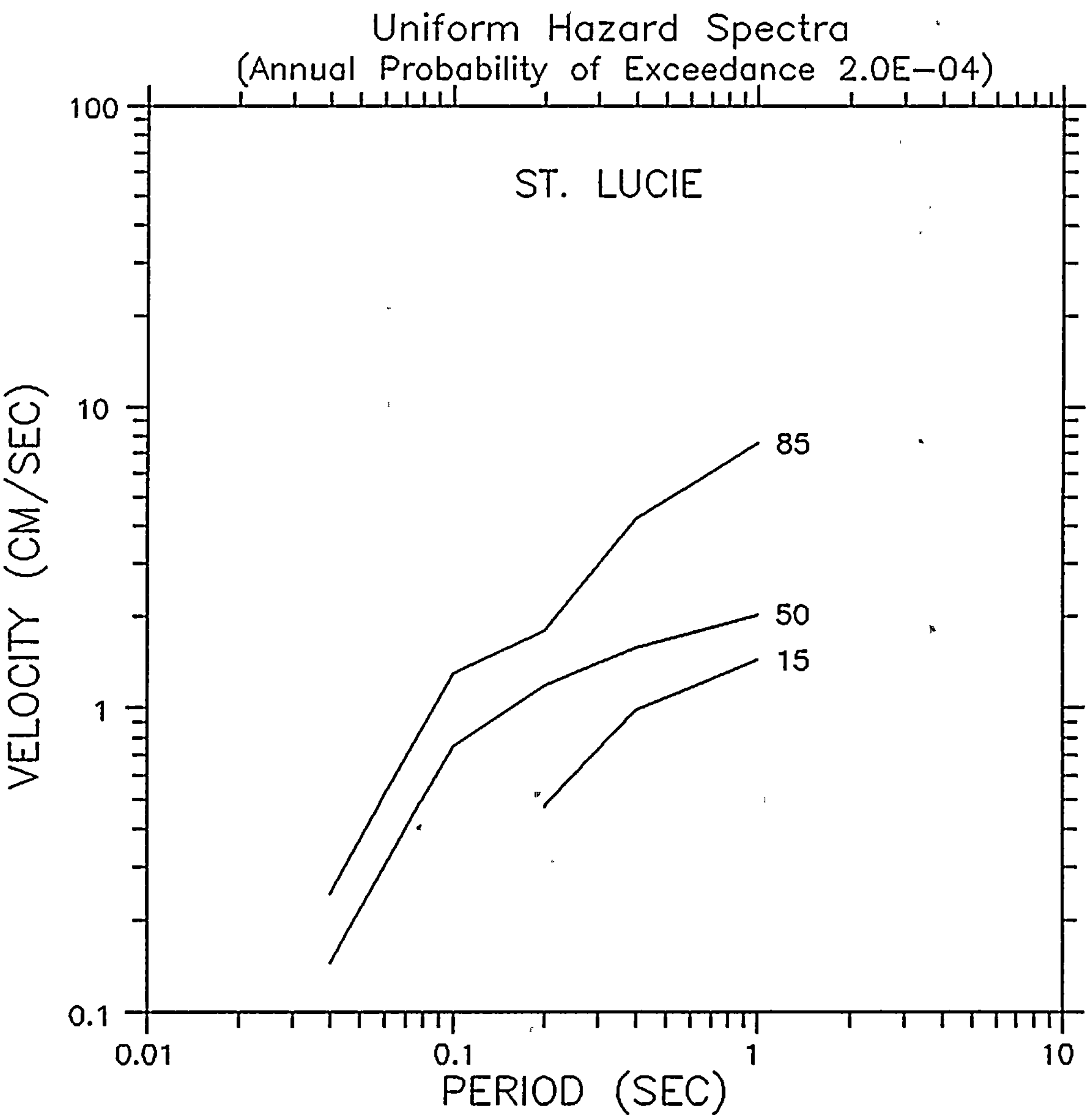

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FIGURE 7-20

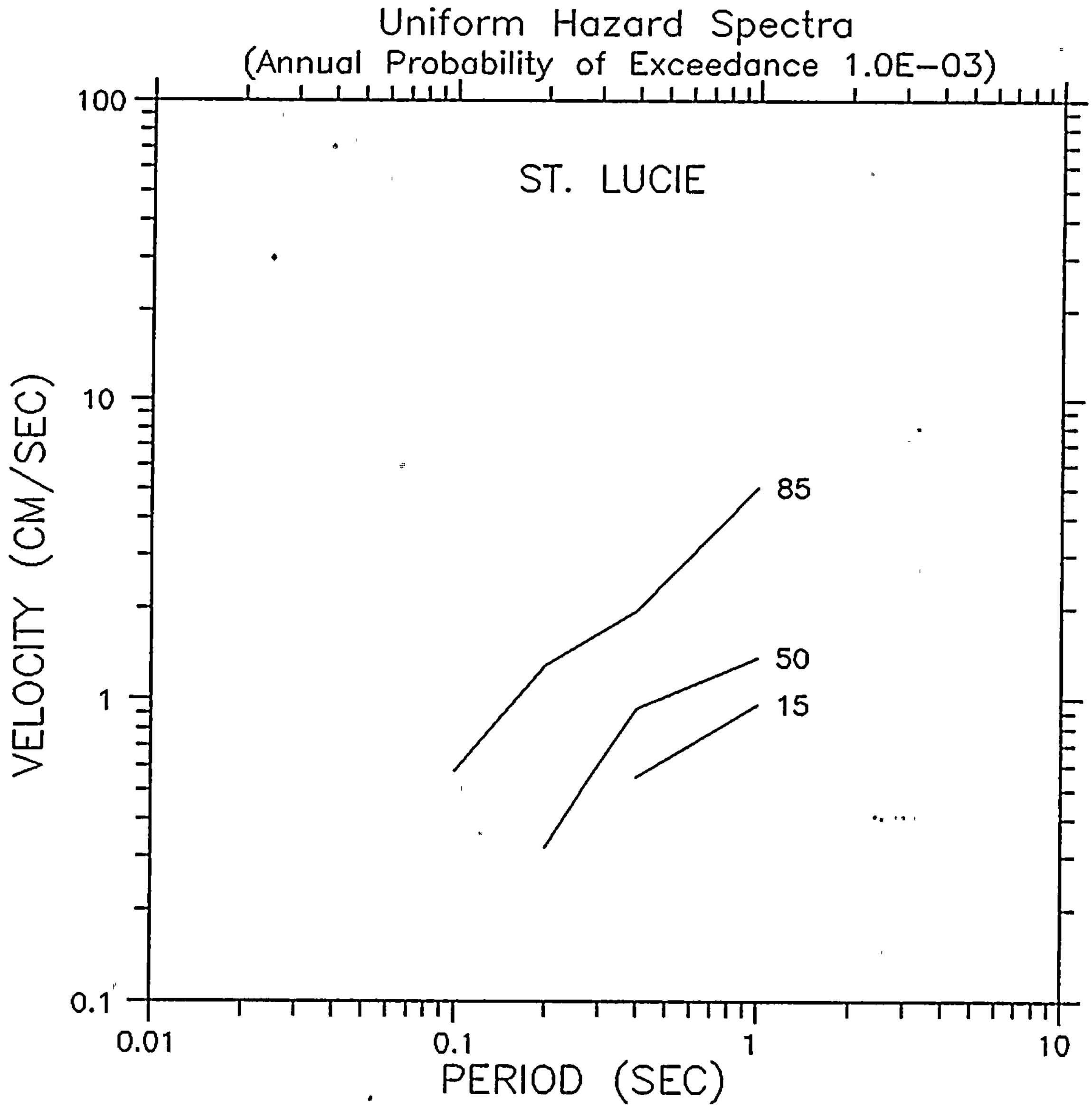

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FIGURE 7-21

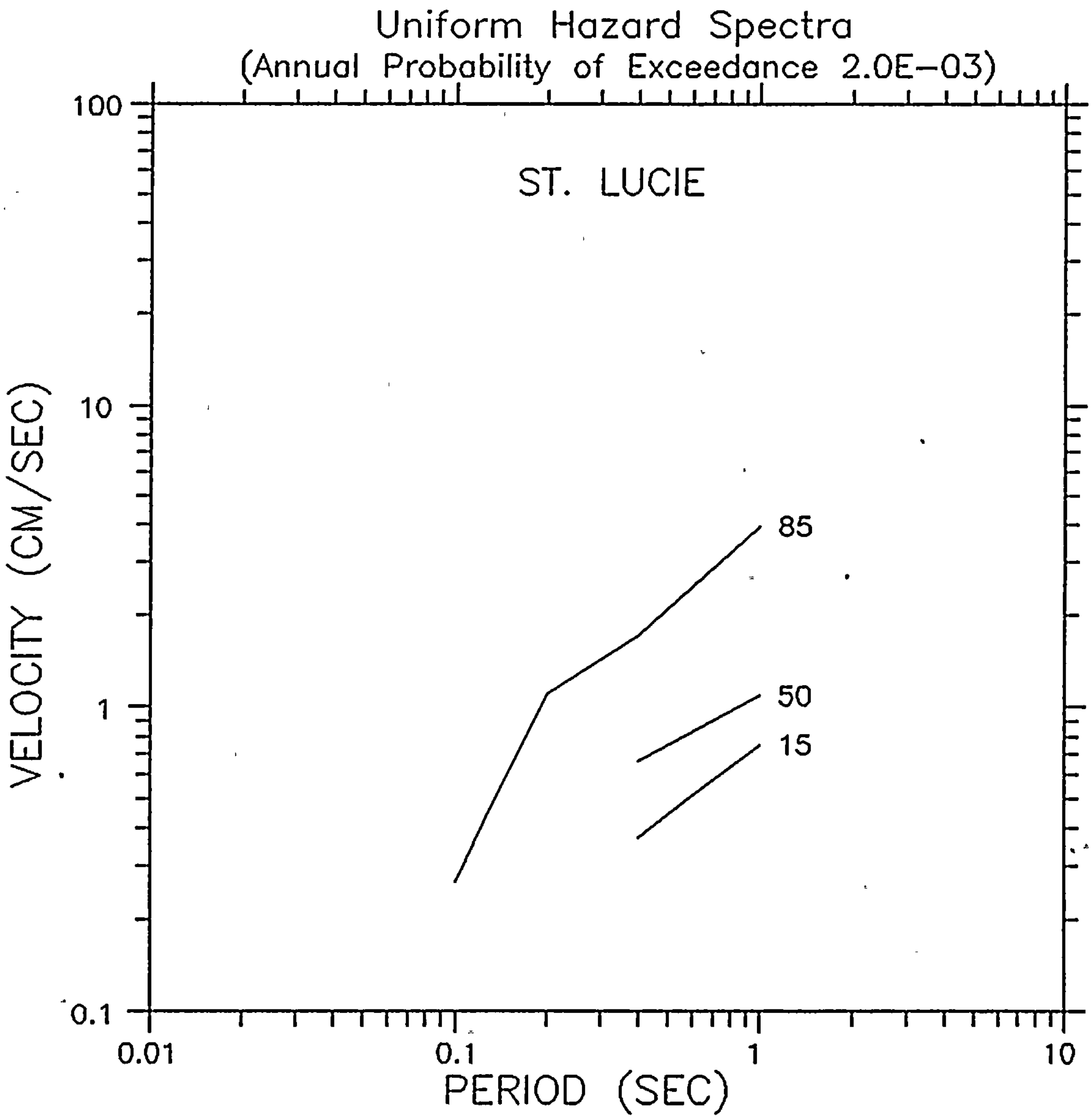

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FIGURE 7-22

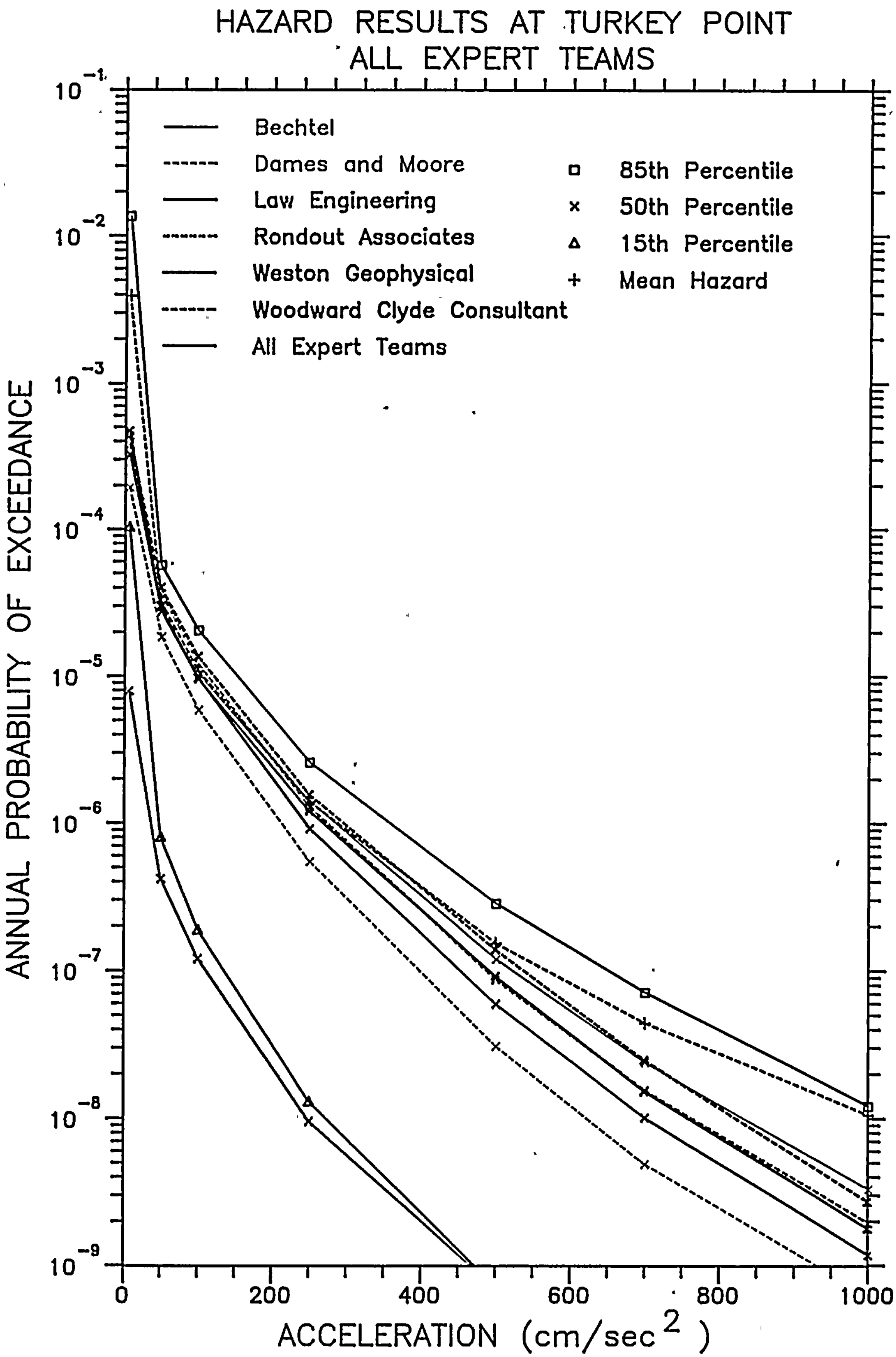

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FIGURE 7-23

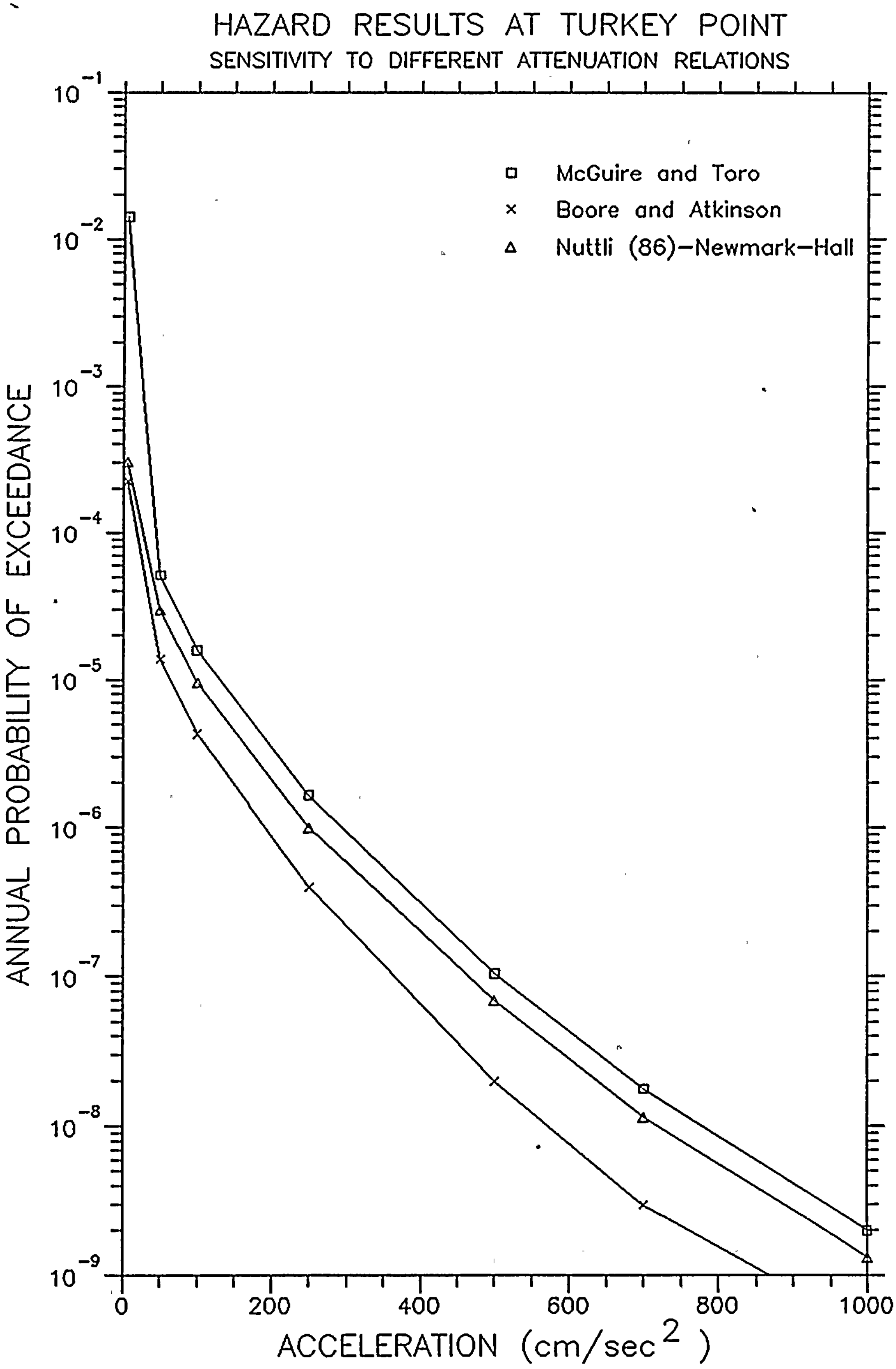

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FIGURE 7-24

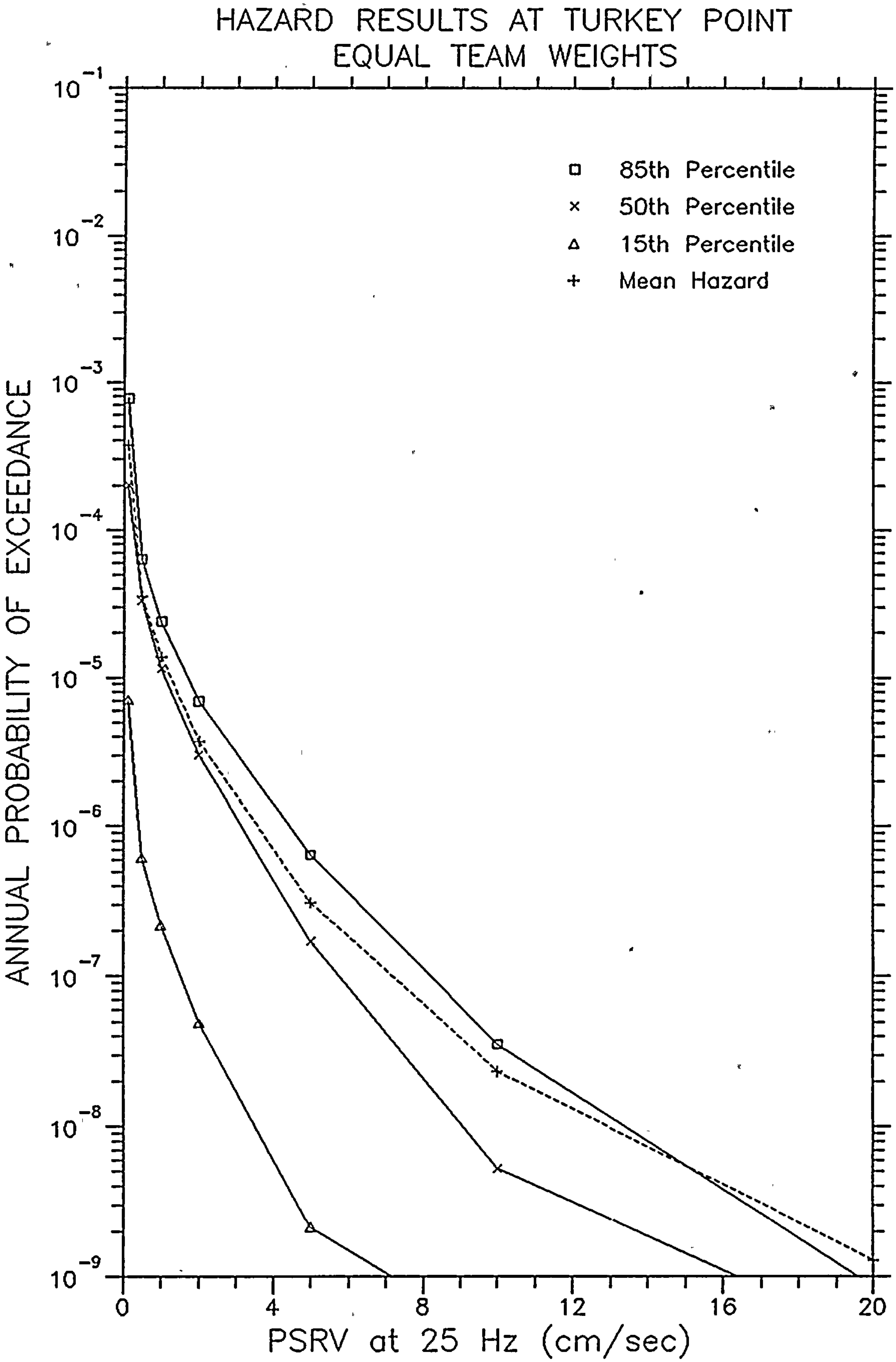

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FIGURE 7-25

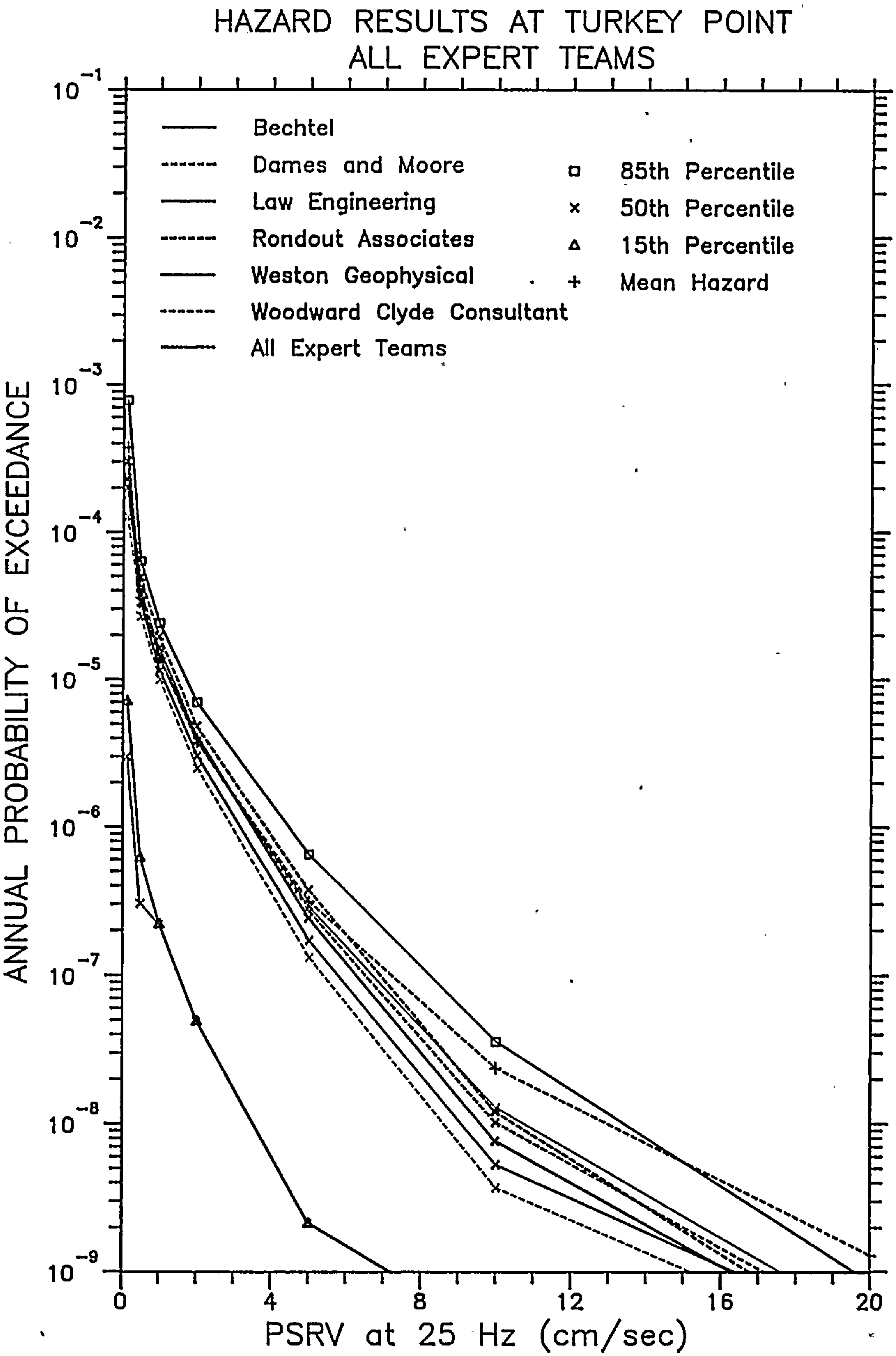

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FIGURE 7-26

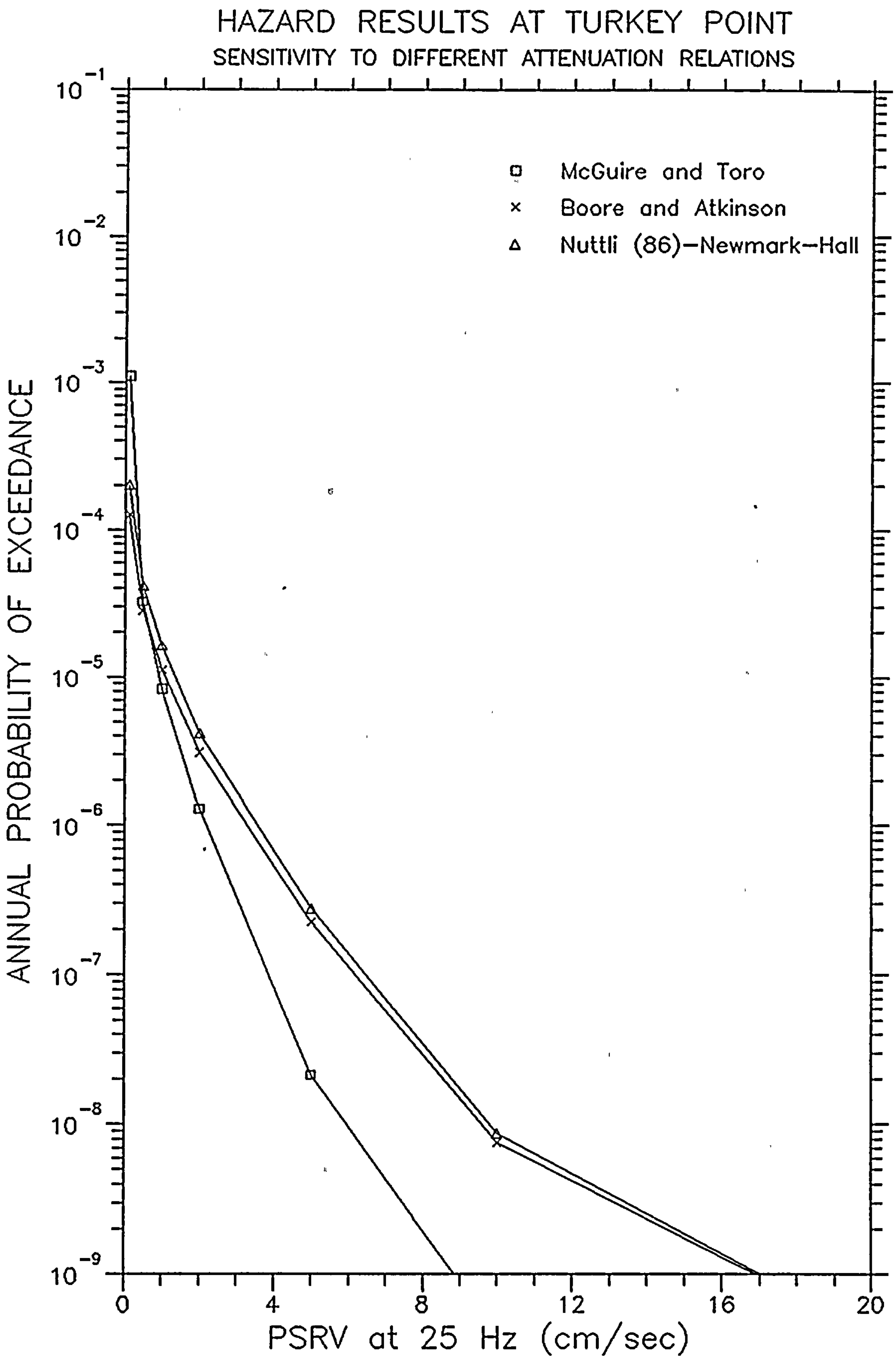

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FIGURE 7-27

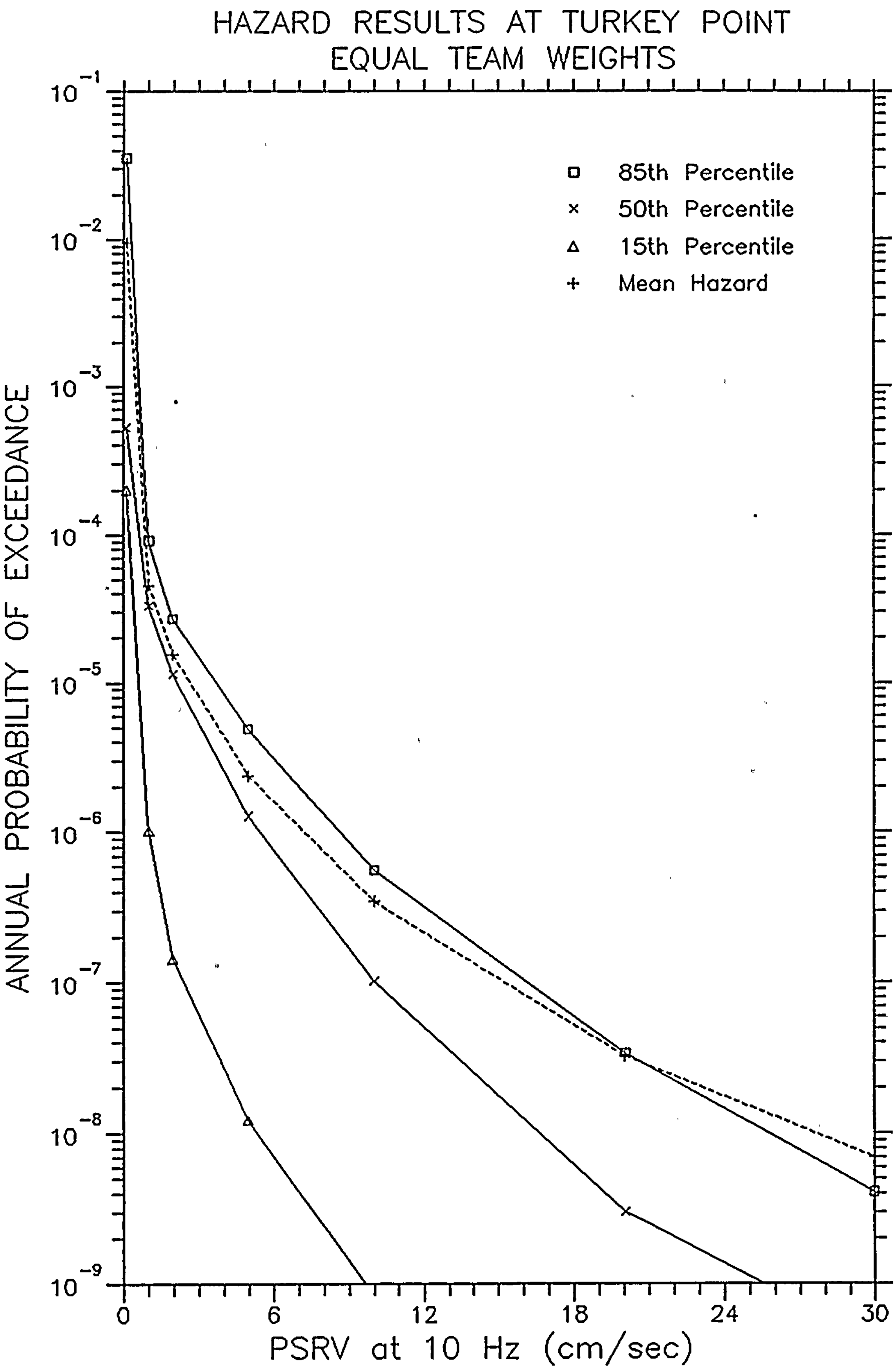

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FIGURE 7-28

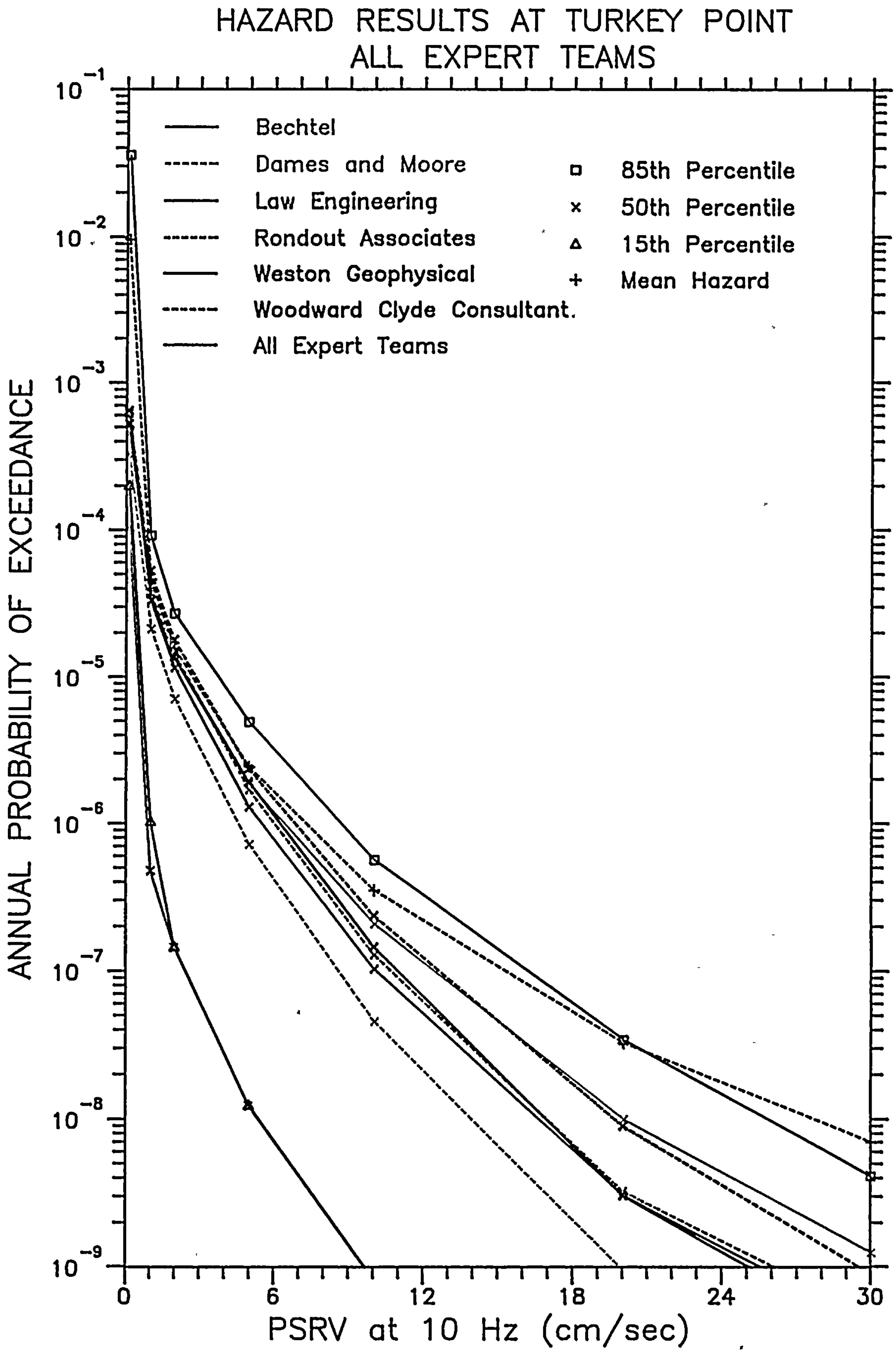

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FIGURE 7-29

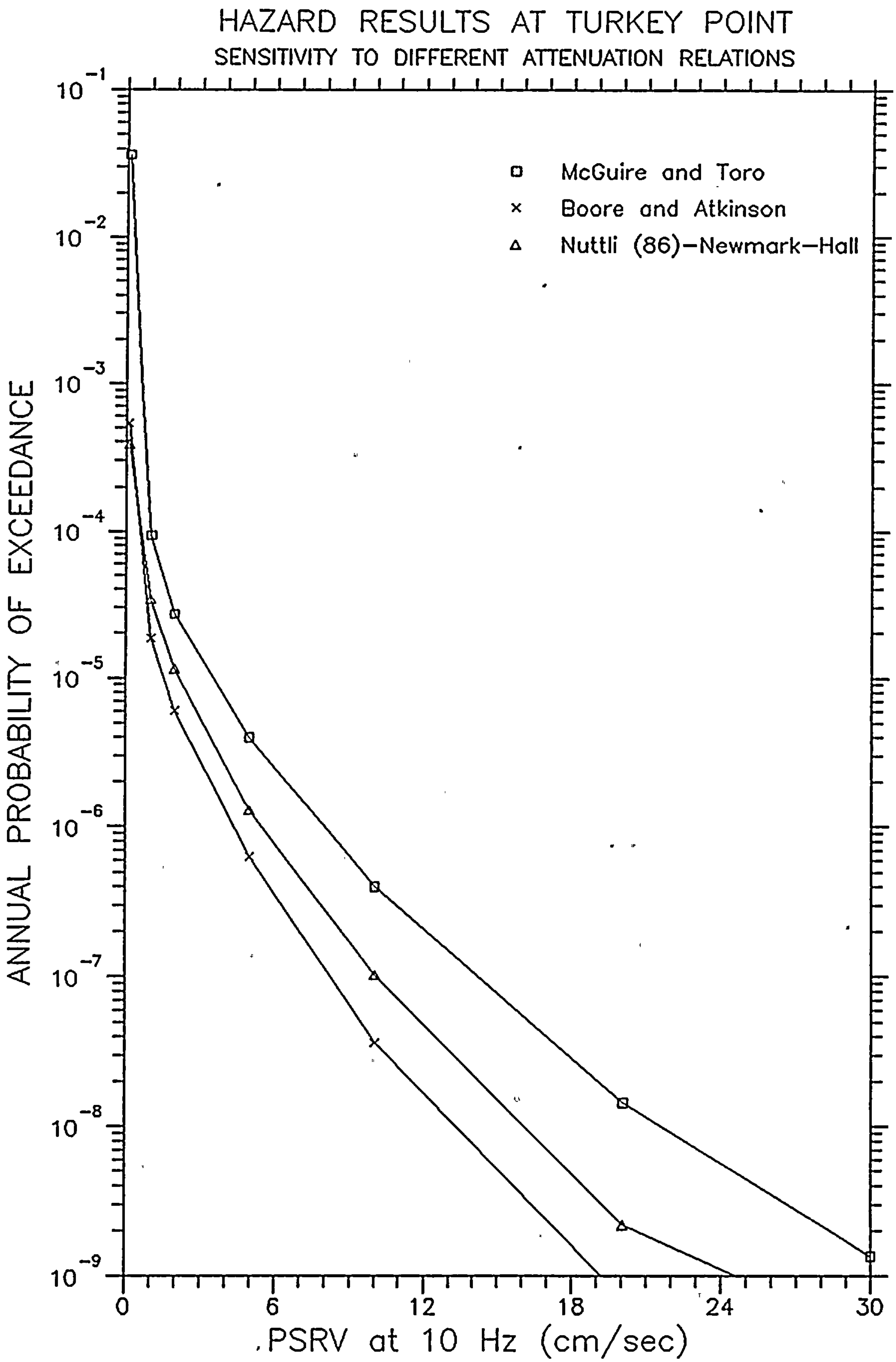

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FIGURE 7-30

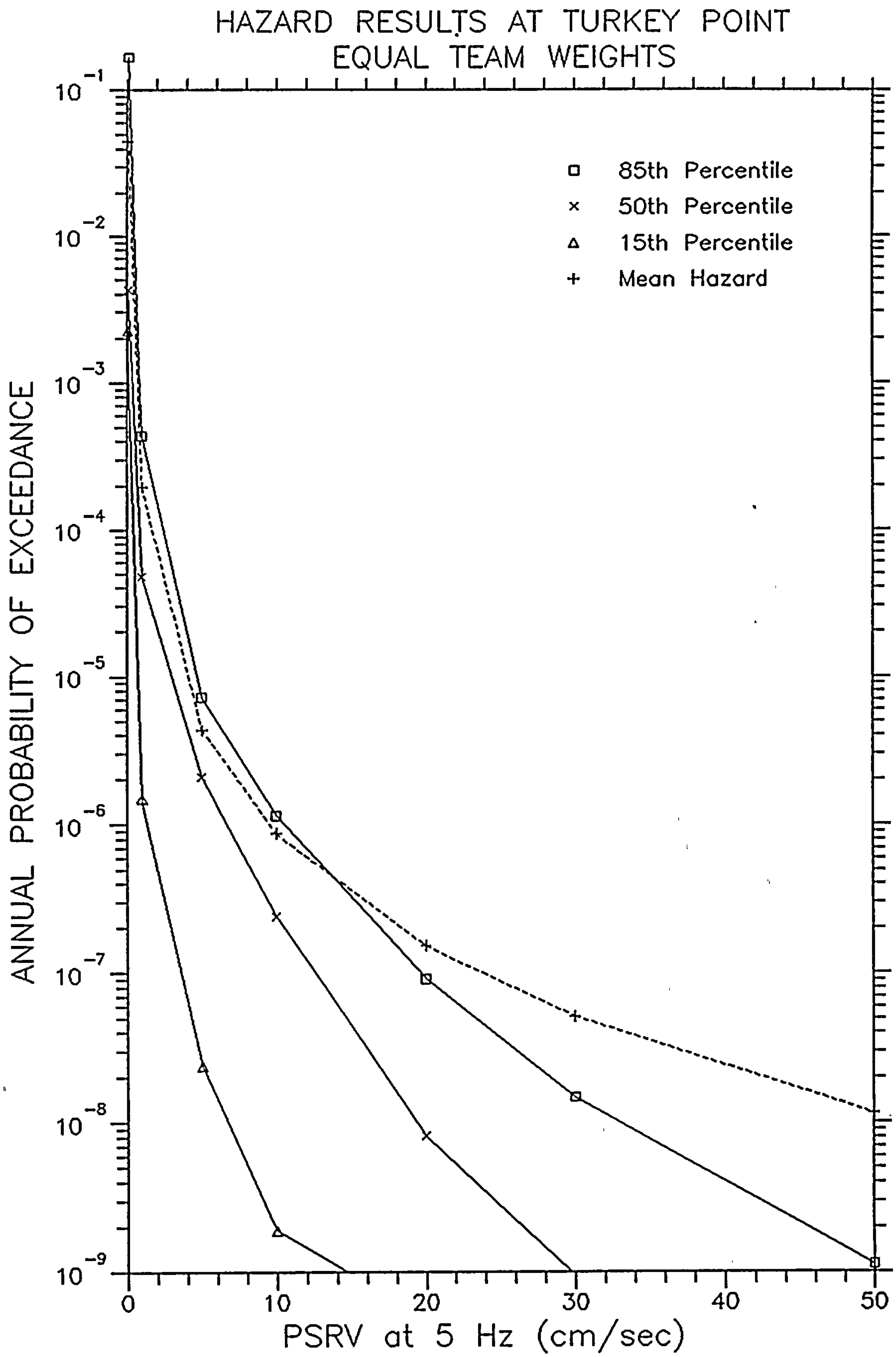

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FIGURE 7-31

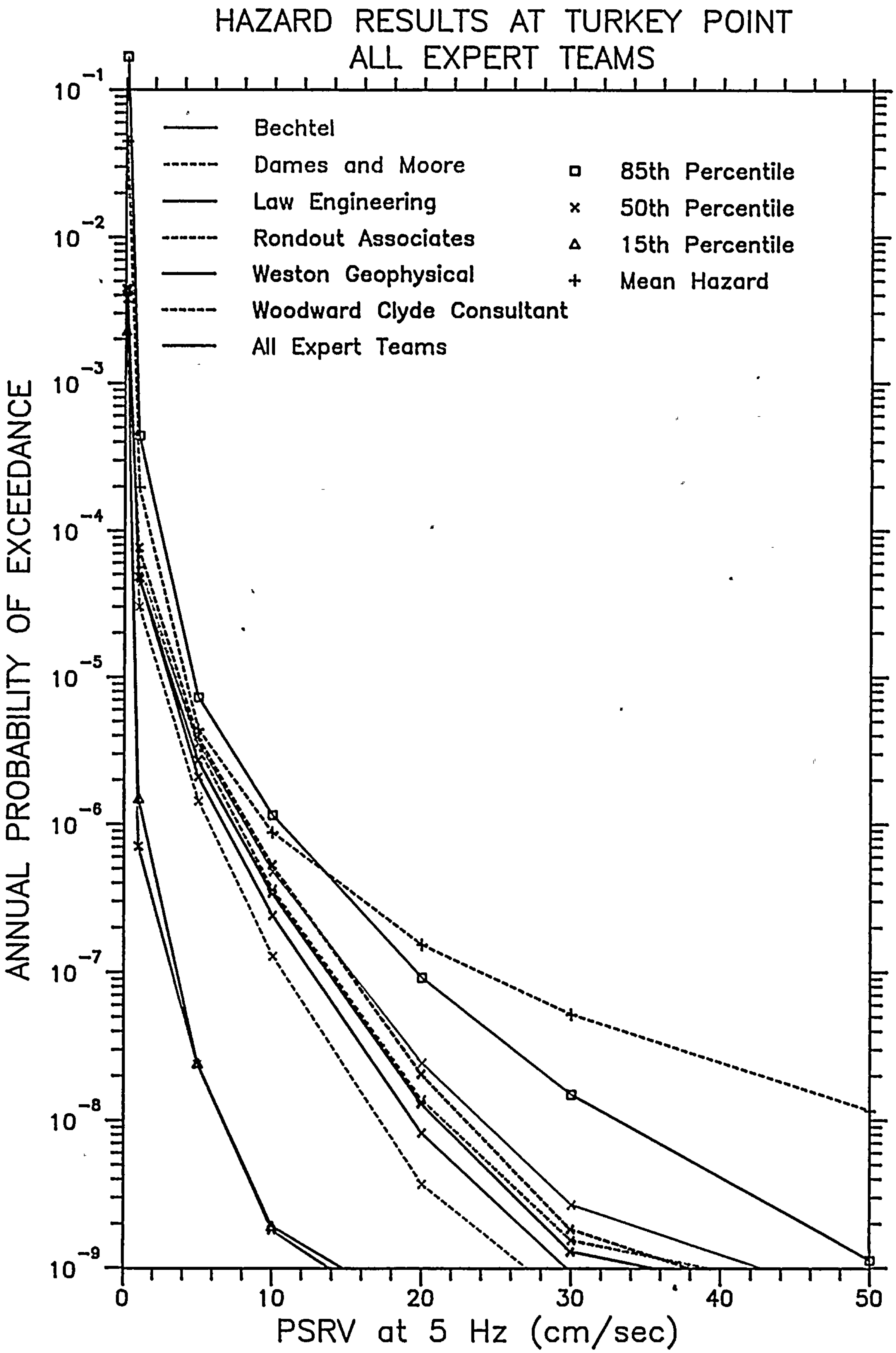

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FIGURE 7-32

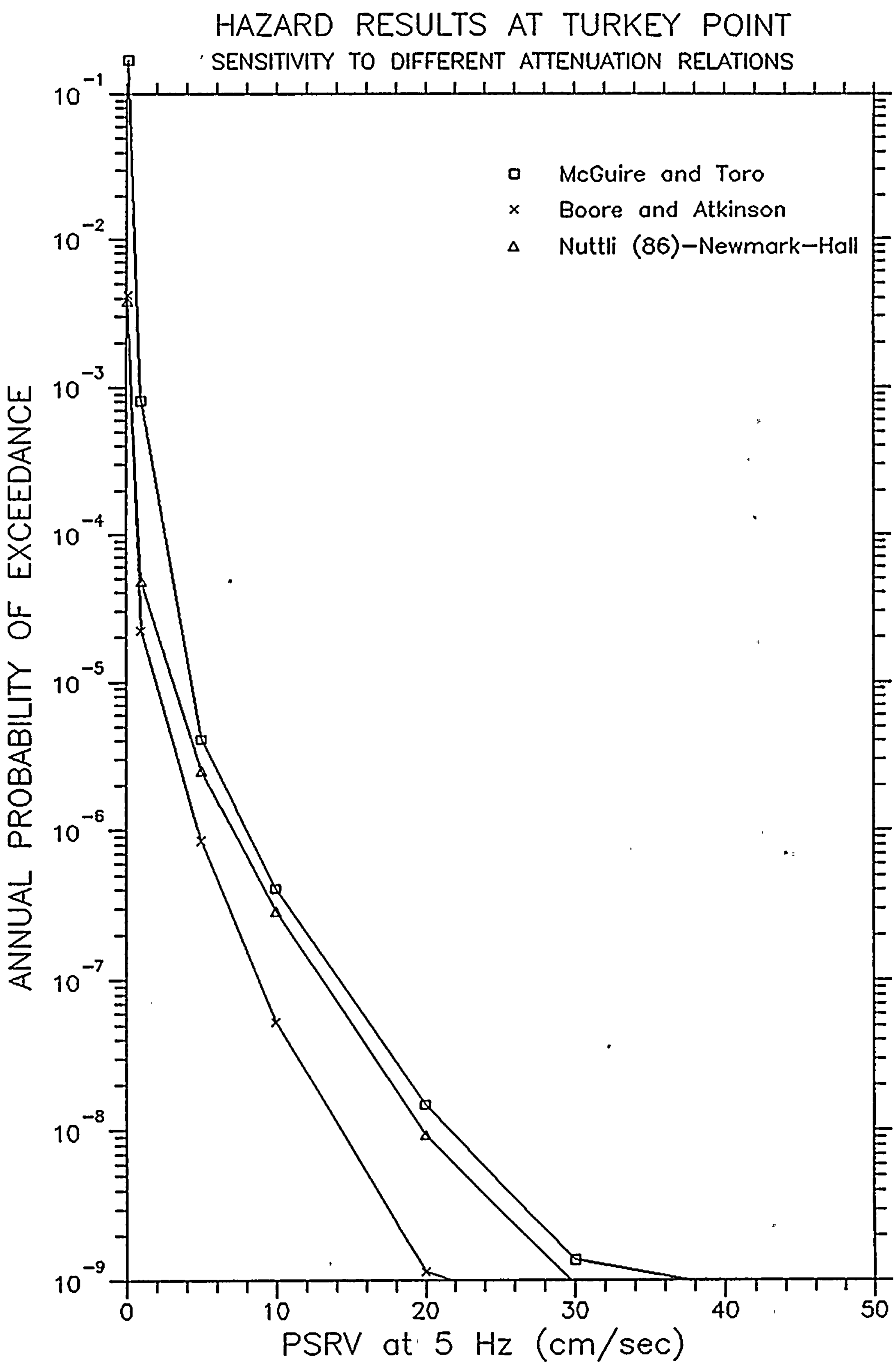

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FIGURE 7-33

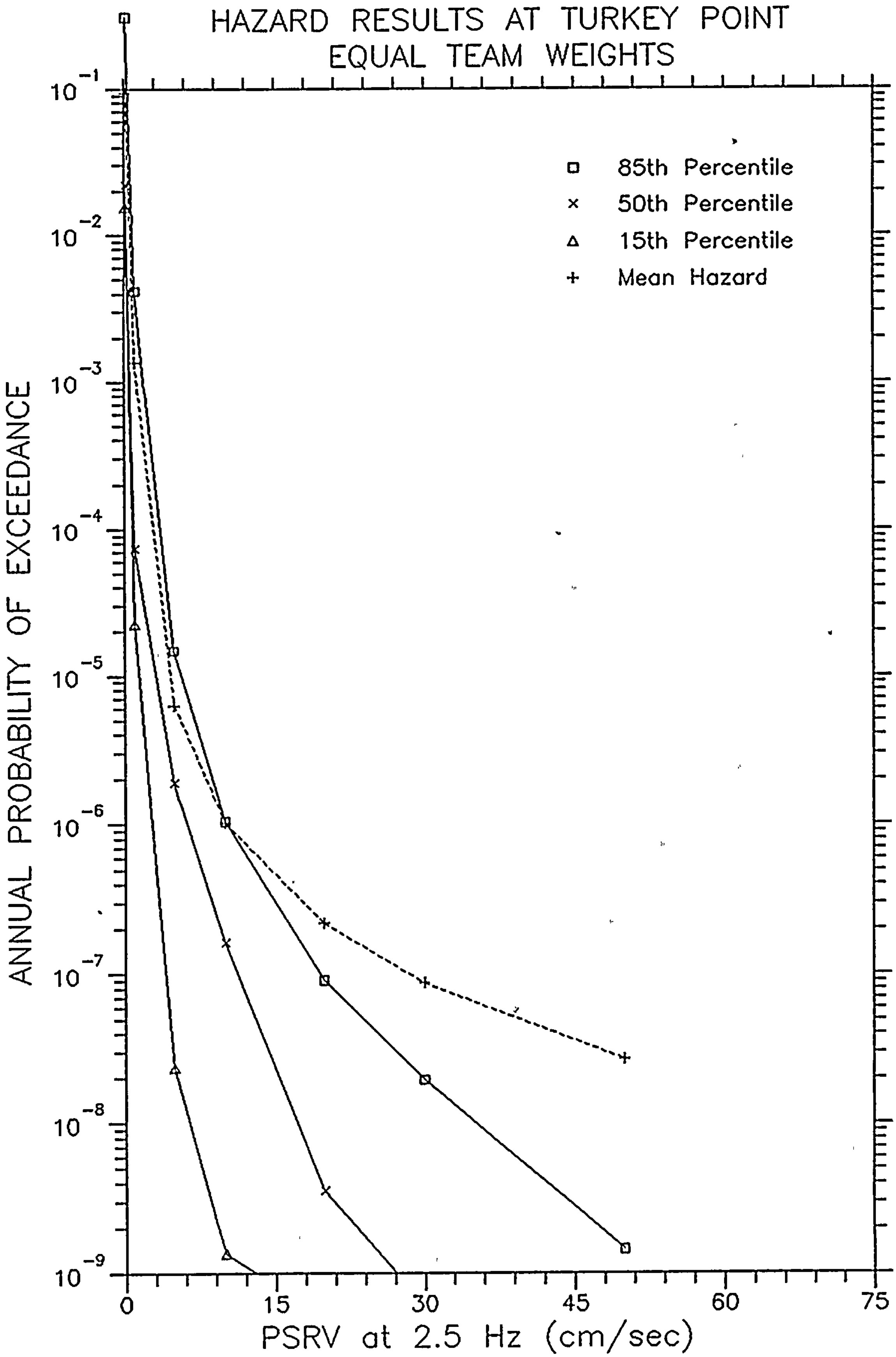

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FIGURE 7-34

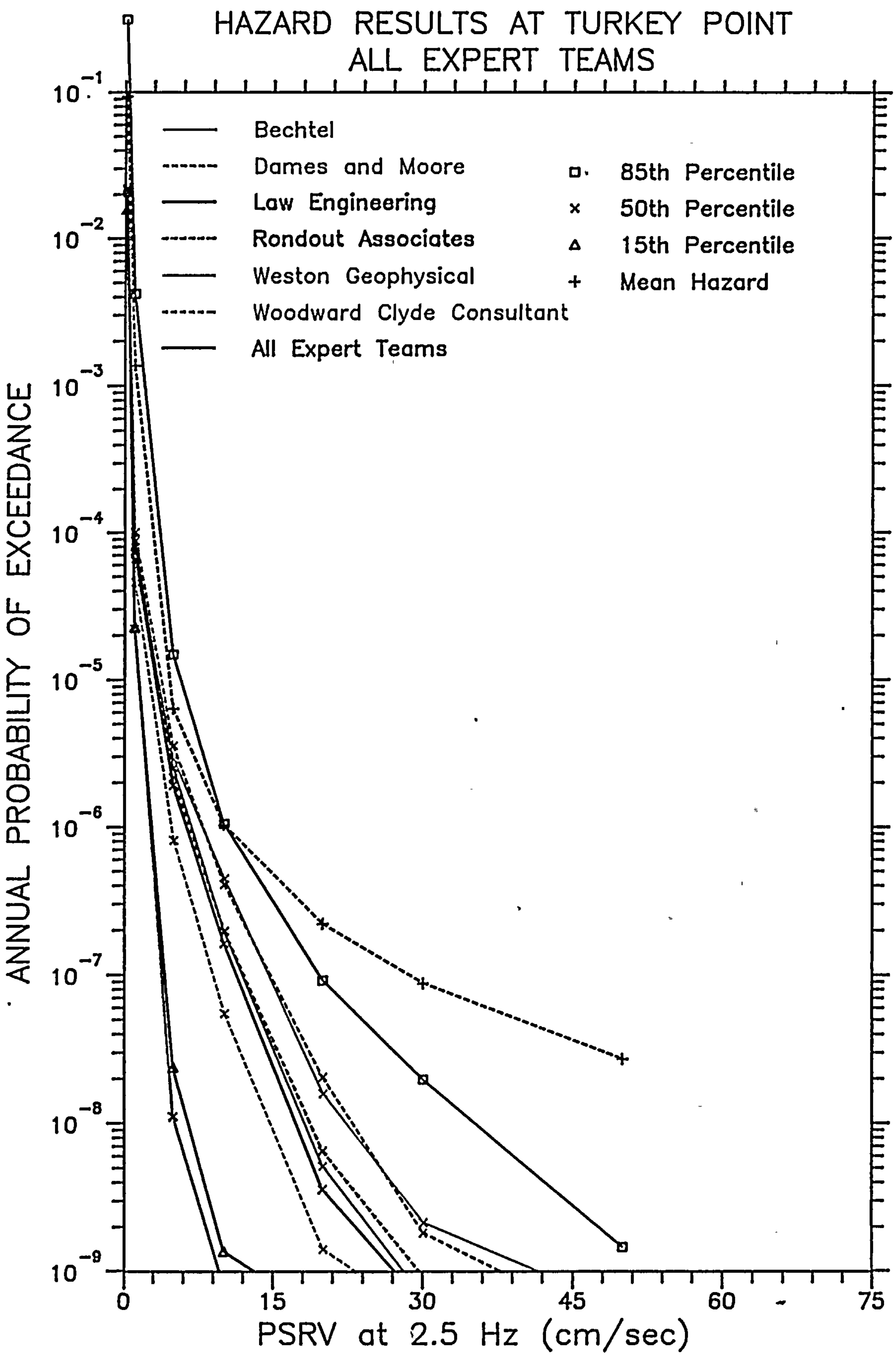

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FIGURE 7-35

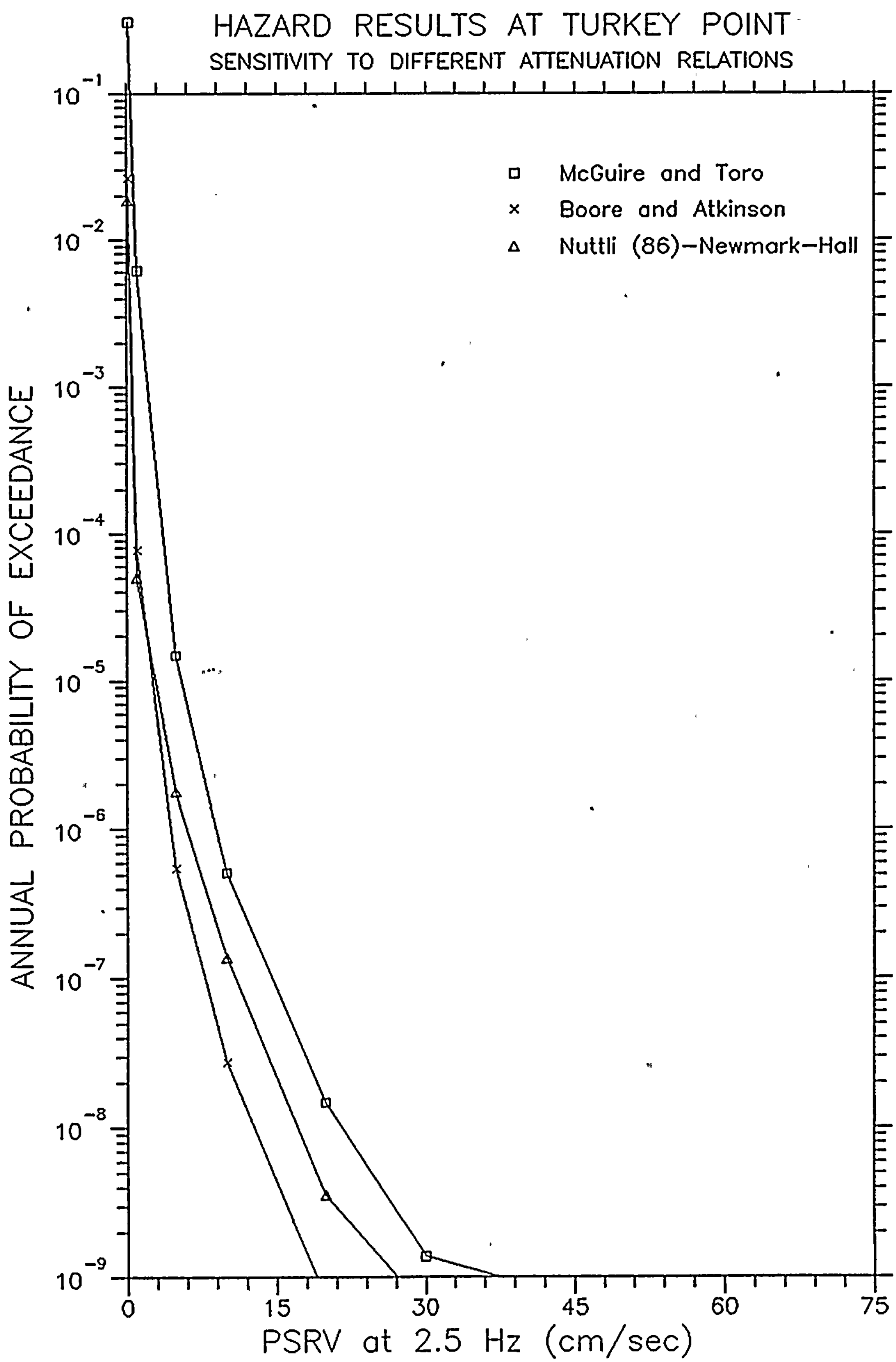

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FIGURE 7-36

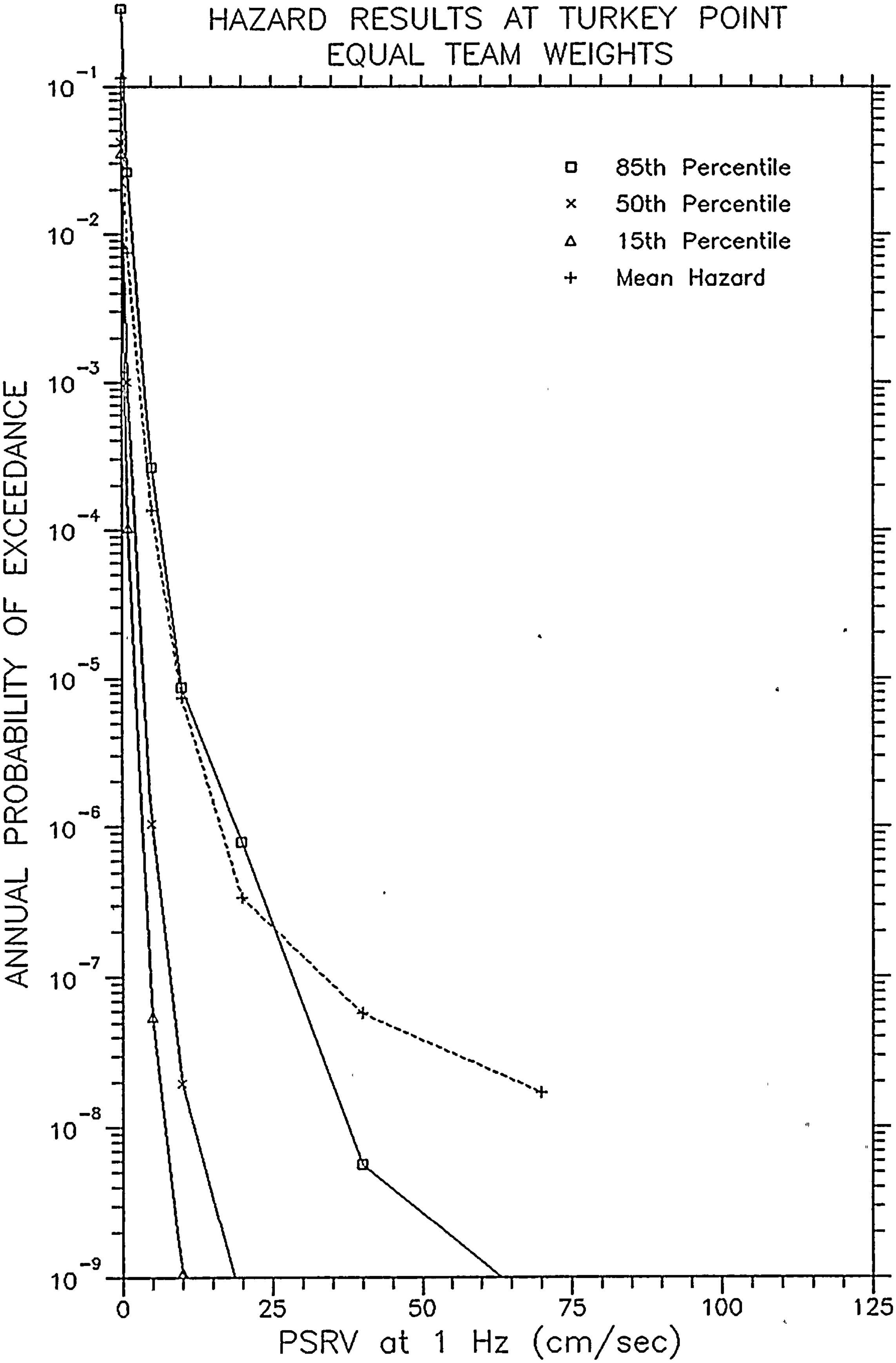

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FIGURE 7-37

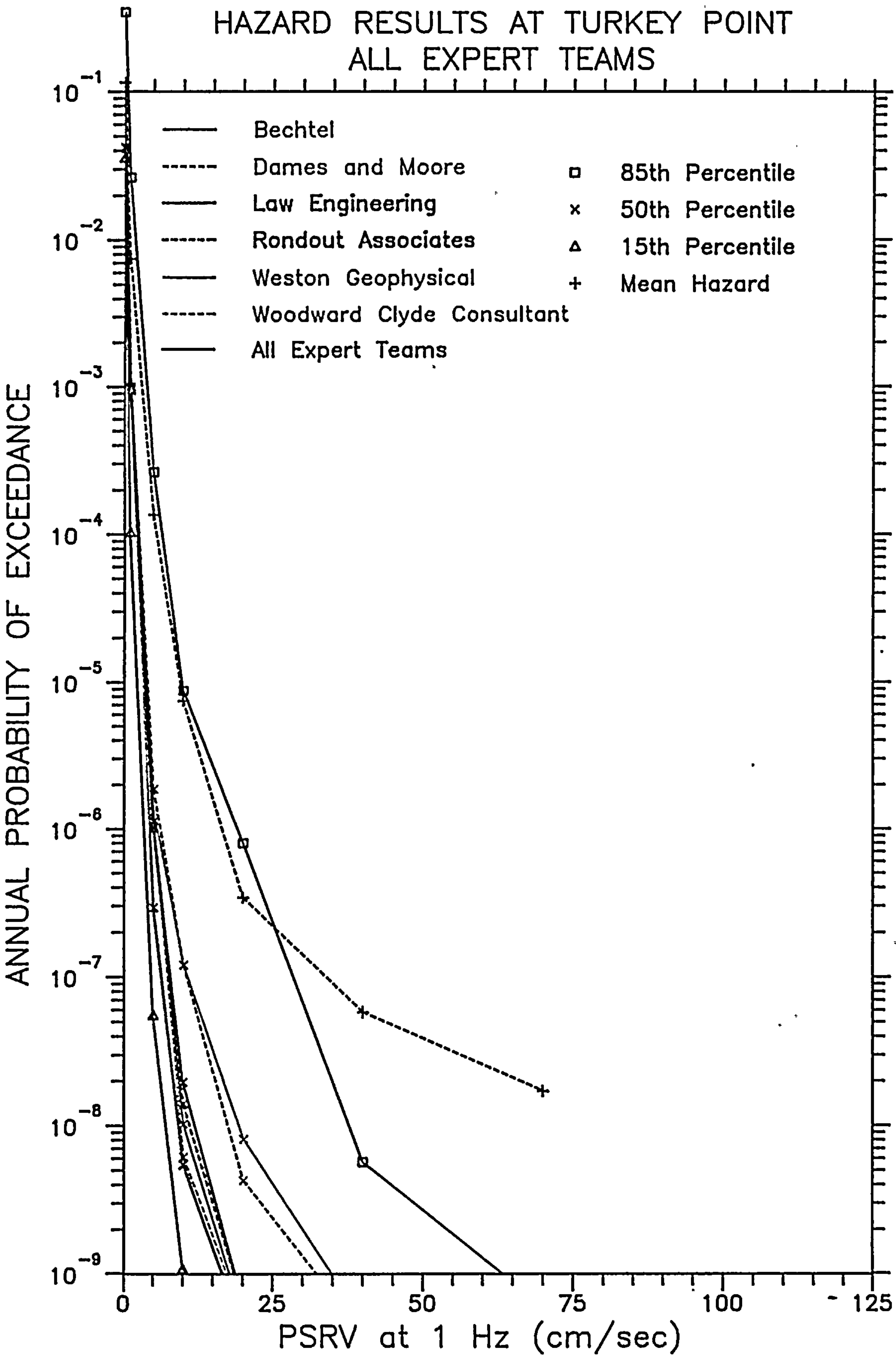

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FIGURE 7-38

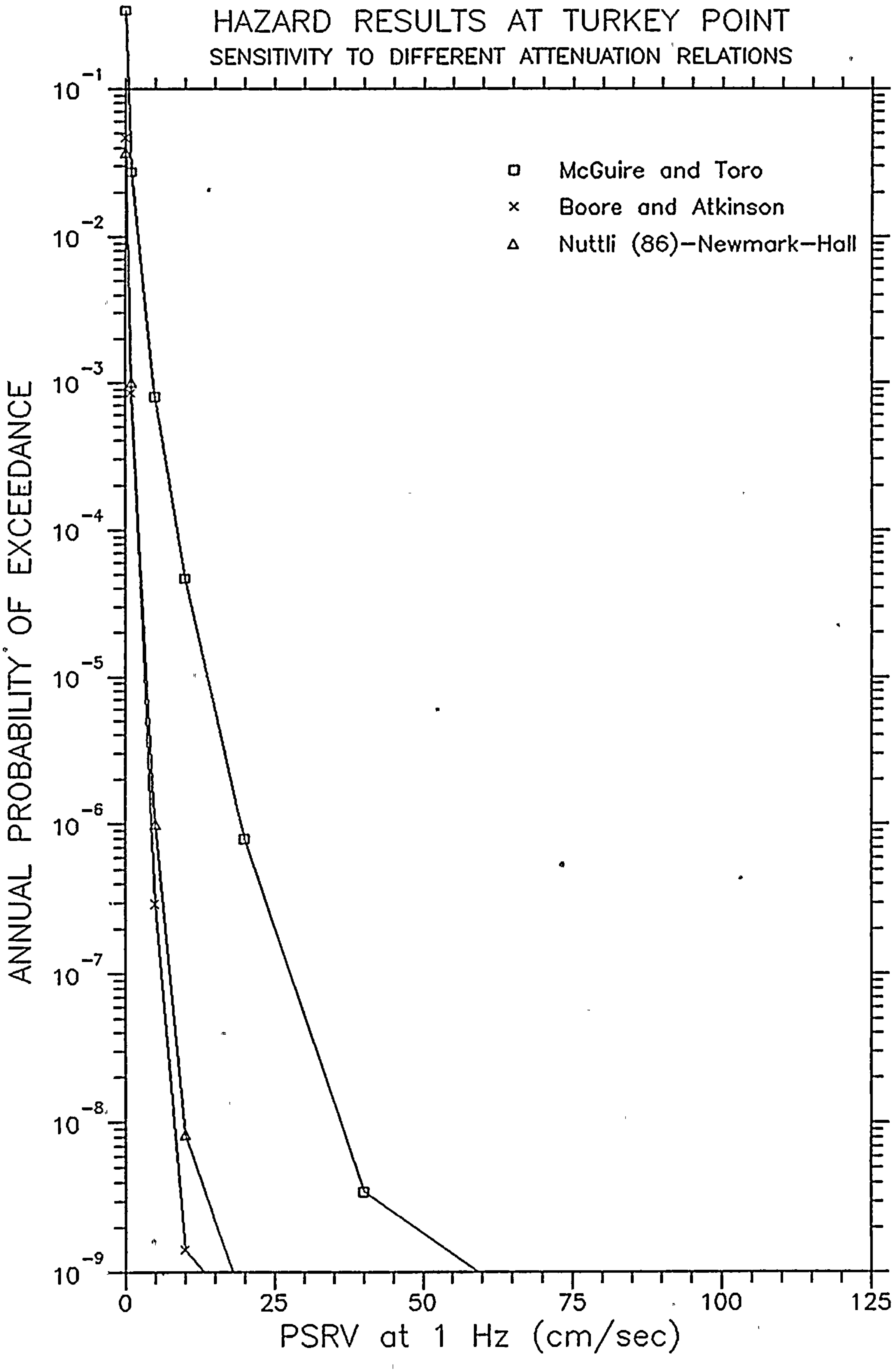

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FIGURE 7-39

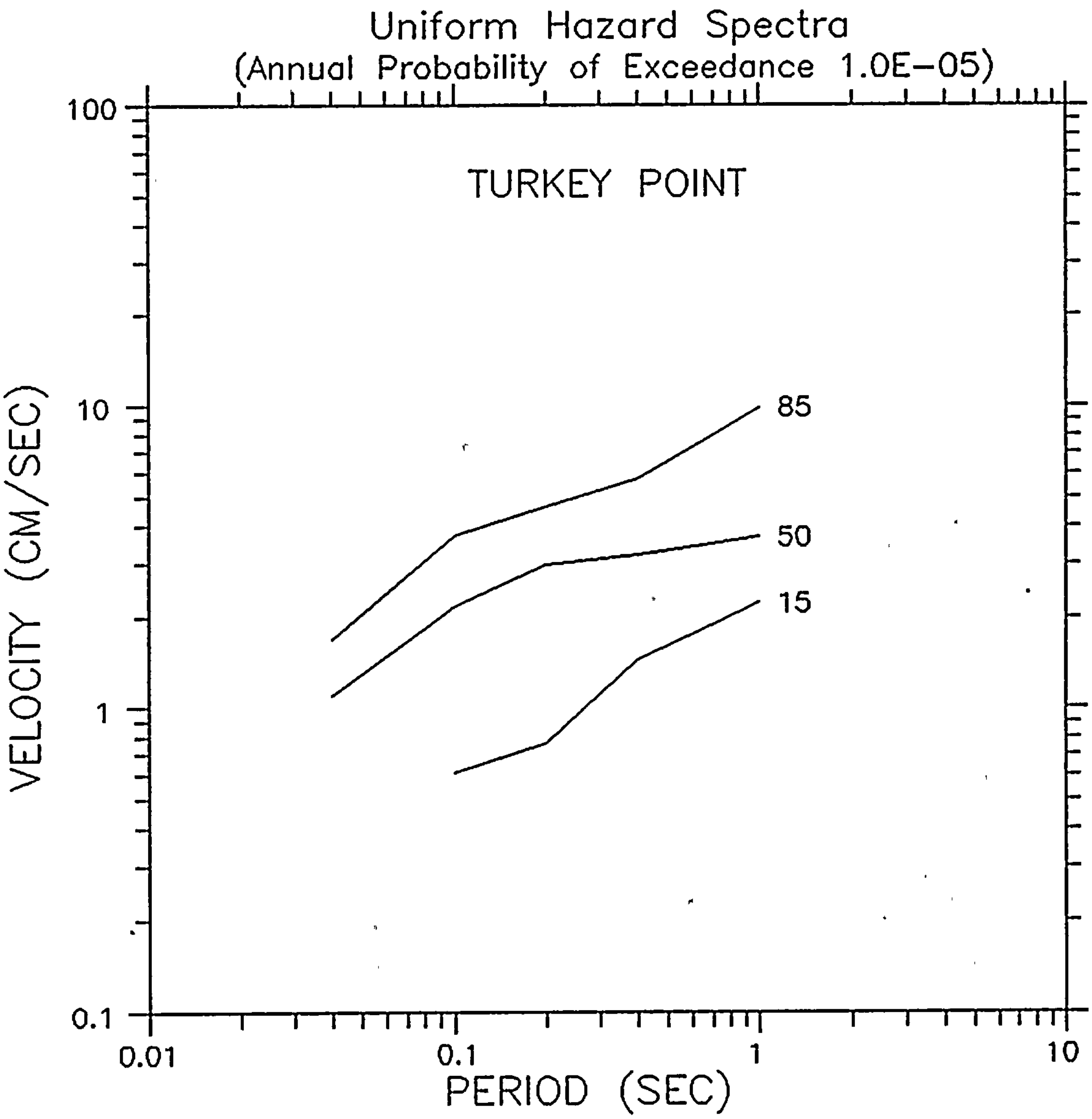

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FIGURE 7-40

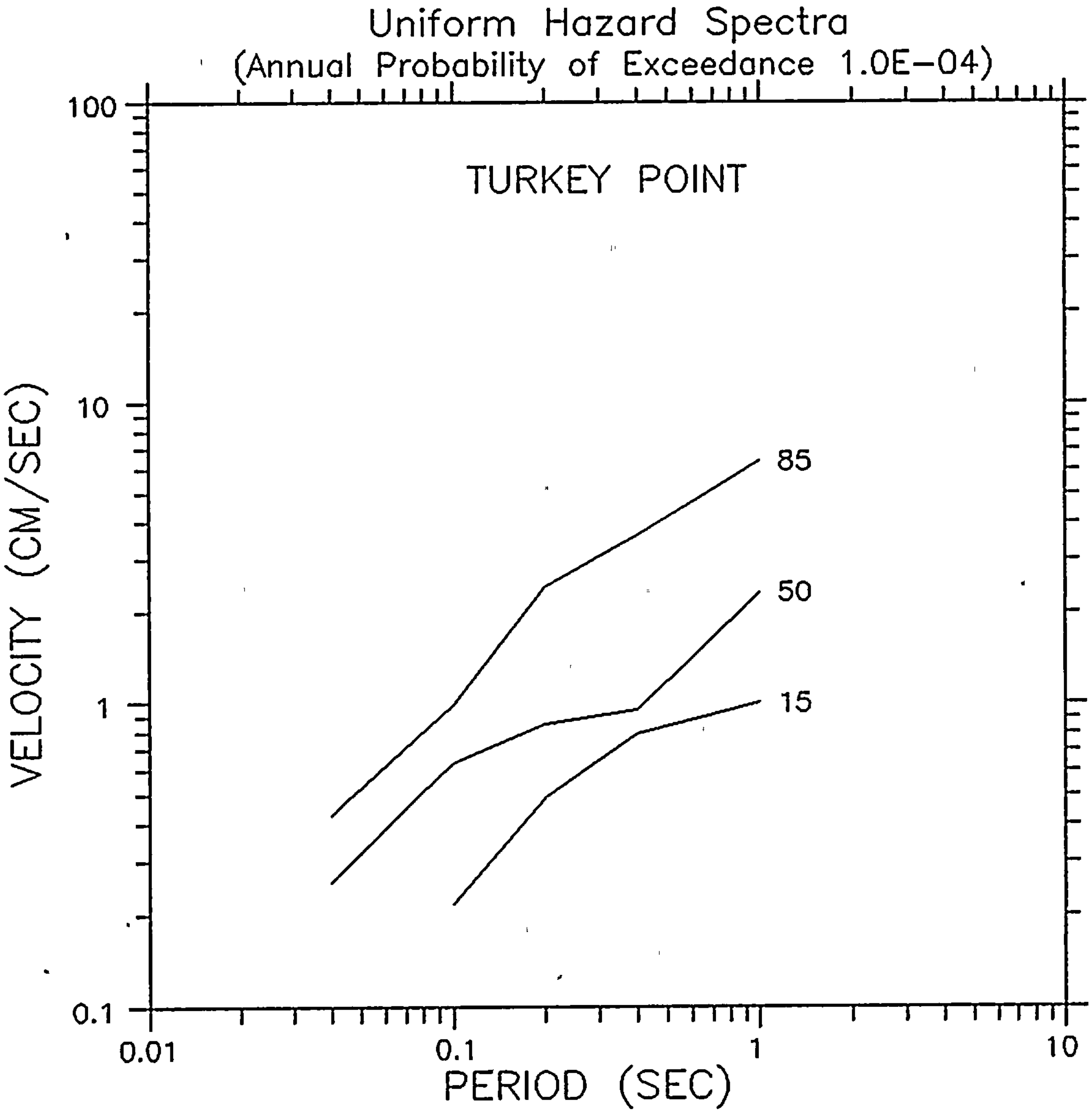

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FIGURE 7-41

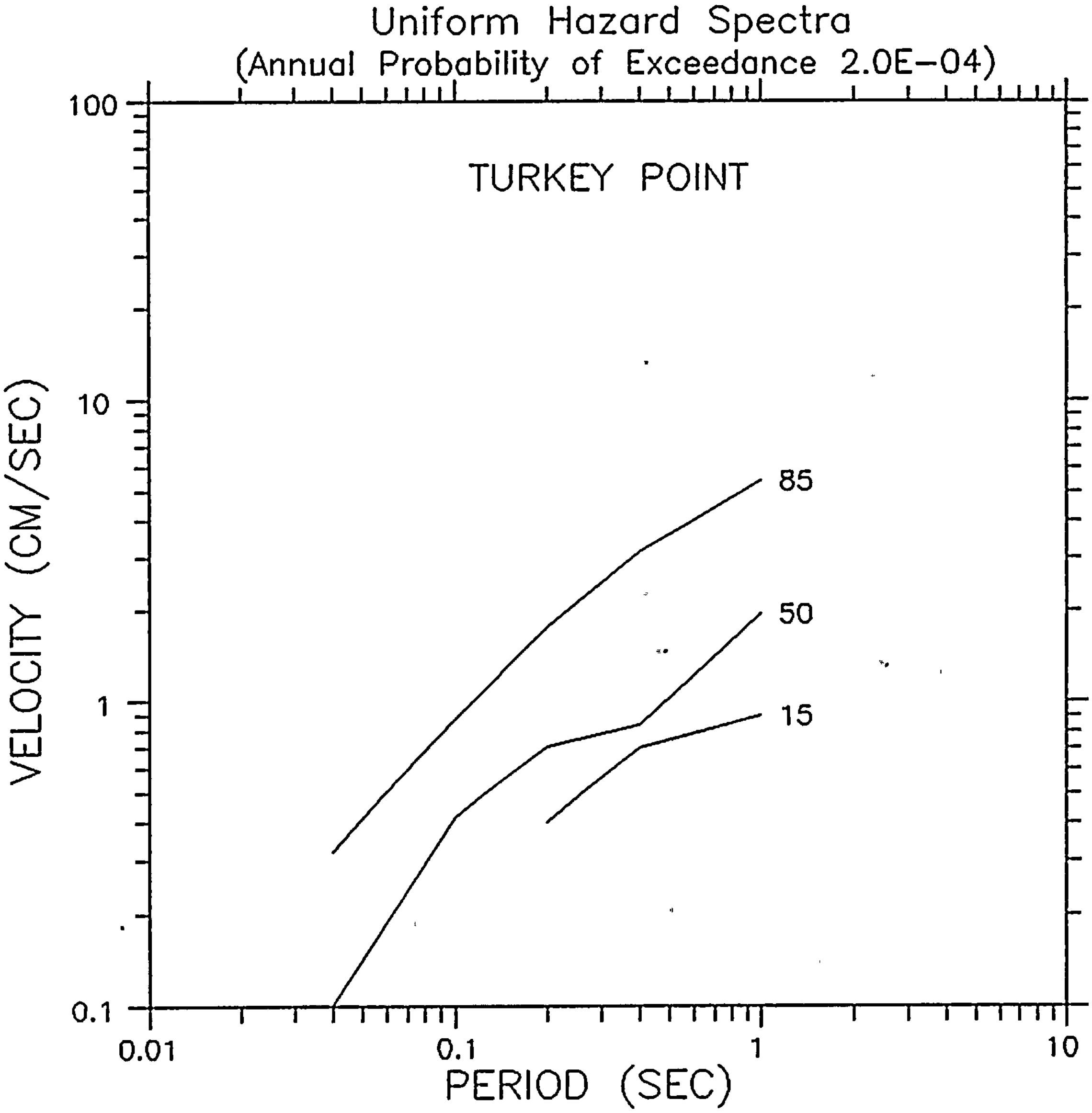

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FIGURE 7-42

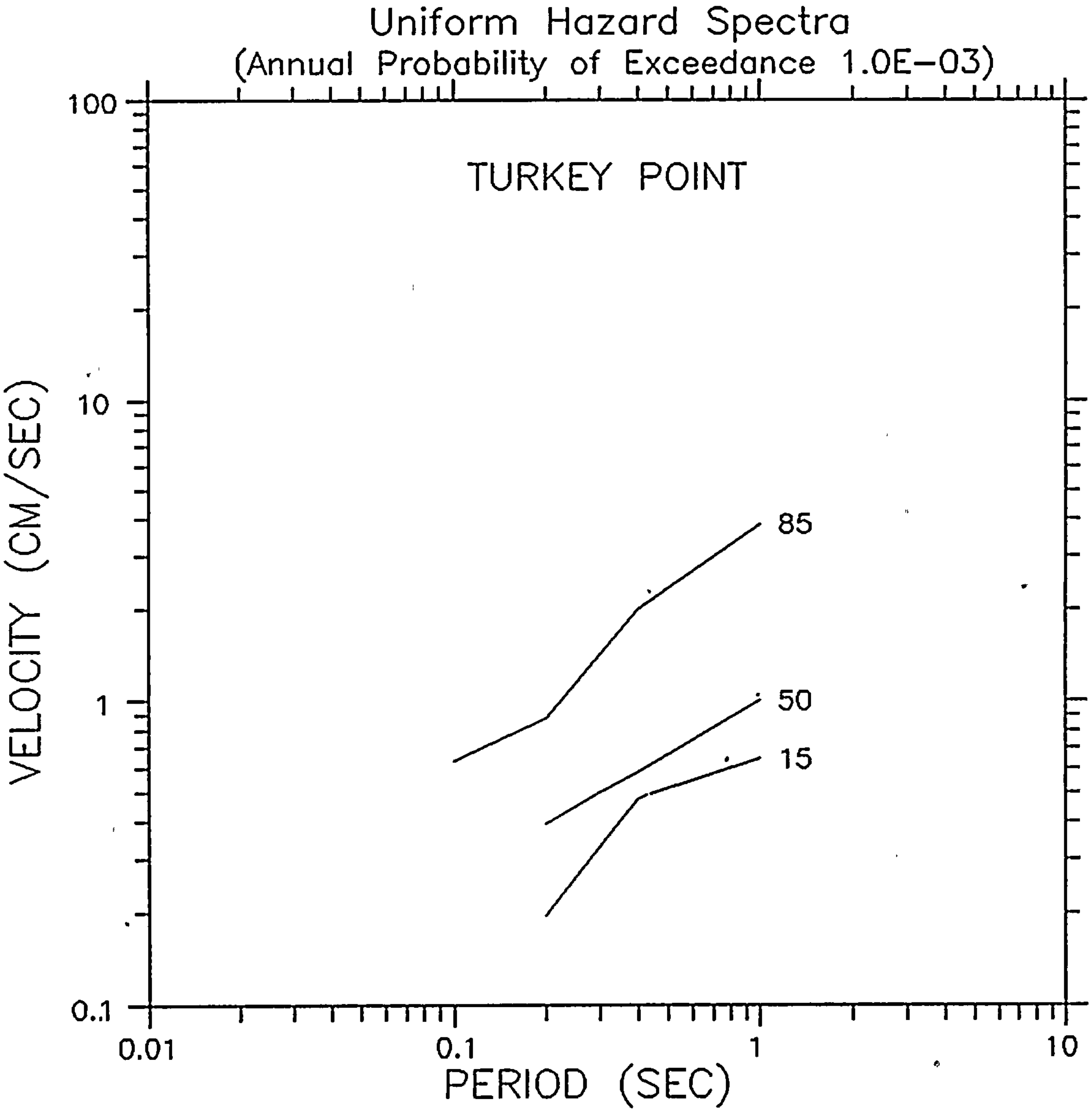

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FIGURE 7-43

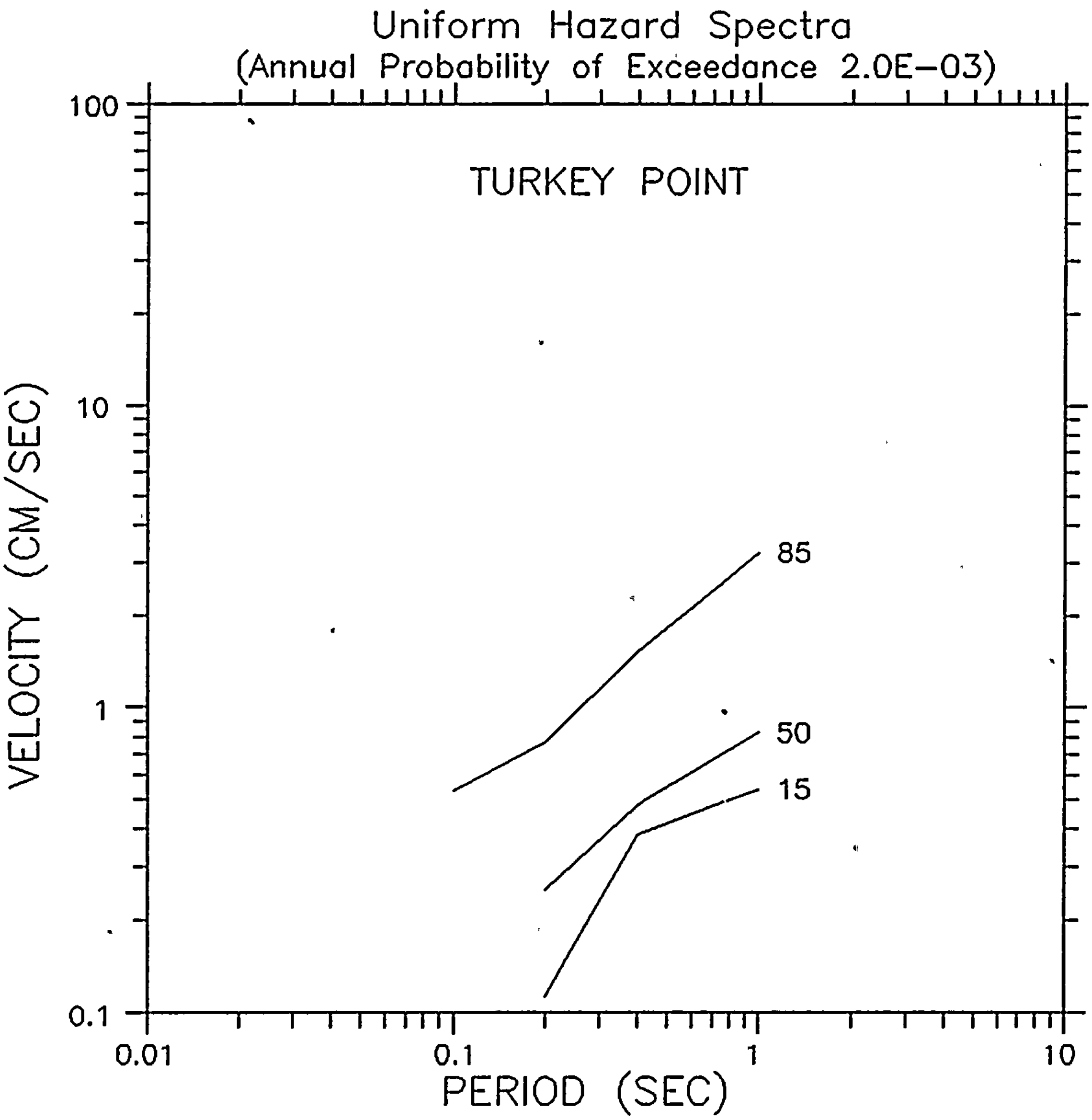

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FIGURE 7-44

8.0 CONCLUSIONS

Probabilistic seismic hazard results for peak ground acceleration, and pseudo relative velocities for 5% damping at frequencies 25, 10, 5, 2.5 and 1 hz were derived for the St. Lucie and Turkey Point sites, using the EPRI methodology and software package EQHAZARD. The contribution of northern Caribbean sources were also considered in the analysis.

Site specific, frequency and amplitude dependent, amplification factors were used in the hazard computation. The St. Lucie site was treated as a deep soil site, and the Turkey Point site was treated as a rock site.

Hazard curves for pseudo relative velocities at different frequencies were used to derive constant percentile and mean uniform hazard spectra (UHS), at various specified risk levels.

As one would expect from a general observation of seismicity of the Florida peninsula, within the context of the Eastern U.S. seismicity as seen on an epicenter map, the level of seismic hazard at St. Lucie and Turkey Point sites is very low. Most of the contribution to the hazard at the two sites, for each of the earth science teams, comes from the background source containing the site. Background sources have been characteristically assigned low maximum magnitudes by all TEC teams in comparison to other sources in the eastern U.S. It was also noted that distant sources making contribution to the hazard at the two sites for low frequency ground motion make less contribution at the sites for high frequency ground motion. It appears that the high frequency components of ground motion attenuate at a more rapid rate with distance than lower frequency components. Thus some distant sources whose contribution was negligible in the computation of high frequency ground motion, were included in the computation of total annual probability of exceedance.

In summary, the results of the probabilistic seismic hazard evaluation for Florida Power and Light's St. Lucie and Turkey Point sites, using the EPRI methodology, yield very low values for each site's seismic hazard.

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APPENDIX A
QUALITY ASSURANCE FOR THE ADAPTATION OF EPRI'S EQHAZ AND EQPOST PROGRAMS

For the estimation of probabilistic seismic risk at the St. Lucie and Turkey Point sites, the EQHAZ and EQPOST software packages provided by the EPRI were used in this investigation. These software packages were adapted to Ebasco's computing facilities (IBM/PC compatibles and IBM mainframe of Power Computing).

In order to ensure the accuracy of the adaptation of the EPRI programs to the Ebasco computer system, a program of quality assurance was initiated. Under this program, a complete run of the EQHAZ and EQPOST programs by EPRI for the Crystal River nuclear power plant was acquired.

A.1 EQHAZ PROGRAM

Using the same data set as used by EPRI for one of the Technical Evaluation Contractors, viz., Bechtel, we executed the EQHAZ program. The results thus derived for peak ground acceleration and pseudo relative velocity for 5% damping at frequencies 1, 2.5, 5, 10 and 25 hz were compared with the corresponding results obtained by EPRI. The two sets of computations produced identical results, thus attesting to the accuracy of the Ebasco's implementation of the EQHAZ program.

A.2 EQPOST PROGRAM

To check the accuracy of Ebasco's implementation of EQPOST program, input data file for the peak ground acceleration was used. The output results obtained by Ebasco were compared with those provided by EPRI. The output results included separate computations for each of the six earth science teams, as well as combined computations for all six teams.

Results were identical for Law Engineering, Woodward Clyde Consultants, Weston Geophysical Corporation, although some small differences were noted in fractile hazard functions for Dames & Moore, Bechtel Incorporated and Rondout Associates. However, the results for all six teams combined were identical.

Evidently, both computers were running EQPOST correctly, but because of small data base and differing architecture of the two computers (EPRI and EBASCO/Power Computing), the risk value corresponding to the next ordered probability level was picked up in one of the computers. This problem is not present in runs with data for all six teams combined, when the data set becomes considerably larger.

the generally diffuse nature of the boundary, some correlations between spatial concentrations of earthquakes and strike slip faults and subduction zones, are apparent.

B.2 Relationship of Earthquakes to Faults and Subduction Zones

There are concentrations of earthquakes between longitudes 75 to 77 W, along the Oriente fault zone (the northern boundary of the Cayman trough, with epicenters aligned parallel to the southern coast of Cuba), and longitudes 85 to 87 W, along the Swan fault zone (the southern boundary of the Cayman trough). The Mid-Cayman spreading center is marked by a northerly trending cluster of earthquakes between longitudes 81 and 82 W (Figures B-2 and B-3). The number of earthquakes increases noticeably along the eastern extension of the Oriente fault zone, in northern Hispaniola, forming a broad east-west trending belt of seismicity between longitudes 70.5 and 74 W, parallel to the Septentrional fault zone. Another grouping of relatively high seismic activity extends between latitudes 18 and 20 N and longitudes 68 and 70.5 W. This grouping has a distinct northwest trend, across the eastern tip of Hispaniola (Figures B-2 and B-3). Further east, the Puerto Rico trench is marked by an even greater concentration of earthquakes along a wider east-west trending belt of earthquakes, between longitudes 64 and 68.5 W (Figures B-2 and B-3). The maximum magnitude of the trench related earthquakes is as large as 7 and 8, greater than the largest earthquakes that occur in the Cayman trough (Mann and Burke, 1984). An arcuate belt of shallow earthquakes can be traced offshore of southern Puerto Rico and southern Hispaniola. This belt coincides with the location of the Muertos trough, an incipient subduction zone of descending Caribbean plate (Sykes and others, 1982). East of longitude 64 W, the belt of seismicity changes trend from nearly east-west to a northerly trend. In addition, there is a noticeable difference between the concentration of earthquakes in the region of the Puerto Rico trench and that in the northern Lesser Antilles (Figures B-2 and B-3). These sudden changes in the trend and concentration of earthquakes appear to occur across the Anegada Trough (Figure B-1). There is a prominent northeast-southwest trending alignment of epicenters within the trough parallel to the Anegada fault zone (Figure B-3).

A diffuse east-west trending belt of seismicity extends across southern Hispaniola and through Jamaica, suggesting that the active PBZ in this region is much wider (about 250 km) than the PBZ towards the west in the Cayman trough (about 100 km). There is general correspondence between these earthquakes and faults in southern Hispaniola and Jamaica. The "North Jamaica Fault Zone" was defined on the basis of the alignment of epicenters of earthquakes ranging in magnitude from 4 to 6 (Shepherd and Aspinall, 1980, and Mann and Burke, 1980). The presence of the "South Jamaica Fault Zone" was suggested from the detection of smaller events by the seismic network of the University of the West Indies near Kingston. The magnitude 7 earthquake of 1941 and its aftershocks of the same year are related to the fault zone southwest of Jamaica (Mann and Burke, 1984). The shallow focus epicenter map of Sykes and others (1982) suggests that the South Jamaica Fault Zone may extend as far east as the Beata Ridge south of Hispaniola and may explain the width of the PBZ in this region.

B.3 Seismic Source Zones of the Northern Caribbean

Using the concept of primary or first level seismic source zones, in which the outline of a source zone is based on a close fit to tectonic features or group of tectonic features (EPRI, 1985), six distinct seismic source zones can be outlined along the North Caribbean PBZ (Figure B-4). These are: 1) the Cayman Trough source zone, 2) the Jamaica-Western Hispaniola source zone, 3) the Eastern Hispaniola source zone, 4) the Puerto Rico trench Source zone, 5) the Muertos Trough source zone, and 6) the Greater Antilles-Lesser Antilles transition source zone.

B.3.1 The Cayman Trough Source Zone

The Cayman Trough, about 100 km wide by 1,200 km long, was formed by creation of oceanic crust between plates of anomalously thick and buoyant Caribbean sea-floor crust (Holcombe and Sharman, 1983). In plate-tectonics terms, the Cayman Trough is primarily a long transform boundary offset by the mid-Cayman spreading center. Such a

transform dominated boundary is very sensitive to minor changes in the direction of relative motion between plates. Small changes may result in a component of closing (transpression) or opening (transtension) on the transform faults.

B.3.2 The Jamaica-Western Hispaniola Source Zone

Burke and others (1980) identified about 40 km of cumulative offset in Jamaica along east-west, left-lateral, strike slip faults during the past 10 million years. They also suggest that at least 0.4 cm/yr of interplate motion has occurred within Jamaica during that interval. Igneous rocks of Neogene age on the sea floor near the eastern tip of Jamaica seem to be linked through a small zone of extension with major left-lateral strike slip faults in southwestern Hispaniola. The southern and northern seismic zones in Hispaniola have been the loci of some large and destructive earthquakes (Sykes and others, 1982). Recent instrumental record as well as historic data indicate that motion between the Caribbean and North American Plates is taken up in the vicinity of Jamaica and in northern and southern Hispaniola along these left-lateral strike slip faults.

West of longitude 70.5 W all of the events in the Greater Antilles for which the depth is well constrained are shallow (less than 70 km), while east of this longitude intermediate-depth shocks have been recognized (Figure B-3). Intermediate depth earthquakes are not found in the western half of Hispaniola (Sykes and others, 1982), but they occur in Eastern Hispaniola and in the Puerto Rico Trench area. Plate motion in the Western half of Hispaniola is taken up by widespread crustal deformation and not by subduction of oceanic lithosphere, since subduction is probably inhibited by the presence of the thicker lithosphere of the Bahama Bank and the Beata Ridge along the northern and southern coasts respectively (Figure B-1, and McCann and Sykes, 1984).

B.3.3 The Eastern Hispaniola Source Zone

There is a good agreement among scientists on the existence and approximate alignment of the Cayman Trough and Puerto Rico Trench faults in the Caribbean region. At their

juncture, in Eastern Hispaniola, a slab of North American lithospheric plate seems to be thrusting beneath the Caribbean plate (Bracey and Vogt, 1970, 1971; and Molnar and Sykes, 1971). Seismic data are compatible with this concept of underthrusting and the formation of a mini-arc in this area. The maximum depth of earthquakes reaches 200 km and the strike of the zone of intermediate depth shocks is northwesterly beneath Eastern Hispaniola (McCann and Sykes, 1984). In addition, the axis of an arcuate negative isostatic gravity anomaly parallels the proposed downthrust slab and resembles the characteristic negative gravity anomalies found on the convex side of other known arc structures (Bracey and Vogt, 1970). The bathymetry of the area north and east of Eastern Hispaniola also indicates the presence of an arcuate depression indicative of an incipient or partially buried trench in this region (Bracey and Vogt, 1970). The Eastern Hispaniola-Puerto Rico Trench junction is shown diagrammatically on Figure B-5.

B.3.4 The Puerto Rico Trench Source Zone

Most of the larger historical and instrumentally located earthquakes near Puerto Rico are situated to the north of the island (Figures B-2 and B-3). North of Puerto Rico and the Virgin Islands, a shallow seismic zone, striking east-west, follows the inner wall of the Trench. The depth of the deepest shocks beneath Puerto Rico reach 120 to 140 km (McCann and Sykes, 1984). Consequently, the main locus of plate motion in this region probably lies along the Puerto Rico trench.

While a few small earthquakes have occurred within Puerto Rico and along the Muertos Trough to the south (Figures B-2 and B-3), most of the large shocks in Eastern Hispaniola and the Puerto Rico Trench appear to occur on two differently oriented seismic zones. The abrupt change in the configuration of the downgoing seismic zone occurs near the west coast of Puerto Rico (Figures B-2 and B-3). A former transform fault near Western Puerto Rico may have connected the westerly striking subduction zone to the north of Puerto Rico with the northwesterly striking subduction zone in Eastern Hispaniola (McCann and Sykes, 1984). There is no record of a severe shock

within Puerto Rico itself or along its southern coast as there is for Eastern Hispaniola and the Puerto Rico Trench area (Sykes and others, 1982).

B.3.5 The Muertos Trough Source Zone

Ladd and Watkins, 1978, and Ladd and others, 1981 describe late Cenozoic deformation of sediments and a minimum of 40 km of underthrusting of the sea floor of the Venezuela basin beneath the Muertos trough, along the southeastern margin of Hispaniola and south of Puerto Rico. The lack of intermediate depth earthquakes along the Muertos trough, however, indicates that the amount of subduction has been minor in that area. The difference in the strike of the Muertos Trough and the intermediate depth events south of Eastern Hispaniola makes it difficult to differentiate between the shallow events associated with the northerly subduction of the Caribbean plate and the southwesterly subduction of the North American plate (McCann and Sykes, 1984).

B.3.6 The Greater Antilles-Lesser Antilles Transition Source Zone

The northeastern Caribbean marks the transition from westerly underthrusting of lithosphere beneath the north trending Lesser Antilles to oblique slip (oblique underthrusting) along the westerly striking Puerto Rico trench where the North American plate moves westerly relative to the Caribbean plate along near-horizontal fault planes (Molnar and Sykes, 1969 and Sykes and others, 1982). This zone of transition from underthrusting to oblique slip in the northeastern Caribbean is a complex segment of the arc. It extends from the region of the trench that interacts with the Barracuda Ridge, in the southeast, to near the intersection of the Anegada Trough with the trench, near latitude 19.5 N and longitude 63 W (Figures B-1 and B-4). Historic and recent seismic activity is relatively low in this segment and most of the shocks are generally less than 70 km in depth. This crustal section of the Caribbean plate is relatively short, thus limiting the size of the largest shocks that can occur in this region (McCann and Sykes, 1984).

B.4 Estimation of Recurrence Relations for the Northern Caribbean Sources

For a study of the seismicity, in particular for the determination of the a and b parameters in the magnitude-frequency relation for different source zones, earthquake catalogs of the Caribbean Region (15-22 N, 62-90 W) were compiled using the following sources:

Gutenberg and Richter's Catalog (1904-1952)
International Seismological Summary (1918-1959)
Catalog of Significant Earthquakes, National Geophysical Data Center (2000 B.C.-1985)
National Oceanic and Atmospheric Administration (1824-1983)

Reliable magnitude and depth information on earthquakes has been available since 1963 when the worldwide standardized seismograph stations became fully operational. For this reason, the NOAA (National Oceanic and Atmospheric Administration) catalog was used in the preparation of a seismicity map of the pertinent portion of the Caribbean region. In the absence of a complete catalog, with magnitude or intensity information, for a longer period of time, the NOAA catalog for 20 years (1964-1983) was used for the determination of a and b parameters for each of the source zone in the region. Earthquakes in the catalog were sorted out for each source zone, thus a catalog for each zone was prepared. The maximum likelihood method for the estimation of earthquake recurrence parameters described by Weichert (1980) was used in this analysis.

The results obtained are summarized as follows:

	SEISMIC SOURCE	a	b
1.	Cayman Trough source zone	4.58	0.93
2.	Jamaica-Western Hispaniola source zone	4.02	0.87
3.	Eastern Hispaniola source zone	4.08	0.79
4.	Puerto Rico Trench source zone	5.26	1.00
5.	Muertos Trench source zone	3.13	0.77
6.	Greater Antilles-Lesser Antilles source zone	4.81	1.04

B.5 Estimation of Maximum Magnitude Earthquakes

Seismic activity is high along limited segments of the North American-Caribbean plate boundary zone. Zones of higher activity are separated by zones of relatively little seismicity. The long period of time over which the distribution of seismicity is observed (up to 80 years) and the ability to correlate the level of seismic activity with tectonic features strongly suggest that the distribution of seismicity is not random but rather is associated with long term tectonic processes occurring along the main plate boundary (McCann and Sykes, 1984).

Much of the geological and geophysical information gathered for the northeastern Caribbean indicates that the main plate boundary is segmented by transverse structures.

Recognition of this segmentation provides valuable clues to the dimension of the tectonic blocks and, therefore, of the maximum size of earthquakes that can occur. Estimates of the maximum seismic potential of a plate segment can be made by use of the historic record and inferences on the size of future shocks based on regional tectonics. Based primarily on the work of Sykes and others (1982), Mann and Burke (1984), and McCann and Sykes (1984), the following maximum magnitude earthquakes can be assigned to the source zones:

1) the Cayman Trough source zone, magnitude 7.0 to 7.5,
2) the Jamaica-Western Hispaniola source zone, magnitude 7.0 to 7.5,
3) the Eastern Hispaniola source zone, magnitude 8.0 to 8.5,
4) the Puerto Rico Trench source zone, magnitude 8.0 to 8.5,
5) the Muertos Trench source zone, magnitude 6.0 to 6.5, and
6) the Greater Antilles- Lesser Antilles Transition source zone, Magnitude 7.0 to 7.5.

B.6 Results of Seismic Hazard Calculations for the Northern Caribbean Sources

A total of six different seismic sources were identified in the northern Caribbean. Seismic hazard calculations for each of the six Caribbean sources were carried out using EPRI's EQHAZ program for a suite of six ground motion measures, including peak acceleration, pseudo relative spectral velocity for 5% damping at 25, 10, 5, 2.5, and 1 hz. Two seismic sources, viz., Cayman Trough and Jamaica-Western Hispaniola, contributed to the annual probability of exceedance. However, the contribution of these two sources at the St. Lucie site for peak ground acceleration and pseudo relative velocity at 25 and 10 hz were small.

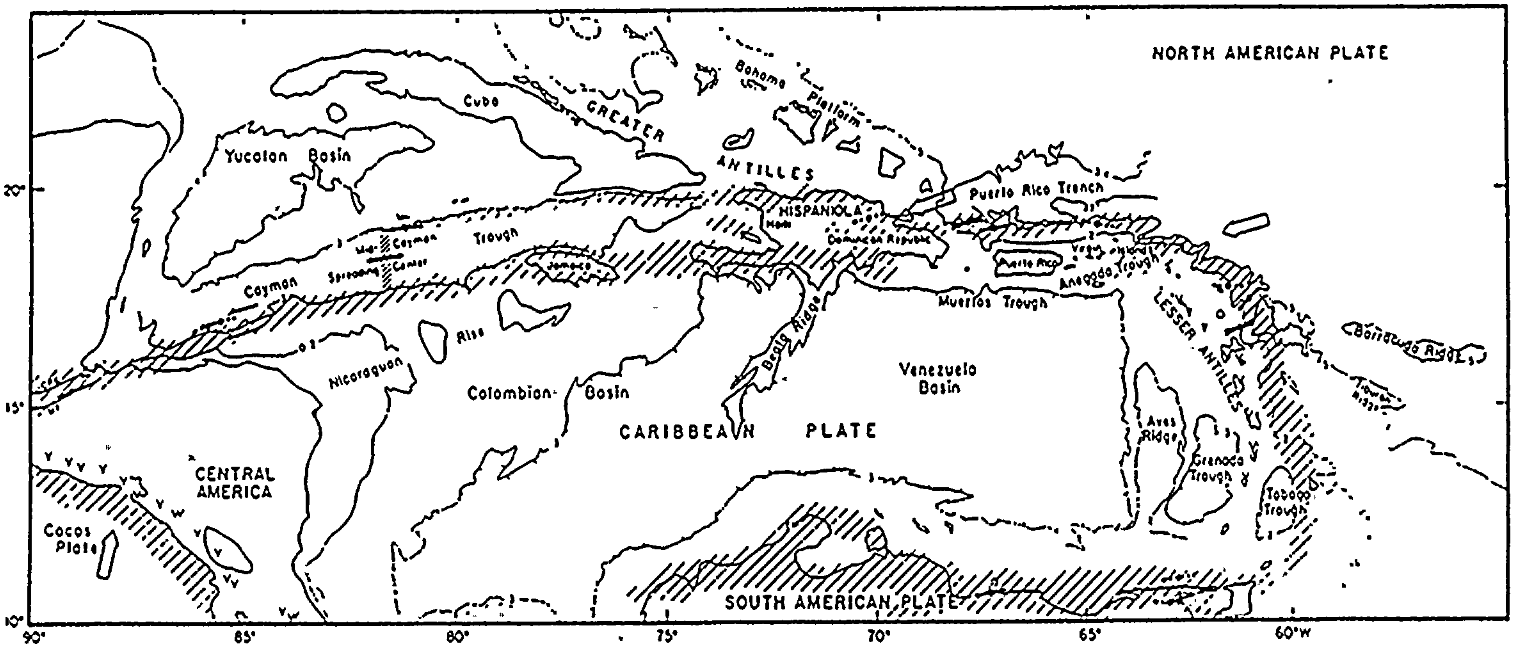

Plate tectonic framework and place names for Caribbean region. Large open arrows indicate motion of either North American or Cocos plates with respect to the Caribbean plate. Diverging arrows indicate seafloor spreading along mid-Cayman spreading center. Arrows along southern margin of Cayman trough indicate relative plate motion, i.e., strike slip motion along nearly vertical faults. Small solid and dashed arrows are slip vectors of earthquakes. Diagonal hatching indicates zones of higher earthquake activity and major interplate motion. V's are historically active volcanoes after Gutenberg and Richter [1954]. Bathymetry in kilometers after Case and Holcombe [1980]. Note zone of broad plate interaction between mid-Cayman spreading center and eastern Hispaniola.

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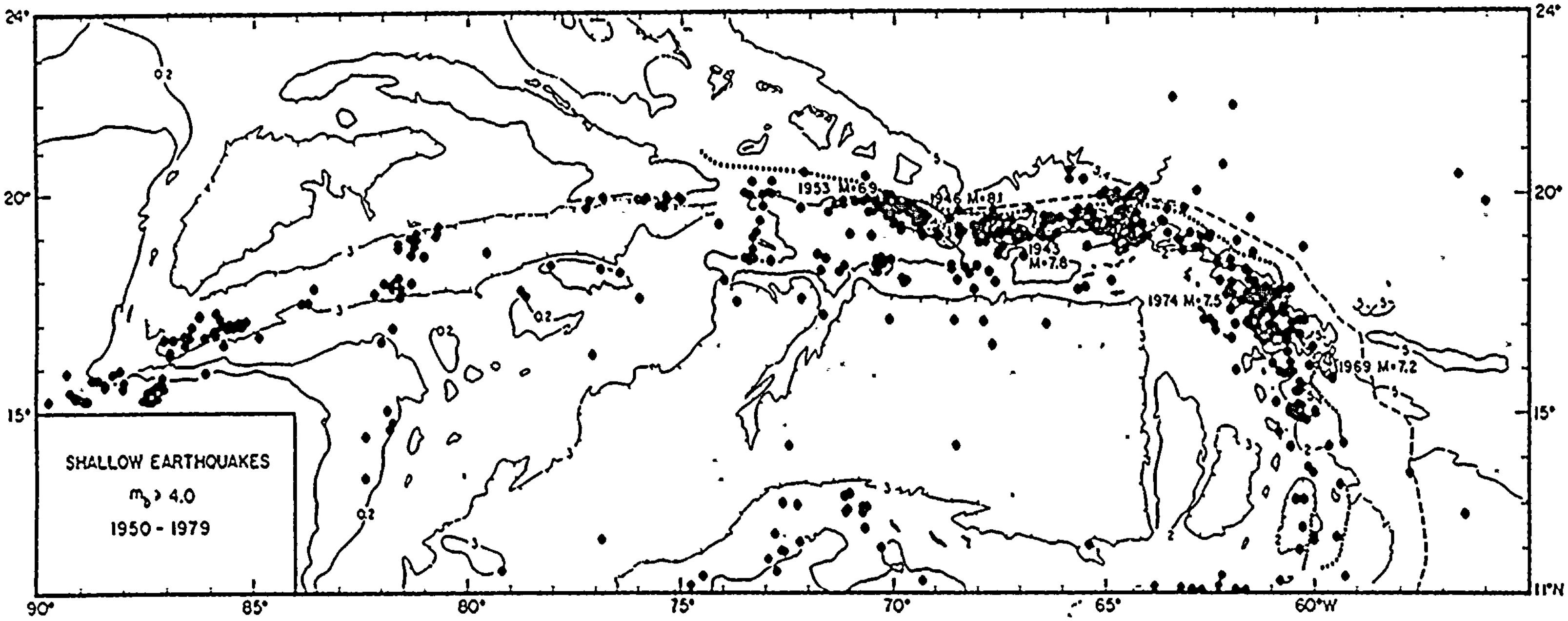
FIGURE B.1



Shallow earthquakes (depths 0 to 70 km) of magnitude 4 or greater (solid circles) as located by computer from 1950 to 1979. Epicenters from Sykes and Ewing [1965], Molnar and Sykes [1969] and Preliminary Determination of Epicenters. Aftershock zones of larger shallow earthquakes from 1943 to 1979 indicated by hatched lines. Dashed line denotes seaward limit of sedimentary deformation along Lesser Antillean and Puerto Rico trenches [after Case and Holcombe,1980]. Small open circles denote free-air gravity minimum [after Bowin, 1976]. Bathymetry as in Figure 1. Note wide zone of seismic activity from 68° to 82°W.

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FIGURE B.2

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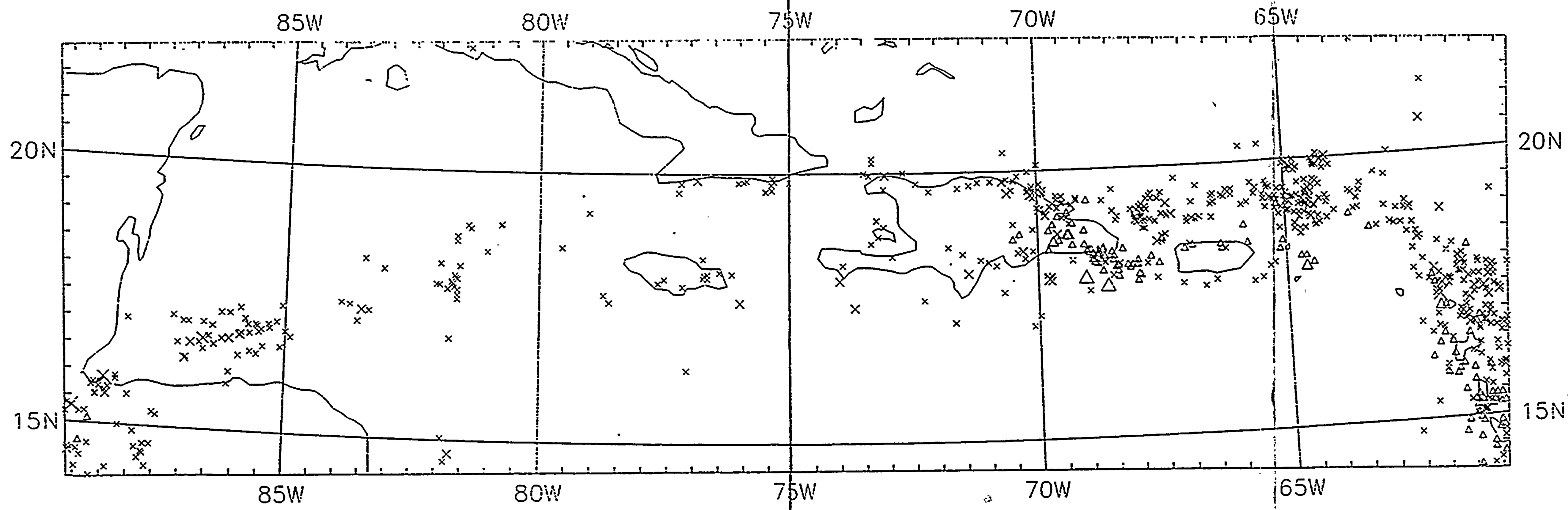

NOAA Instumentally Located Earthquakes

X Shallow Depth (0 to 70km)

△ Intermediate Depth (71 to 300km)

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FIGURE B.3

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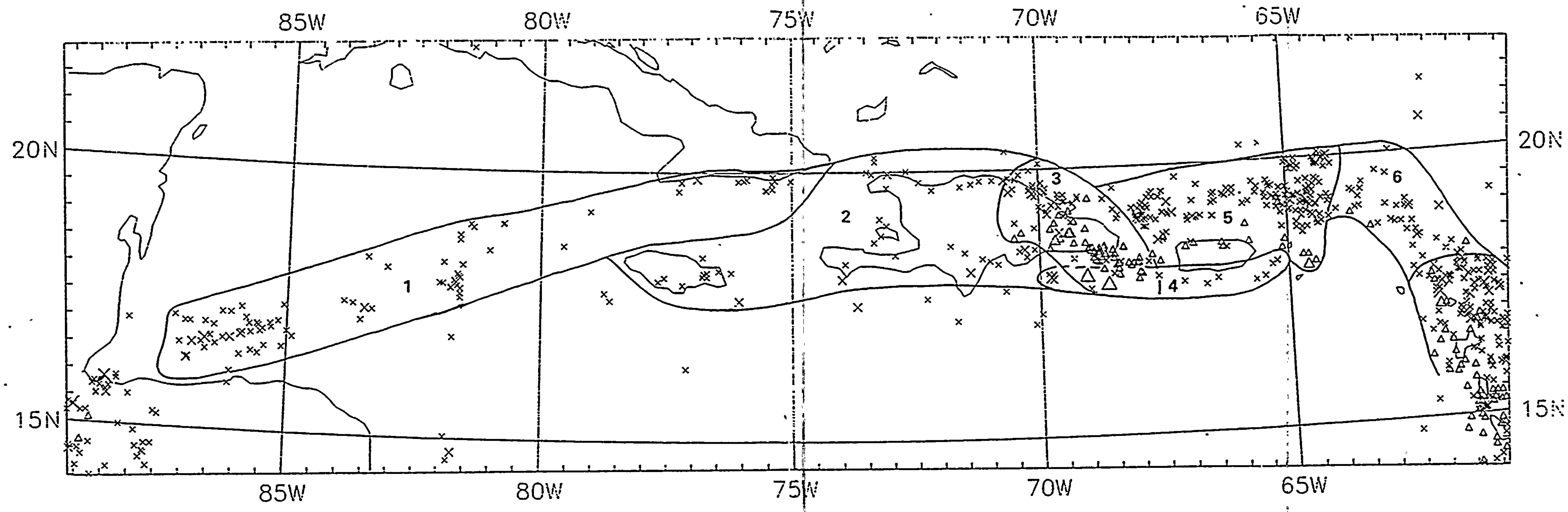

Outline of Seismic Source Zones in the Northern Caribbean

Source Zone Number	Name
1	Cayman Trough
2	Jamaica—Western Hispaniola
3	Eastern Hispaniola
4	Puerto Rico Trench
5	Muertos Trench
6	Greater Antilles—Lesser Antilles Transition

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FIGURE B.4

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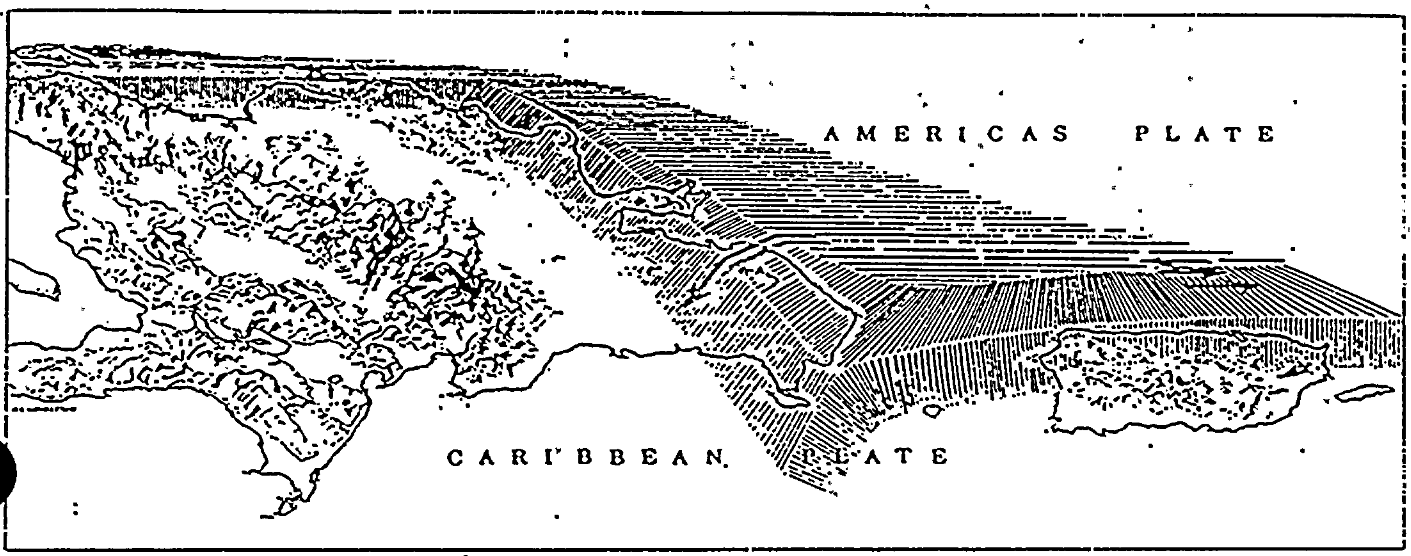
PLATE TECTONICS IN THE HISPANIOLA AREA



Block diagram showing hypothesized Americas plate-Caribbean plate interaction in the Hispaniola area.

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FIGURE B.5

APPENDIX C
SITE SPECIFIC AMPLIFICATION FOR ST. LUCIE SITE

C.1 Location and Physiography

The St. Lucie site consists of approximately 1,100 acres located on Hutchinson Island, midway between Stuart and Fort Pierce along the east coast of Florida (Figure C-1). Hutchinson Island was probably developed as an offshore bar during one of the interglacial stages of the Pleistocene epoch, and was subsequently exposed as sea level dropped in relation to the adjacent land surface. The site is bounded on the east by the Atlantic Ocean and on the west by the Indian River. Land surface on Hutchinson Island ranges from mean sea level to 19 ft above. The site and surrounding area lie within the Atlantic Coastal Plain physiographic province (Figure C-2).

C.2 Regional Stratigraphy

The Coastal Plain sediments consist predominantly of Cretaceous, Tertiary, and Quaternary carbonate rocks. For the most part, these deposits were accumulated in shallow transgressive and regressive seas. Occasionally, major regressions of the sea exposed sections of the Coastal Plain, resulting in buried erosional surfaces and unconformities.

Figure C-3 is a generalized stratigraphic column showing the names and subdivisions of the various formations encountered in the area of the site. In the St. Lucie region, the upper 600 ft. of sediments consist of partially cemented and indurated sands and clays. Below 600 ft., sediments are moderately hard to hard limestones and dolomites with some sandstones, shales and anhydrites. The Pre-Cretaceous basement complex in the St. Lucie area is about 13,000 ft. deep.

C.3 Site Stratigraphy

At the site, four to six feet of peat lie on top of the Anastasia Formation of Pleistocene age (1 M.Y. to present). The Anastasia Formation consists of gray, slightly clayey and silty, fine to medium sand with fragmented shells; and in places fragmented shell beds with slightly clayey and silty fine sands. There are also discontinuous pockets of cemented sand with shells and sandy limestone. These discontinuous cemented pockets are generally found between elevation minus 35 ft. and minus 60 ft. Discontinuous plastic clay lenses were also found in the upper portion of the formation. The Anastasia extends down to elevation minus 135 to minus 155 ft. (Figure C-3).

The Hawthorne formation of Miocene age (25 to 13 M.Y.) unconformably underlies the Anastasia Formation. This erosional surface is responsible for some minor induration along the contact which occurs between elevations minus 140 ft. and minus 157 ft. The upper 100 to 150 ft of the Hawthorne formation consists of green, slightly clayey and silty, very fine sand. The lower part becomes generally more clayey, and the lithology changes slightly to a gray white, phosphatic, sandy clay in the site area below elevation minus 450 ft. The Hawthorne formation extends to about elevation minus 600 ft. to minus 700 ft. in the site area.

The Tampa limestone of lower Miocene age is absent in the St. Lucie area. Instead, the Hawthorne formation overlies unconformably the Suwannee limestone of Oligocene age (36 to 25 M.Y.). The Suwannee varies from a hard very fossiliferous limestone, to a soft, granular, dolomitic limestone containing broken fragments of shells, echinoids and barnacles. The Suwannee formation averages 135 ft. thick in borings drilled at the site. The Suwannee rests unconformably on rocks of the Ocala group of Upper Eocene age (45 to 36 M.Y.). The Ocala group is essentially a soft to moderately hard foraminiferal limestone

C.4 Properties of Subsurface Materials

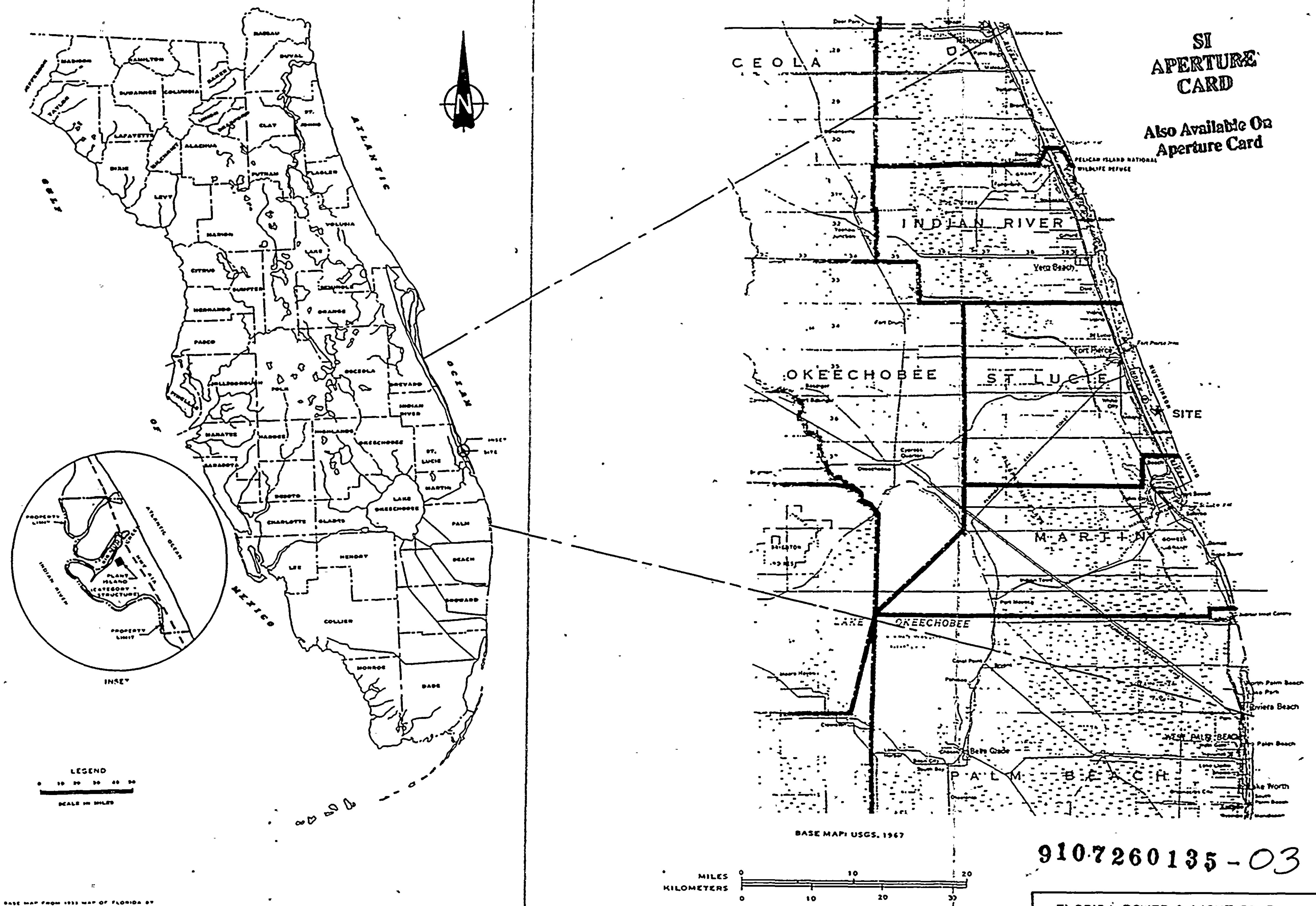
Based upon the results of site investigations and tests, the subsurface materials were separated into three foundation zones. The upper or shallow zone of 50 to 60 feet, consisting of loose to medium dense sand with small amounts of silt and clay, contains isolated pockets of shell fragments and limestone nodules. An intermediate zone extends from 60 feet to 150 feet in depth. The soils of the intermediate zone differ from the shallower soil in that it is denser, contains a greater percentage of fines (material finer than the No. 200 sieve) and has very few pockets of limestone nodules and shell fragments. The deep zone extends from 150 feet to at least 400 feet in depth. This material is considerably more clayey than the material above it, is very dense and does not contain pockets of shells and limestone nodules. The soils at the site are normally consolidated under the existing overburden load.

The surface organics and peat, and the sediments of the upper shallow zone were removed prior to the construction of the St. Lucie Units 1 and 2. These in-situ soils were removed to elevation minus 60 feet and replaced with a selected fill compacted to a relative density of at least 85 percent. The intermediate and deep zones required no remedial treatment since they showed no potential for liquefaction.

C.5 Foundation Conditions

The general plant layout is shown on Figure C-4. Figures C-5 and C-6 are geologic cross sections through the site indicating that the in-situ upper foundation zone was removed during construction to elevation minus 60 feet and replaced with selected fill material emplaced under controlled conditions. The final plant grade was established at elevation plus 18.5 feet, and the foundation level of the reactor buildings at minus 15 feet (peripheral) and minus 25.50 feet (central). The plant area is underlain by over 500 feet of partially cemented sands and clays and is considered to be a deep soil site.

EPRI developed generalized amplification factors to account for a range of soil thicknesses at nuclear power plant sites in Eastern North America (EPRI NP-6074, October 1988; Engineering Model of Earthquake Ground Motion for Eastern North America). The St. Lucie Site falls within the Gategory of deep soil sites (Category V, characterized by over 400 feet of soil above bedrock). Figures C-7 through 12 show the site amplification factors for pseudo relative velocity at 1, 2.5, 5, 10, and 25 hz and for the peak ground acceleration (PGA).



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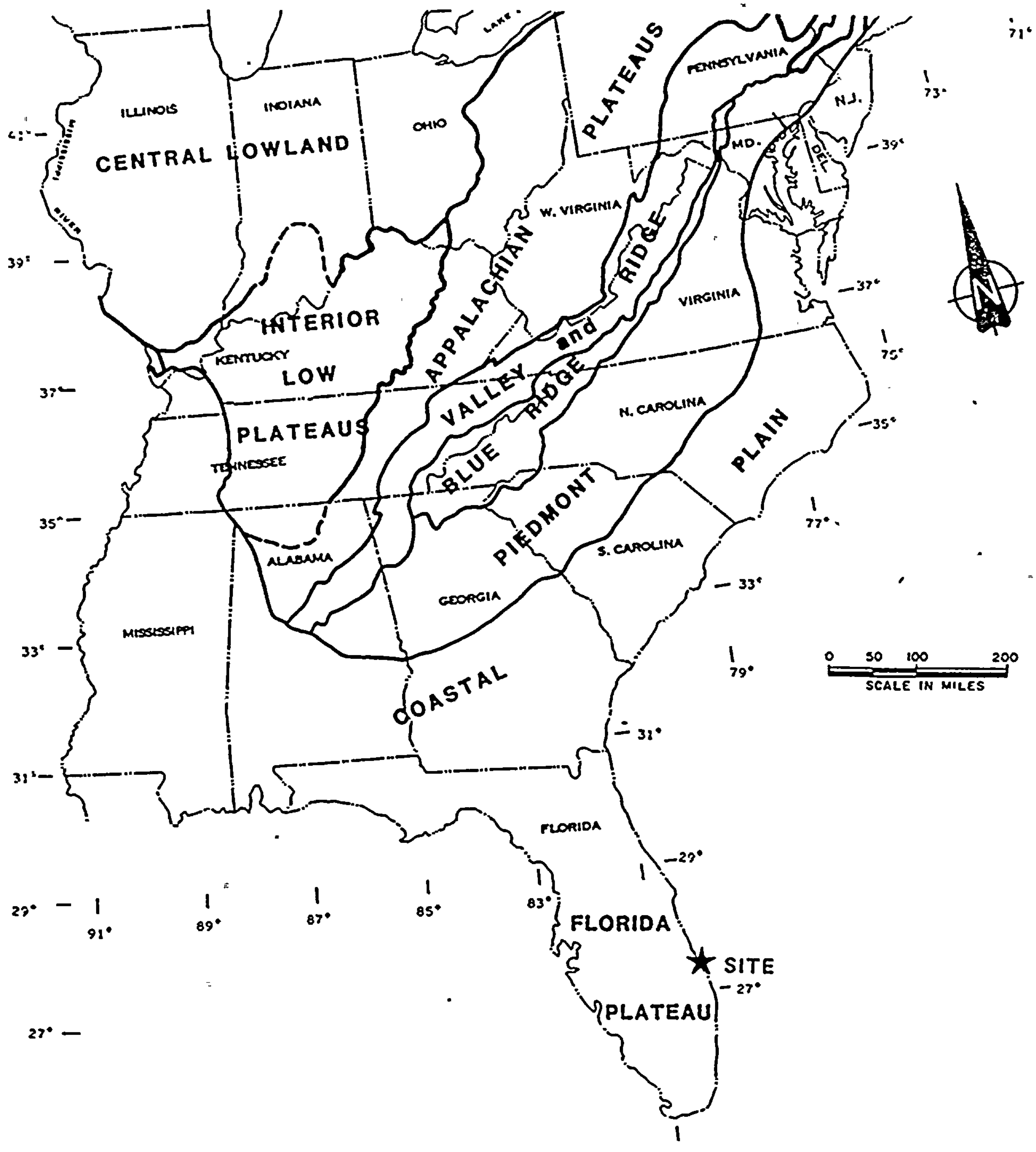
FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SITE LOCATION MAP

FIGURE C-1

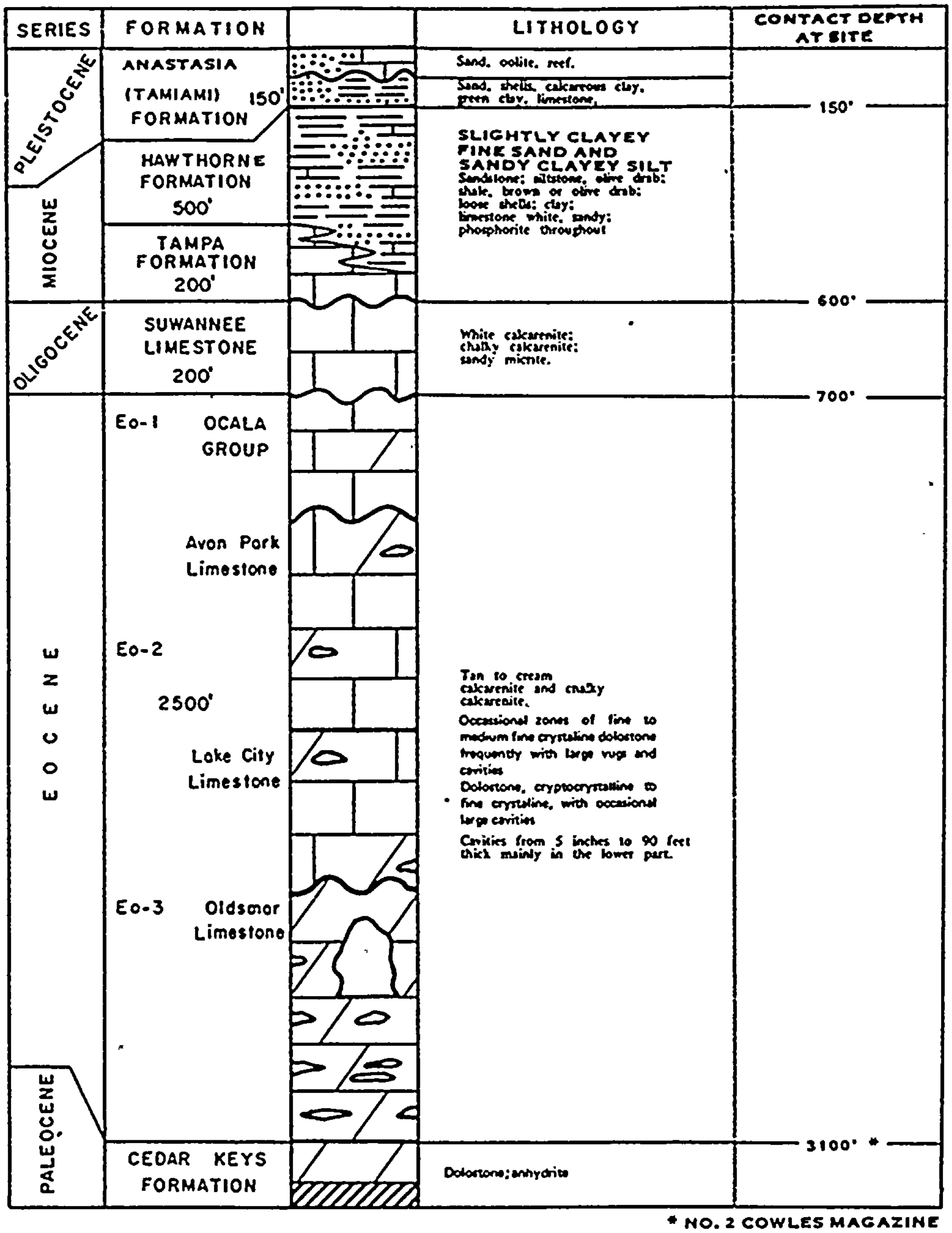


MODIFIED FROM: FENNEMAN AND JOHNSON, 1946
KING, 1951
RODGERS, 1970

FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

REGIONAL PHYSIOGRAPHIC MAP

FIGURE C-2



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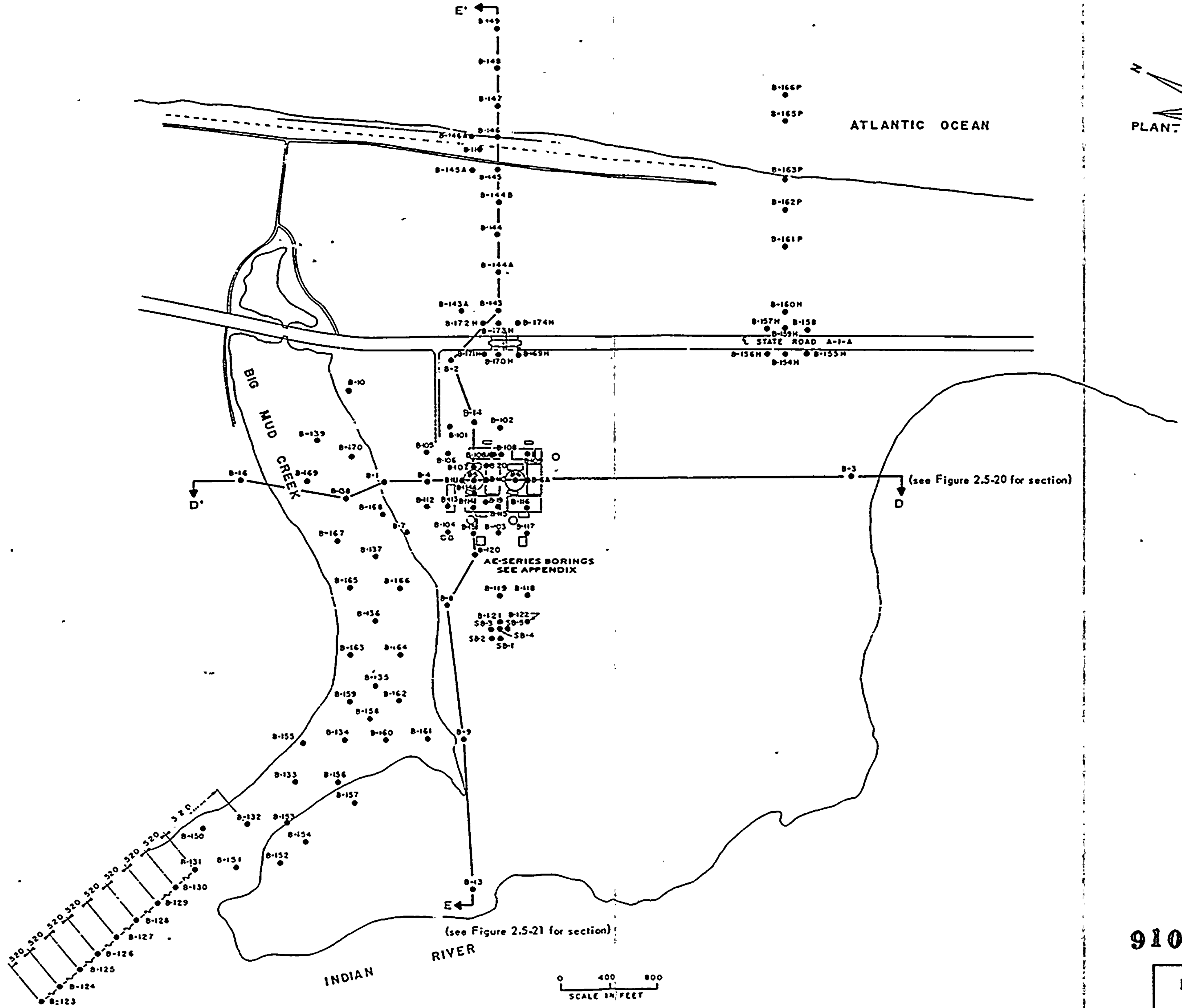
FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

GENERALIZED STRATIGRAPHIC COLUMN

FIGURE C-3



SI APERTURE CARD

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9107260135 -04

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SITE BORING LOCATION PLAN

FIGURE C-4

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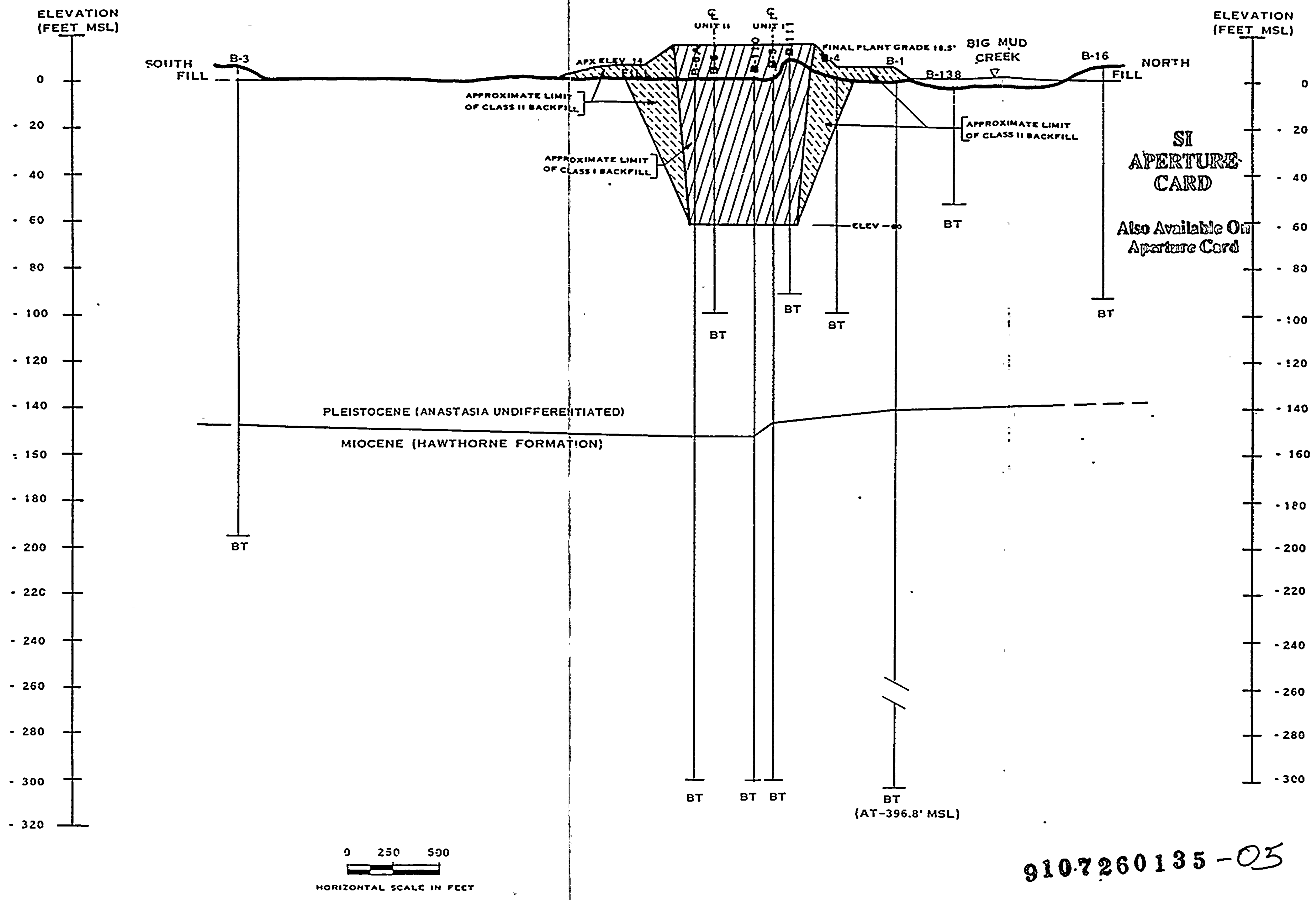

FLORIDA POWER & LIGHT COMPANY
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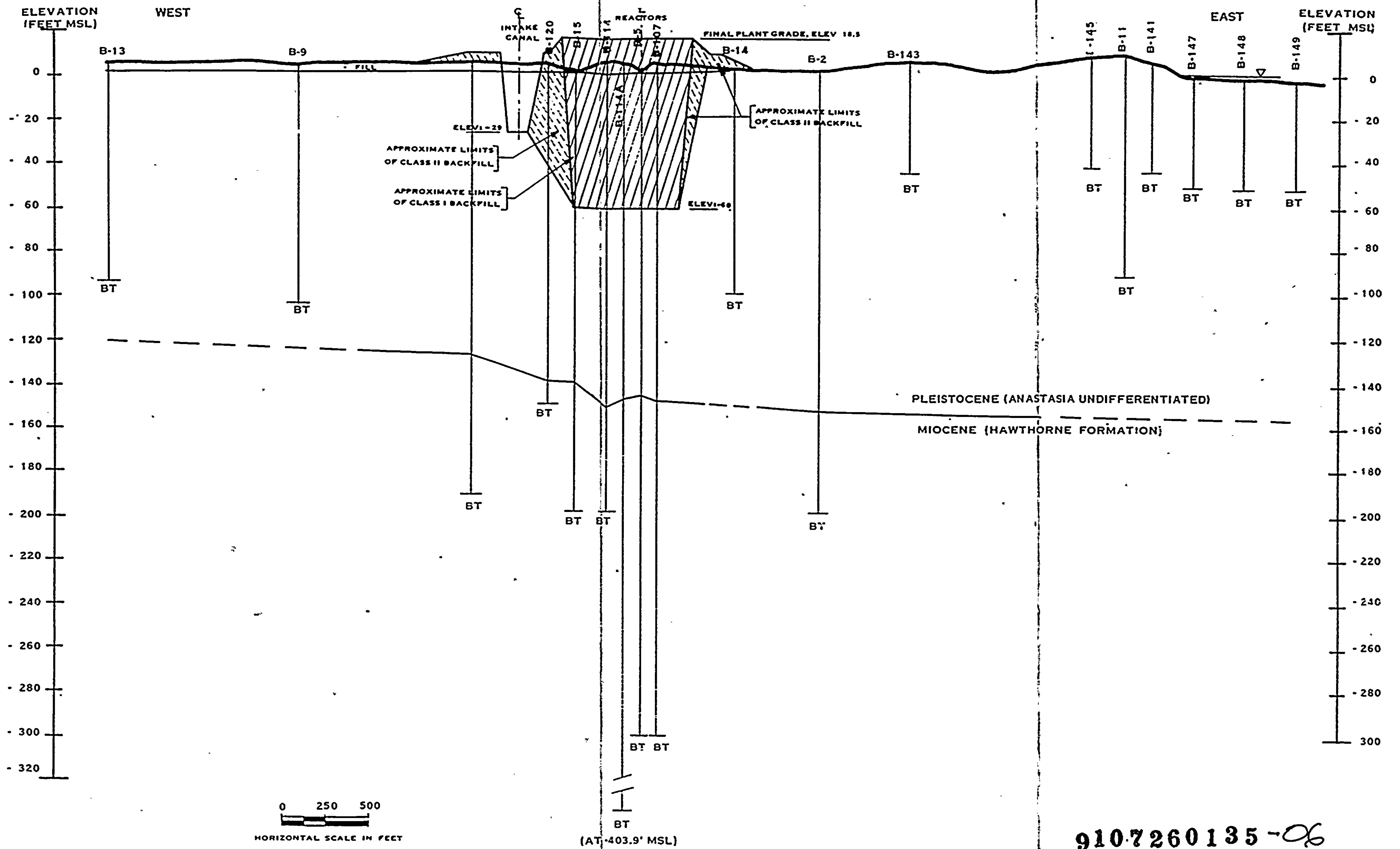
NORTH – SOUTH
SITE GEOLOGIC SECTION DD'

FIGURE C-5



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FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

EAST – WEST
SITE GEOLOGIC SECTION EE'

FIGURE C-6

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Also Available On
Aperture Card

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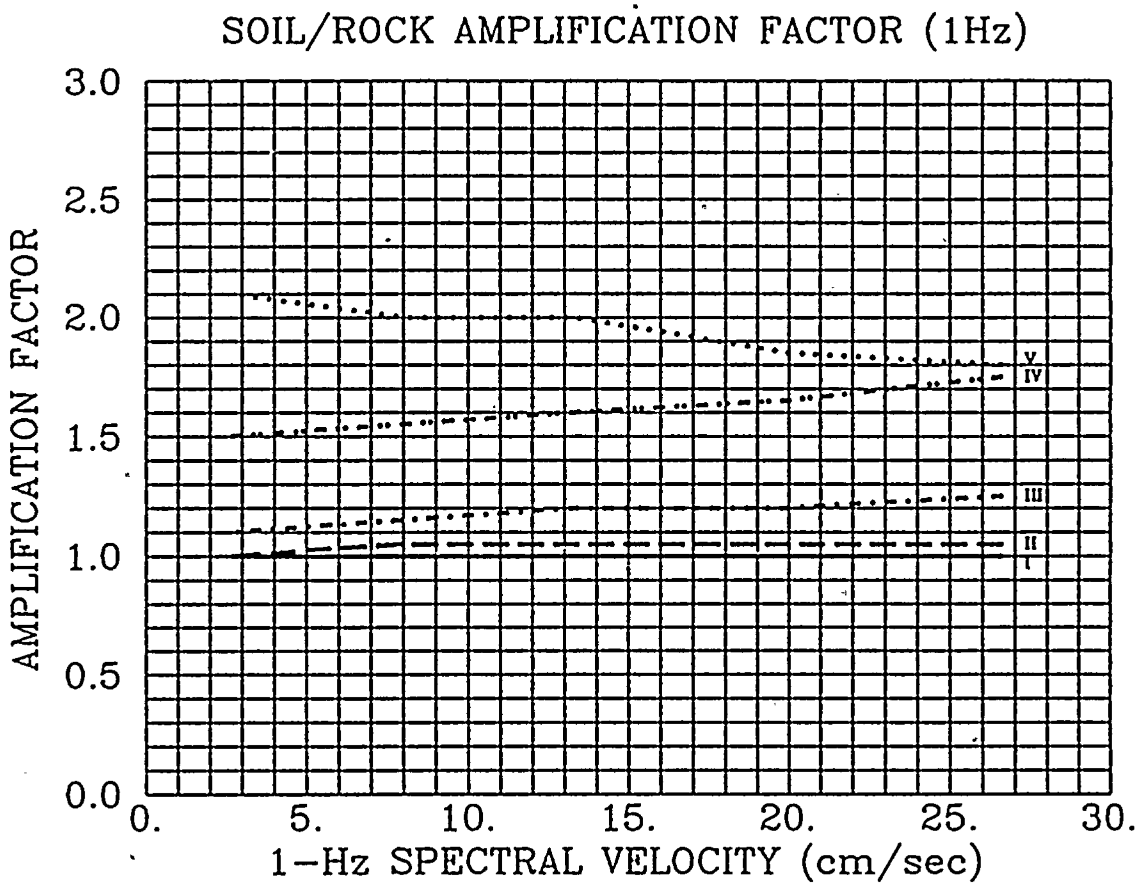

Figure C-7 Site amplification factors for the 5 site categories as a function of rock-site spectral velocity (1 Hz).

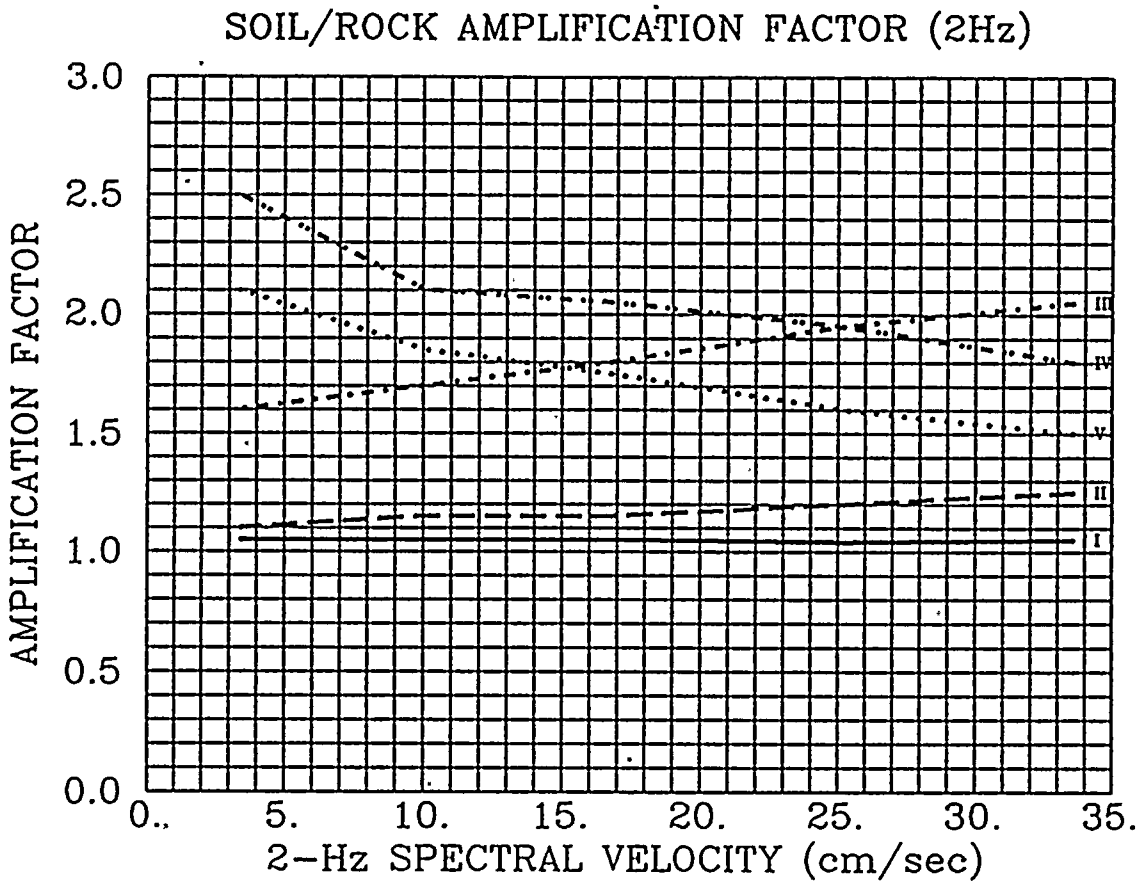

Figure C-8 Site amplification factors for the 5 site categories as a function of rock-site spectral velocity (2 Hz).

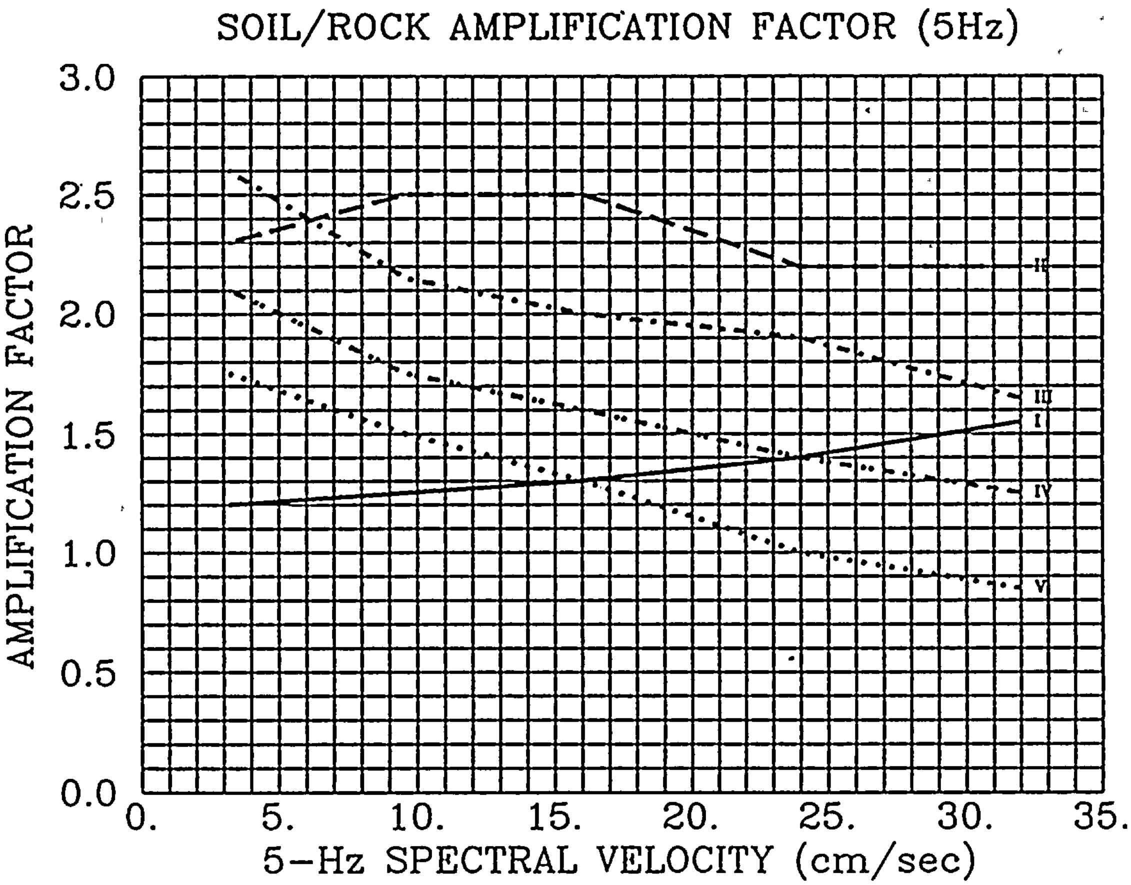

Figure C-9 Site amplification factors for the 5 site categories as a function of rock-site spectral velocity (5 Hz).

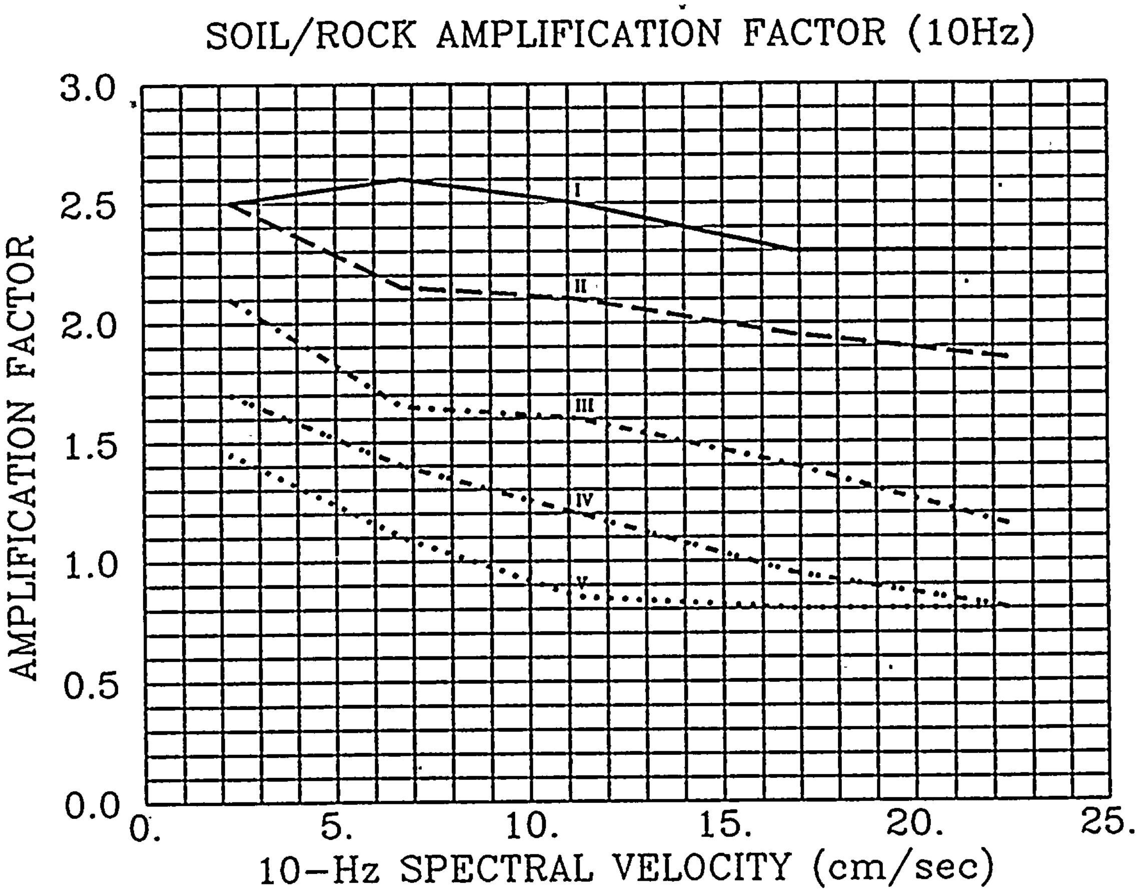

Figure C-10 Site amplification factors for the 5 site categories as a function of rock-site spectral velocity (10 Hz).

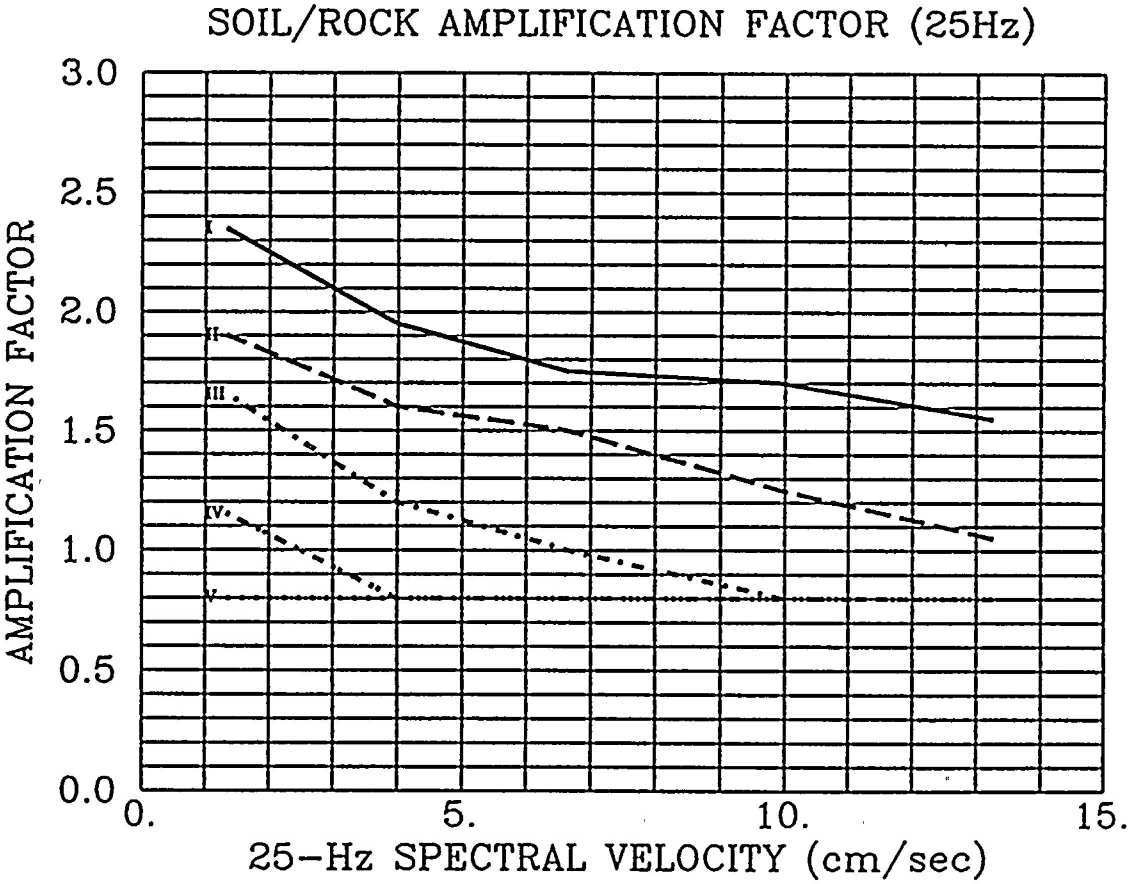

Figure C-11 Site amplification factors for the 5 site categories as a function of rock-site spectral velocity (25 Hz).

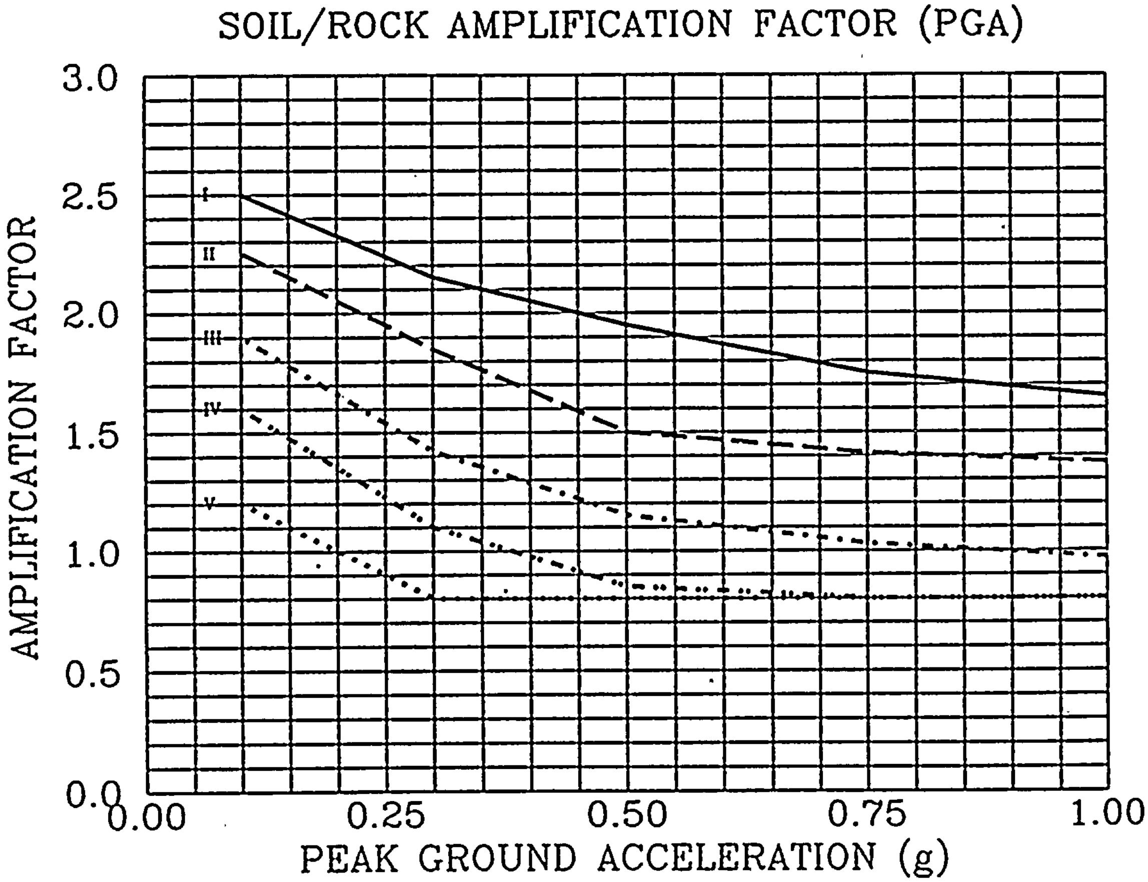

Figure C-12 Site amplification factors for the 5 site categories as a function of rock-site peak ground acceleration.

APPENDIX D
SITE SPECIFIC AMPLIFICATION FOR TURKEY POINT SITE

D.1 Location and Physiography

The Turkey Point site consists of approximately 3,300 acres located on the shore of Biscayne Bay, about 25 miles south of Miami, eight miles east of Florida City, Florida (Figure D-1). The site has been developed to accommodate both nuclear and fossil-fueled units. The immediate area surrounding the nuclear units is flat and rises very gently from sea level at the shoreline of Biscayne Bay to an elevation of about 10 feet above mean sea level about 8 to 10 miles west of the site. To the east, 5 to 8 miles across Biscayne Bay, is a series of offshore islands running in a northeast-southwest direction between the Bay and the Atlantic Ocean, the largest of which is Elliot Key. The site and surrounding area lie within the Atlantic Coastal Plain physiographic province (Figure D-2).

D.2 Regional Stratigraphy

The site lies within the Floridan Plateau, a partly submerged section of the North American continental shelf. In the vicinity of the site, the edge of the shelf is located some 18 miles offshore to the east. The Plateau is underlain by a thick series of sedimentary rocks, which in the southern part of the state consist essentially of gently dipping or flat-lying limestones and associated calcareous formations. Beneath these sedimentary formations are igneous and metamorphic basement rocks which correspond to those which underlie most of the eastern North American continent. The sedimentary rocks overlying the basement complex range in thickness from 4,000 feet, in the northern parts of the state, to more than 15,000 feet, in southern Florida. Deep borings in the region indicate that the rock in the uppermost 5,000 feet is predominently calcareous and ranges in age from late Cretaceous to Pleistocene. The Mesozoic limestones, chalk and sandstones are underlain by Paleozoic shales and sandstones resting unconformably over a Pre-Cambriam granitic basement.

D.3 Site Stratigraphy

A prominent surface feature near the site is the Atlantic Coastal Ridge, which represents an area of bedrock outcrop of the Miami (oolitic) limestone. This Pleistocene formation underlies the site where it is overlain by organic, mangrove swamp soils averaging four to eight feet in thickness. Pockets of silt and clay are encountered locally, separating the organic soils from the limestone bedrock.

The Miami oolite, a deposit of highly permeable limestone, extends to about 20 feet below sea level. The rock contains random zones of harder and softer rock and heterogeneously distributed small voids and solution channels, many of which contain secondary calcite deposits. This limestone lies unconformably on the Ft. Thompson formation, a complex sequence of limestone and calcareous sandstones.

The upper five to ten feet of the Ft. Thompson formation contains much coral which may represent the Key Largo formation, a coralline reef rock. This formation is contemporaneous in part with both the Ft. Thompson and the Miami oolitic limestone formations.

At a depth of about 100 feet below sea level, the Ft. Thompson formation unconformably overlies the Tamiami formation, a predominantly clayey and calcareous marl, locally indurated to limestone. The Tamiami formation also contains beds of silty and shelly sands, and is relatively impermeable. The Tamiami and underlying Hawthorne and Tampa formations, silty or clayey sand of Miocene age, comprise a relatively impermeable hydrogeologic unit called the Floridan aquiclude, which is 300 to 500 feet thick in southern Florida.

The Hawthorne formation is underlain unconformably by the St. Marks formation of Middle Miocene age. The unconformity, visible in cores, consists of fine quartz sands mixed with clays and silts. The lower portion of the formation is sandy but contains

beds of siltstone and claystone intermixed with limestone. Infrequent thin seams of light to dark greenish grey sandy or silty clay occur.

A generalized site stratigraphic column is shown on Figure D-3.

D.4 Properties of Subsurface Materials

The bedrock beneath the site is competent with respect to foundation conditions and is capable of supporting heavy loads. Total loads applied on the foundations of the fossil-fueled and nuclear units resulted in settlements which are well below those incorporated in the design.

Seismic refraction studies indicate that the Miami limestone is characterized by velocities in the range of 5,800 to 8,500 fps, the Key Largo limestone by velocities in the range of 9,500 to 10,000 fps, and the Ft. Thompson formation by velocities in the range of 10,800 to 11,500 fps. Consequently Turkey Point is considered a rock site and no correction factors are used to take into account site specific geologic conditions in the computation of the seismic hazard.

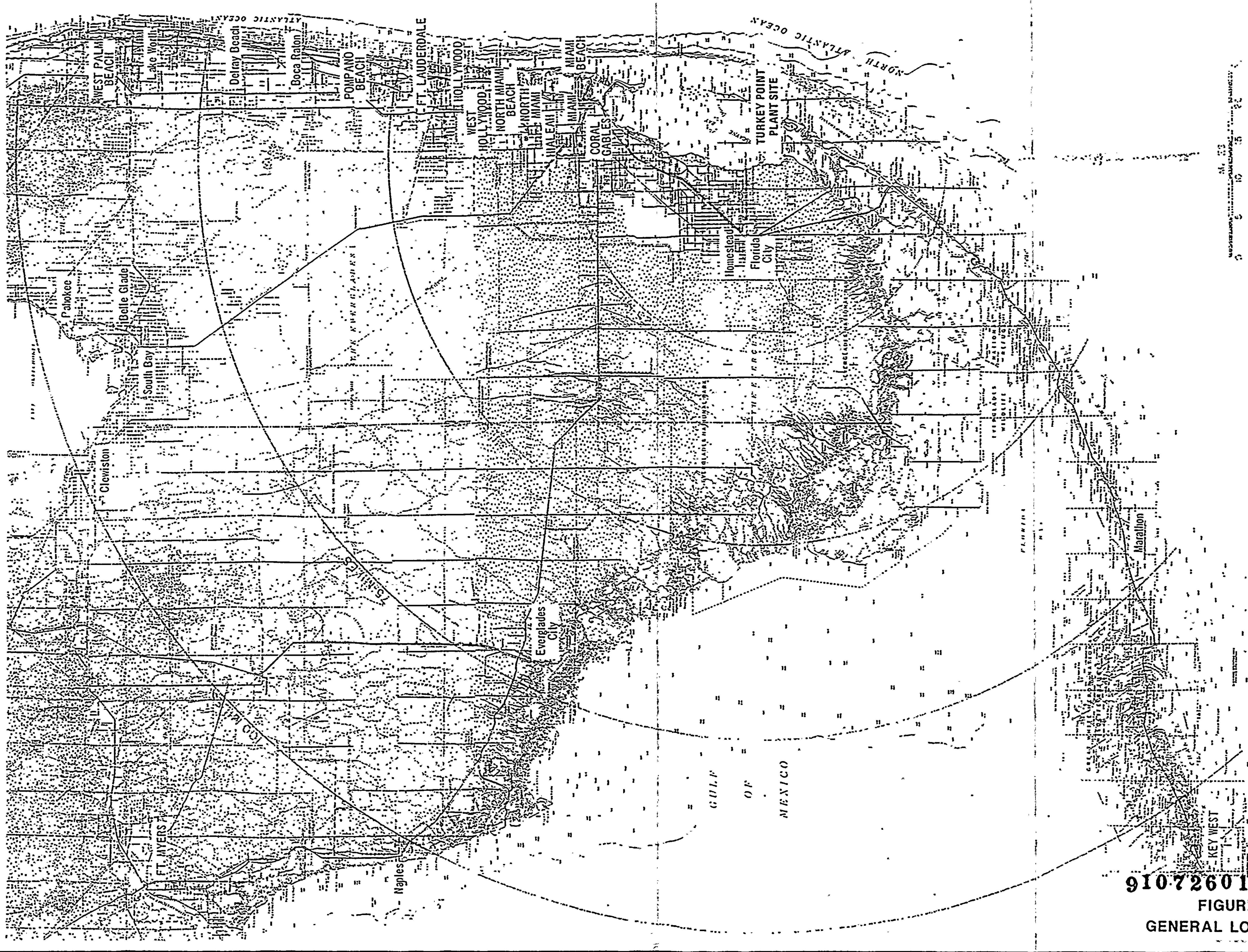

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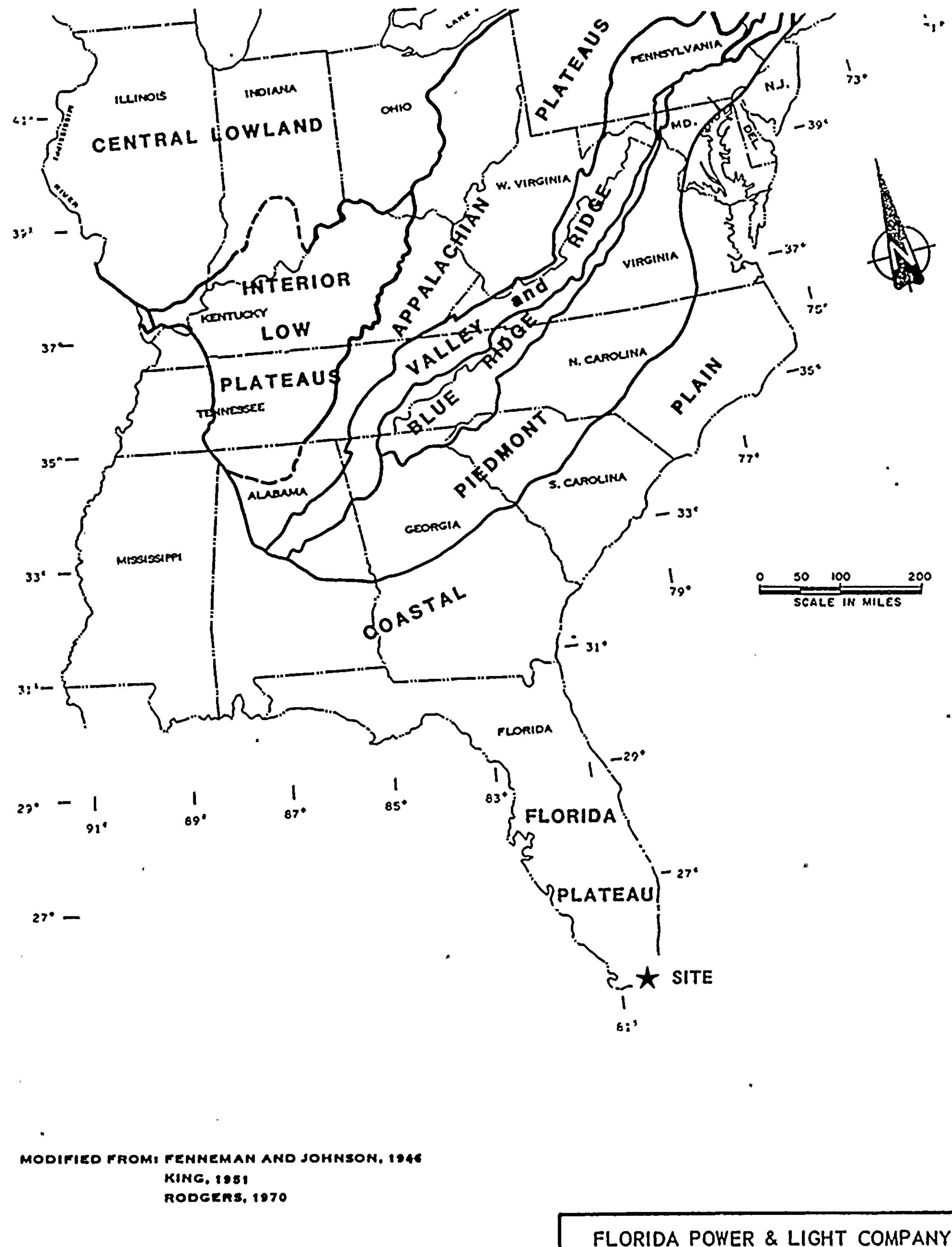
FIGURE D-1
GENERAL LOCATION MAP



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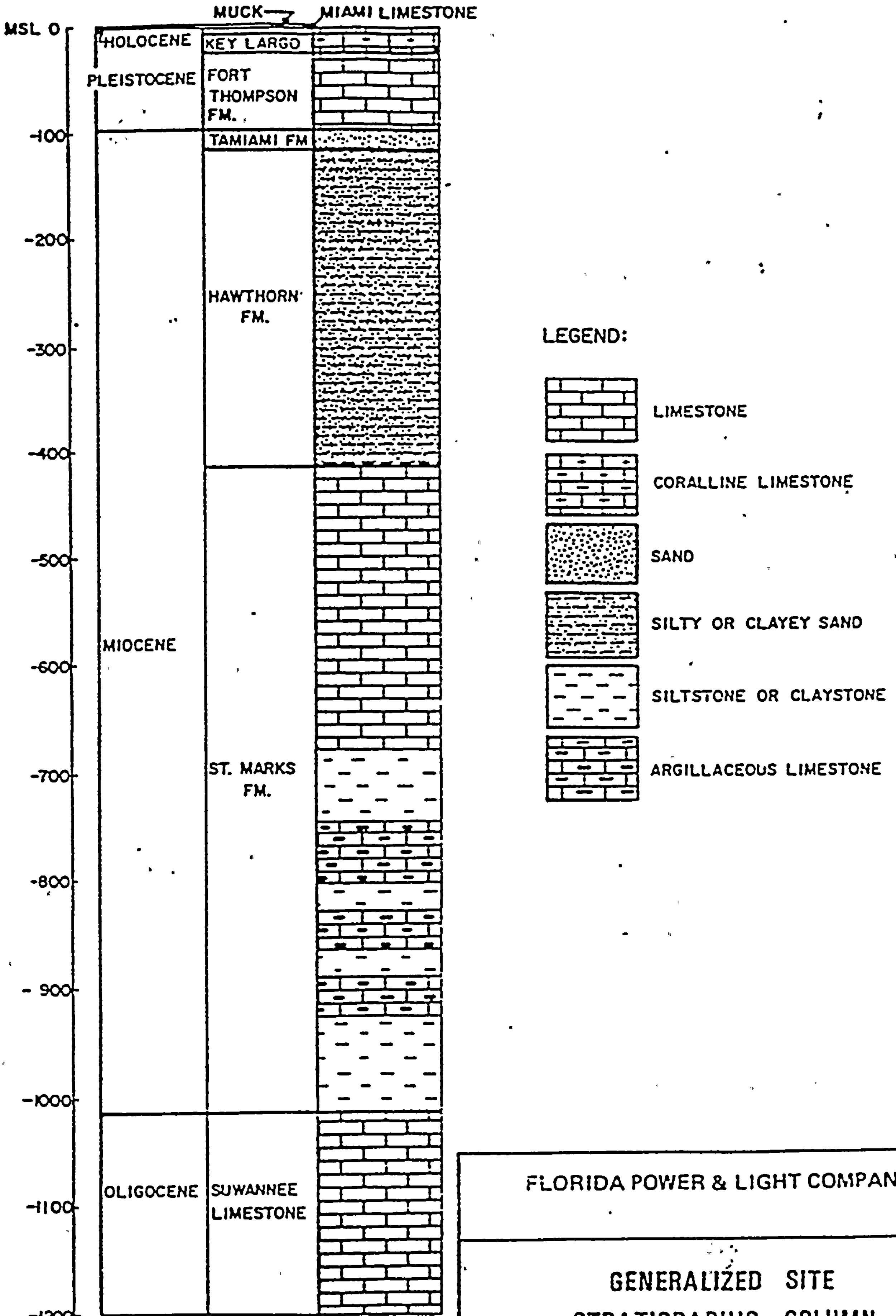
REGIONAL PHYSIOGRAPHIC MAP

FIGURE D-2



FLORIDA POWER & LIGHT COMPANY

GENERALIZED SITE STRATIGRAPHIC COLUMN

FIGURE D-3

PROBABILISTIC SEISMIC HAZARD EVALUATION AND UNIFORM HAZARD SPECTRA

St. Lucie and Turkey Point Nuclear Power Plant Sites

FLORIDA

Executive Summary
prepared for the

Florida Power & Light Company
Nuclear Licensing Department

December 1989

EBASCO

EBASCO SERVICES INCORPORATED
Greensboro, N.C.

EXECUTIVE SUMMARY

1. Introduction

As a result of the unresolved questions regarding the cause and source of seismicity in the region of the United States east of 105°W longitude (Eastern U.S.), the U.S. Nuclear Regulatory Commission (NRC) is actively pursuing the use of probabilistic methods, as alternatives to the deterministic methods used in the past, to determine the adequacy of the seismic design of nuclear facilities in the Eastern U.S. The methodology takes into account the uncertainties in source geometry, seismicity parameters and ground motion for large earthquakes that could occur in the Eastern U.S. As part of the NRC-funded investigations, the Lawrence Livermore National Laboratory (LLNL) initially conducted probabilistic seismic hazard evaluations for ten "sample sites" whose locations are shown on Figure 1. Recently it published an eight volume report on seismic hazard characterization of 69 nuclear plant sites east of the Rocky Mountains, and presented comparisons to previous results for ten test sites (Bernreuter et al., 1989). A parallel probabilistic seismic hazard study, based on an intensive data collection and evaluation effort, was implemented by the Electric Power Research Institute (EPRI) (1986-87) with the assistance of six Technical Evaluation Contractors (TEC). Both the NRC-funded LLNL studies, and the EPRI investigations, funded by a group of nuclear power plant owners in the Eastern U.S., utilize comprehensive seismic and tectonic data bases and recent advances in the probabilistic methodologies to perform a state-of-the-art seismic hazard evaluation for sites located in the Eastern U.S.

In light of these recent advances in probabilistic seismic risk assessment, the Florida Power and Light Company (FP&L), Nuclear Licensing Department requested that Ebasco Services Incorporated (ESI) perform a state-of-the-art seismic hazard evaluation for its St. Lucie and Turkey Point nuclear power plant sites and generate the associated uniform hazard spectra for comparison purposes. The evaluation was performed under the Quality Assurance requirements of 10 CFR 50 Appendix B, and used the methodology, computer programs, and the tectonic and seismic input parameters developed as a result of the EPRI

investigations. In addition, the scope of the ESI investigation included an evaluation of the contribution to seismic hazard at the St. Lucie and Turkey Point sites from the possible occurrence of large magnitude earthquakes in the Northern Caribbean.

2. Procedure

Following the EPRI methodology, the seismic hazards and uniform hazard spectra were computed for the St. Lucie and Turkey Point sites using the seismic source zones and seismicity parameters established by each of the six EPRI Technical Evaluation Contractors (TEC), and the seismic source zones and seismicity parameters identified by ESI for the Northern Caribbean. The location and extent of the seismic source zones that were evaluated in this study are shown on Figures 2 through 8. The source zones that contributed to the seismic hazard at each of the two plant sites have also been listed on these figures. The TEC source zone names, labels, and the EPRI Data Base Manager code numbers are given in Table 1. Two of the Northern Caribbean sources, Cayman Trough and Jamaica-Western Hispaniola, that were identified during this study contributed to the seismic hazard at Turkey Point, but contributed to the hazard at St. Lucie for pseudo relative velocities at frequencies 5 hz and less only. Also contributions of New Madrid area sources to the seismic hazard at both plant sites for each of the six TECs were found to be negligible. The scenarios and weights for the source zones that contributed to seismic hazard at St. Lucie and Turkey Point sites are given in Tables 2 and 3, respectively. The seismic hazard values that were calculated from each TEC model were then aggregated in accordance with the EPRI methodology to generate the final hazard curves.

Site specific, frequency and amplitude dependent, amplification factors were used in the hazard computation as specified by the EPRI methodology (Toro, McGuire and Silva, 1988, and Toro, McGuire and McCann, 1989).

Hazard curves for pseudo relative velocities at different frequencies were used to derive constant percentile and mean uniform hazard spectra (UHS), at various specified risk levels.

3. Results

The mean and 15th, 50th, and 85th percentile hazard, in terms of annual probabilities of exceedance, for different peak ground accelerations at the St. Lucie site are shown in Table 4. The results for the St. Lucie site are presented as constant percentile hazard curves on Figure 9 for peak ground acceleration. On this figure the 15th, 50th, and 85th percentile curves represent the aggregated results of all TECs. The mean hazard curve is shown by a dashed line. Sensitivity of hazard results to different earth science teams is shown in Figure 10 by plotting the 50th percentile hazard curve of each TEC prior to aggregation. For reference, Figure 10 also includes the mean and 85th, 50th, and 15th percentile curves aggregated over all teams.

Figures 11 through 15 show uniform hazard spectrum plots for annual exceedance probabilities of 1.0E-05, 1.0E-04, 2.0E-04, 1.0E-03 and 2.0E-03, each showing the 15th, 50th, and 85th percentile uniform hazard spectra. Figure 16 is a uniform hazard spectrum plot, showing mean spectra for annual exceedance probabilities of 1.0E-05, 1.0E-04, 2.0E-04, 1.0E-03 and 2.0E-03.

Seismic hazard results for the Turkey Point site are presented on Table 5. In the same sequence as for St. Lucie, the hazard curves for peak ground acceleration and uniform hazard spectra for the Turkey Point site are shown on Figures 17 through 24.

The annual probability of exceedance and the corresponding return periods for the 50th percentile hazard at various levels of peak ground acceleration for the St. Lucie and Turkey Point sites are given in Tables 6 and 7, respectively, and for the 85th percentile hazard in Tables 8 and 9, respectively.

4. Summary and Conclusions

As one would expect from a general observation of seismicity of the Florida peninsula, within the context of the Eastern U.S. seismicity as seen on an epicenter map, the level of

seismic hazard at St. Lucie and Turkey Point sites is very low. Most of the contribution to the hazard at the two sites, for each of the earth science teams, comes from the background source containing the site. Background sources have been characteristically assigned low maximum magnitudes by all TEC teams in comparison to other sources in the eastern U.S. It was also noted that distant sources making contribution to the hazard at the two sites for low frequency ground motion make less contribution at the sites for high frequency ground motion. It appears that the high frequency components of ground motion attenuate at a more rapid rate with distance than lower frequency components. Thus some distant sources whose contribution was negligible in the computation of high frequency ground motion, were included in the computation of total annual probability of exceedance.

In summary, the results of the probabilistic seismic hazard evaluation for Florida Power and Light's St. Lucie and Turkey Point sites, using the EPRI methodology, yield very low values for each site's seismic hazard.

5. Bibliography

Bernreuter, D.L., J.B. Savy, R.W. Mensing and J.C. Chen (1989). "Seismic Hazard Characterization of 69 Nuclear Power Plant Sites East of the Rocky Mountains", Volumes 1-8, U.S. Nuclear Regulatory Commission, NUREG/CR-5250, UCID-21517.

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Toro, G.R., R.K. McGuire and W.J. Silva (1988). "Engineering Model of Earthquake Ground Motion for Eastern North America", Electric Power Research Institute, Palo Alto, CA, EPRI NP-6074, Research Project 2556-16.

Toro, G.R., R.K. McGuire and M.W. McCann (1989). "EQHAZARD Primer", Electric Power Research Institute, Palo Alto, CA, EPRI NP-6452-D, Research Project P101-46.

TABLE 1

Computerized Data Base Label No. of Source Zones

TEC Name	TEC Label No. (Used on TEC Maps)	Source Name	Data Base Label No. (Used on Computer Files)
Bechtel Group	13	Mesozoic Basins	01300
	30	New Madrid	03000
	31	Reelfoot Rift	03100
	H	Charleston Area	05200
	N-3	Charleston Faults	05900
	BZ-0	New Madrid Region	00100
	BZ-1	Gulf Coast Background	00600
	BZ-4	Atlantic Coast Background	02000
Dames & Moore	20	Southern Coastal Margin	02000
	21	New Madrid	02100
	22	Reelfoot Rift	02200
	22-21B	Reelfoot Rift-New Madrid	91500
	52	Charleston Rift	05200
	53	Southern Appalachian Default	05300
	54	Charleston Seismic Zone	05400
	65	Dunbarton Triassic Basin	06500
Law Engineering	04a	Reelfoot Rift(A)	00401
	04b	Reelfoot Rift(B)	00402
	22	Reactivated Eastern Seaboard	02200
	08	Mesozoic Basins	00816
	18	Reelfoot Rift Faults	01800
	35	Charleston	03500
	108	Brunswick Background	04300
	126	Southern Coastal Block	06001
	M-37	Mafic Pluton	03837
	M-38	Mafic Pluton	03838
	M-39	Mafic Pluton	03839
	M-40	Mafic Pluton	03840
	M-41	Mafic Pluton	03841
	M-42	Mafic Pluton	03842
	M-43	Mafic Pluton	03843
	M-44	Mafic Pluton	03844
	M-45	Mafic Pluton	03845
	M-48	Mafic Pluton	03848
	M-49	Mafic Pluton	03849
	M-50	Mafic Pluton	03850

Table 1 - continued

TABLE 1 (Continued)

Computerized Data Base Label No. of Source Zones

TEC Name	TEC Label No. (Used on TEC Maps)	Source Name	Data Base Label No. (Used on Computer Files)
Rondout Associates	1	New Madrid	00100
	2	New Madrid Rift	00200
	24	Charleston	02400
	26	South Carolina	02600
	49-05	Appalachian Basement Background	04905
	51	Gulf Coast to Bahamas Background	05100
Weston Geophysical	25	Charleston	02500
	26	South Carolina	02600
	31	New Madrid	03100
	32	Reelfoot Rift	03200
	104	Southern Coastal Plain Background	05400
	107	Gulf Coast Background	05700
	Z032-Z031	Combination (C-11)	91100
	Z104-Z022	Combination (C-20)	92000
	Z104-Z025	Combination (C-21)	92100
	Z104-Z026	Combination (C-22)	92200
	Z104-Z022 -Z026	Combination (C-23)	92300
	Z104-Z022 -Z025	Combination (C-24)	92400
	Z104 -Z028BCDE -Z022-Z025	Combination (C-27)	92700
	Z104 -Z028BCDE -Z022-Z026	Combination (C-28)	92800
Woodward-Clyde	1	Continental Shelf Edge	00100
	29	SC Gravity Saddle (extended)	02900
	29A	SC Gravity Saddle #2	0290A
	30	Charleston NOTA	03000
	40	Central Reelfoot Rift	04000
	41	Combination (C-8)	90800
	44	New Madrid Loading Zone	04400

TABLE 2
Scenarios for Contributing Source Zones[1]
St. Lucie (frequencies greater than 5hz)

TEC Team	Scenario[2]	Weight[3]
Bechtel	00600 + 02000 + 01300 + 05200	0.05
	00600 + 02000 + 01300	0.05
	00600 + 02000 + 05200	0.45
	00600 + 02000	0.45
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + 05400	0.28
	02000 + 05400 + 05200	0.46
	02000 + 05400 + 05300	0.26
Background	02000	1.0
Law Engineering	04300 + 06001 + 02200	0.27
	04300 + 06001 + 00816	0.27
	04300 + 06001	0.46
Background	04300	0.42
	06001	0.49
Rondout Associates	02400 + 02600 + 04905 + 05100	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + 92000	0.001
	05700 + 02500 + 92100	0.012
	05700 + 02600 + 92200	0.069
	05700 + 02600 + 92300	0.312
	05700 + 02500 + 92400	0.368
	05700 + 02500 + 92700	0.126
	05700 + 02600 + 92800	0.100
	05700 + 05400	0.012
Background	05700	1.0
Woodward Clyde Consultants	WCCBK	0.573
	WCCBK + 02900	0.122
	WCCBK + 0290A	0.305
Background	WCCBK	1.0

Table 2 - continued

TABLE 2 (continued)
Scenarios for Contributing Source Zones[1]
St. Lucie (frequencies 5hz and less)

TEC Team	Scenario[2]	Weight[3]
Bechtel	00600 + 02000 + 01300 + 05200 + CB001 + CB002	0.05
	00600 + 02000 + 01300 + CB001 + CB002	0.05
	00600 + 02000 + 05200 + CB001 + CB002	0.45
	00600 + 02000 + CB001 + CB002	0.45
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + 05400 + CB001 + CB002	0.28
	02000 + 05400 + 05200 + CB001 + CB002	0.46
	02000 + 05400 + 05300 + CB001 + CB002	0.26
Background	02000	1.0
Law Engineering	04300 + 06001 + 02200 + CB001 + CB002	0.2700
	04300 + 06001 + 00816 + 03842 + 03848 + 03849 + 03850 + CB001 + CB002	0.1161
	04300 + 06001 + 00816 + CB001 + CB002	0.1539
	04300 + 06001 + 03842 + 03848 + 03849 + 03850 + CB001 + CB002	0.1978
	04300 + 06001 + CB001 + CB002	0.2622
Background	04300	0.42
	06001	0.49
Rondout Associates	02400 + 02600 + 04905 + 05100 + CB001 + CB002	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + 92000 + CB001 + CB002	0.001
	05700 + 02500 + 92100 + CB001 + CB002	0.012
	05700 + 02600 + 92200 + CB001 + CB002	0.069
	05700 + 02600 + 92300 + CB001 + CB002	0.312
	05700 + 02500 + 92400 + CB001 + CB002	0.368
	05700 + 02500 + 92700 + CB001 + CB002	0.126
	05700 + 02600 + 92800 + CB001 + CB002	0.100
	05700 + 05400 + CB001 + CB002	0.012
Background	05700	1.0

Table 2 - continued

TABLE 2 (continued)
Scenarios for Contributing Source Zones[1]
St. Lucie (frequencies 5hz and less)

TEC Team	Scenario[2]	Weight[3]
Woodward Clyde Consultants	WCCBK + CB001 + CB002	0.573
	WCCBK + 02900 + CB001 + CB002	0.122
	WCCBK + 0290A + CB001 + CB002	0.305
Background	WCCBK	1.0

Notes: [1] Source Zone numbers correspond to those on Table 1 and on Figures 2 through 7.

[2] Each TEC scenario is made up of the allowable source zone combinations whose total weights, or probability of activity add up to 1.0.

[3] Weight is defined as the fractional probability of activity.

TABLE 3
Scenarios for Contributing Source Zones[1]
Turkey Point (frequencies greater than 5hz)

TEC Team	Scenario[2]	Weight[3]
Bechtel	00600 + 02000 + CB001 + CB002	1.0
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + CB001 + CB002	1.0
Law Engineering	04300 + 06001 + 02200 + CB001 + CB002	0.27
	04300 + 06001 + 00816 + CB001 + CB002	0.27
	04300 + 06001 + CB001 + CB002	0.46
Background	04300	0.42
	06001	0.49
Rondout Associates	04905 + 05100 + CB001 + CB002	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + CB001 + CB002	1.0
Background	05700	1.0
Woodward Clyde Consultants	WCCBK + CB001 + CB002	1.0
Background	WCCBK	1.0

Table 3 - continued

TABLE 3 (continued)
Scenarios for Contributing Source Zones[1]
Turkey Point (frequencies 5hz and less)

TEC Team	Scenario[2]	Weight[3]
Bechtel	00600 + 02000 + CB001 + CB002	1.0
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + 05400 + CB001 + CB002	0.28
	02000 + 05400 + 05200 + CB001 + CB002	0.46
	02000 + 05400 + 05300 + CB001 + CB002	0.26
Law Engineering	04300 + 06001 + 02200 + CB001 + CB002	0.2700
	04300 + 06001 + 00816 + 03842 + 03848 + CB001 + CB002	0.1161
	04300 + 06001 + 00816 + CB001 + CB002	0.1539
	04300 + 06001 + 03842 + 03848 + CB001 + CB002	0.1978
	04300 + 06001 + CB001 + CB002	0.2622
Background	04300	0.42
	06001	0.49
Rondout Associates	02400 + 02600 + 04905 + 05100 + CB001 + CB002	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + 92000 + CB001 + CB002	0.001
	05700 + 02500 + 92100 + CB001 + CB002	0.012
	05700 + 02600 + 92200 + CB001 + CB002	0.069
	05700 + 02600 + 92300 + CB001 + CB002	0.312
	05700 + 02500 + 92400 + CB001 + CB002	0.368
	05700 + 02500 + 92700 + CB001 + CB002	0.126
	05700 + 02600 + 92800 + CB001 + CB002	0.100
	05700 + 05400 + CB001 + CB002	0.012
Background	05700	1.0

Table 3 - continued

TABLE 3 (continued)
Scenarios for Contributing Source Zones[1]
Turkey Point (frequencies 5hz and less)

TEC Team	Scenario[2]	Weight[3]
Woodward Clyde Consultants	WCCBK + CB001 + CB002	0.573
	WCCBK + 02900 + CB001 + CB002	0.122
	WCCBK + 0290A + CB001 + CB002	0.305
Background	WCCBK	1.0

Notes: [1] Source Zone numbers correspond to those on Table 1 and on Figures 2 through 7.

[2] Each TEC scenario is made up of the allowable source zone combinations whose total weights, or probability of activity add up to 1.0.

[3] Weight is defined as the fractional probability of activity.

TABLE 4
St. Lucie
Annual Probability of Exceedance for Peak Ground Acceleration (PGA)

PGA (cm/sec^2)	PGA (g)	Mean	Percentiles 15	50	85
7.00	0.007	7.36E-04	1.82E-05	4.97E-04	1.60E-03
65.00	0.07	3.89E-05	7.80E-07	3.15E-05	6.84E-05
120.00	0.12	1.24E-05	2.00E-07	1.05E-05	2.29E-05
225.00	0.23	1.61E-06	1.40E-08	1.04E-06	2.75E-06
400.00	0.41	1.78E-07	5.82E-10	7.48E-08	3.08E-07
560.00	0.57	5.08E-08	1.97E-10	1.32E-08	8.60E-08
800.00	0.82	1.22E-08	1.91E-10	1.51E-09	1.41E-08

TABLE 5
Turkey Point
Annual Probability of Exceedance for Peak Ground Acceleration (PGA)

PGA (cm/sec^2)	PGA (g)	Mean	Percentiles 15	50	85
5.00	0.005	3.90E-03	1.02E-04	3.27E-04	1.34E-02
50.00	0.05	3.18E-05	7.89E-07	2.75E-05	5.61E-05
100.00	0.10	1.08E-05	1.87E-07	9.57E-06	2.02E-05
250.00	0.26	1.39E-06	1.29E-08	9.19E-07	2.58E-06
500.00	0.51	1.52E-07	7.26E-10	5.95E-08	2.85E-07
700.00	0.71	4.33E-08	3.91E-10	9.89E-09	7.16E-08
1000.00	1.02	1.04E-08	3.91E-10	1.17E-09	1.21E-08

TABLE 6
Peak Ground Acceleration (PGA)
Annual Probability of Exceedance and Return Periods

Seismic Hazard Results
Summary for St. Lucie Site
50th Percentile

Acceleration (g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
0.007	4.97E-04	2,012
0.07	3.15E-05	31,746
0.12	1.05E-05	95,238
0.23	1.04E-06	961,538
0.41	7.48E-08	13,368,984
0.57	1.32E-08	75,757,576
0.82	1.51E-09	662,251,655

TABLE 7
Peak Ground Acceleration (PGA)
Annual Probability of Exceedance and Return Periods

Seismic Hazard Results
Summary for Turkey Point Site
50th Percentile

Acceleration (g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
0.005	3.27E-04	3,058
0.05	2.75E-05	36,364
0.10	9.57E-06	104,493
0.26	9.19E-07	1,088,139
0.51	5.95E-08	16,806,723
0.71	9.89E-09	101,112,234
1.02	1.17E-09	854,700,854

TABLE 8
Peak Ground Acceleration (PGA)
Annual Probability of Exceedance and Return Periods

Seismic Hazard Results
Summary for St. Lucie Site
85th Percentile

Acceleration (g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
0.007	1.60E-03	625
0.07	6.84E-05	14,620
0.12	2.29E-05	43,668
0.23	2.75E-06	363,636
0.41	3.08E-07	3,246,753
0.57	8.60E-08	11,627,907
0.82	1.41E-08	70,921,986

TABLE 9
Peak Ground Acceleration (PGA)
Annual Probability of Exceedance and Return Periods

Seismic Hazard Results
Summary for Turkey Point Site
85th Percentile

Acceleration (g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
0.005	1.34E-02	75
0.05	5.61E-05	17,825
0.10	2.02E-05	49,505
0.26	2.58E-06	387,597
0.51	2.85E-07	3,508,772
0.71	7.16E-08	13,966,480
1.02	1.21E-08	82,644,628

Key to Site Index Numbers

* Sites considered by LLNL to fall in the Southeastern Region of the U.S.

1. Limerick *
2. Shearon Harris *
3. Braidwood
4. La Crosse
5. River Bend
6. Wolf Creek
7. Watts Bar *
8. Vogtle *
9. Millstone
10. Maine Yankee

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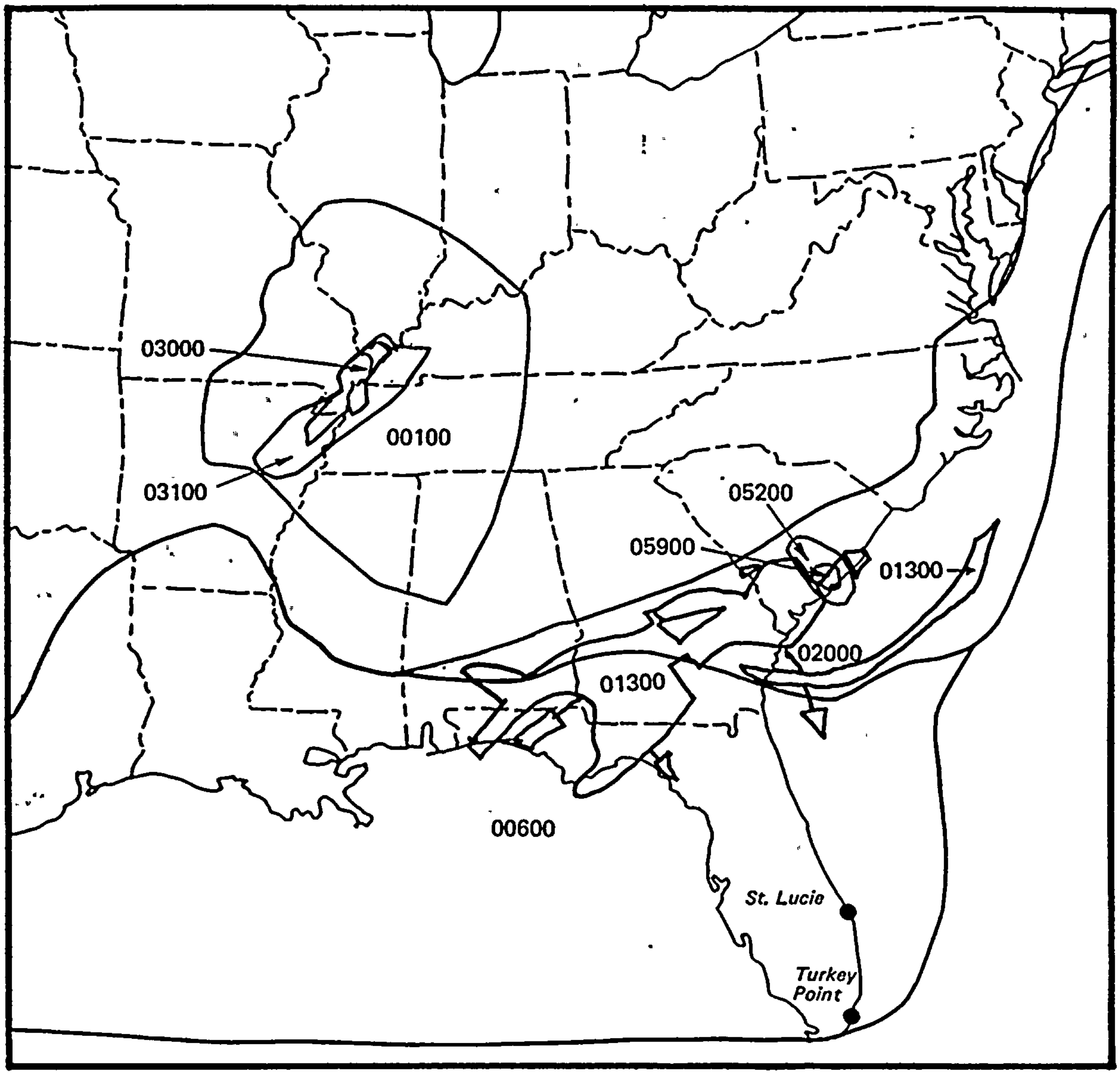
Location of the LLNL Sample Sites and St. Lucie and Turkey Point

FIGURE 1



Source Zone Number	Name	Source Zone Contributing to Hazard: St. Lucie	Turkey Point
01300	Mesozoic Basins	01300	
03000	New Madrid		
03100	Reelfoot Rift		
05200	Charleston Area	05200	
05900	Charleston Faults		
00100	New Madrid Background		
00600	Site Background	00600	00600
02000	Adjacent Background	02000	02000

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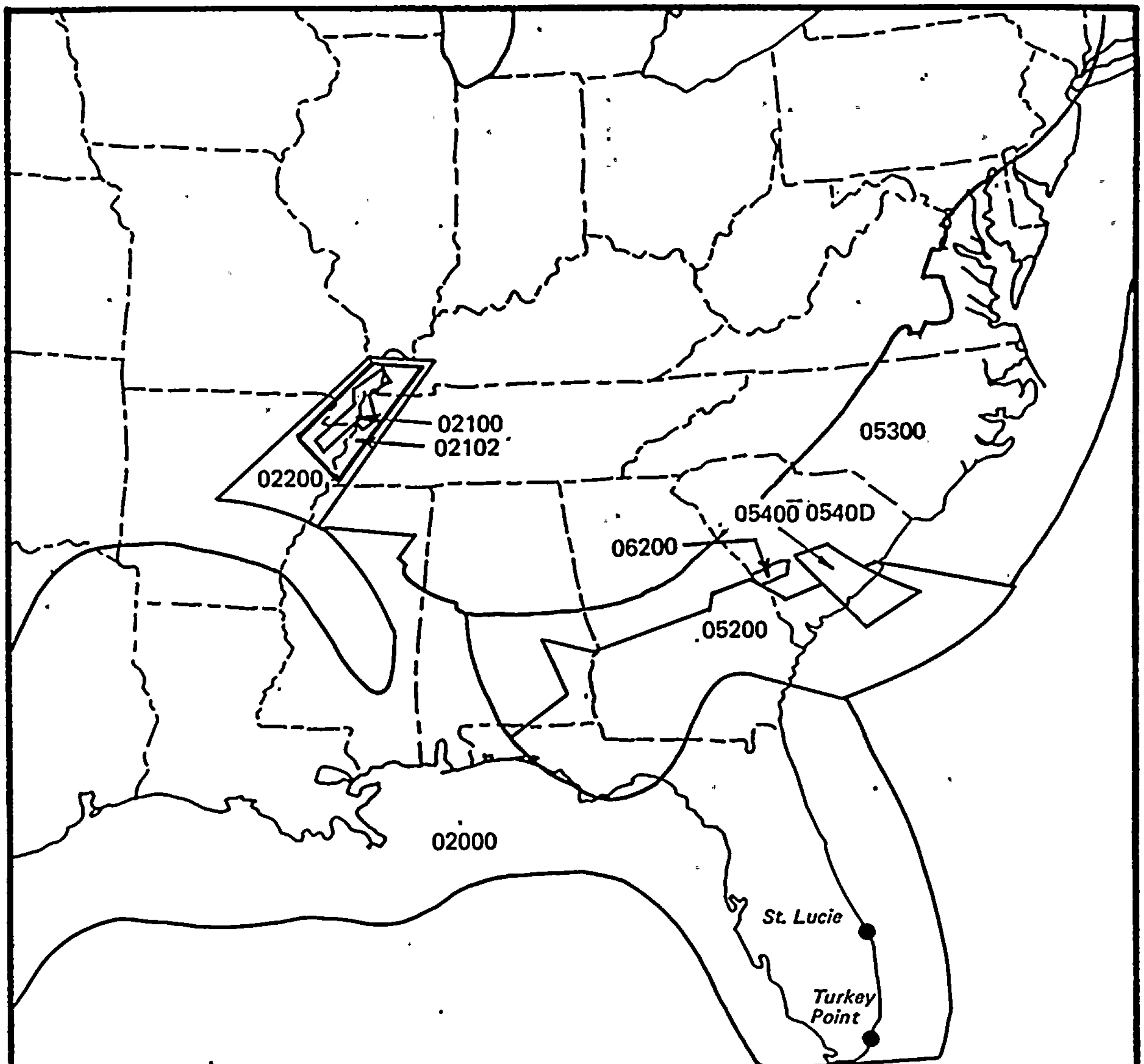
Seismic Source Zones Considered for the Florida Power and Light Company (Bechtel Group Inc. Model)

FIGURE 2



Note: 0540D is Default Zone for 05400

Source Zone Number	Name	Source Zone Contributing to Hazard: St. Lucie	Turkey Point
02000	Southern Coastal Margin	02000	02000
02100	New Madrid		
02200	Reelfoot Rift		
05200	Charleston Rift	05200	05200
05300	Southern Appalachian Default	05300	05300
05400	Charleston Seismic Zone	05400	05400
0540D	Charleston Default Zone	0540D	0540D
06200	Dunbarton Triassic Basin		

NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

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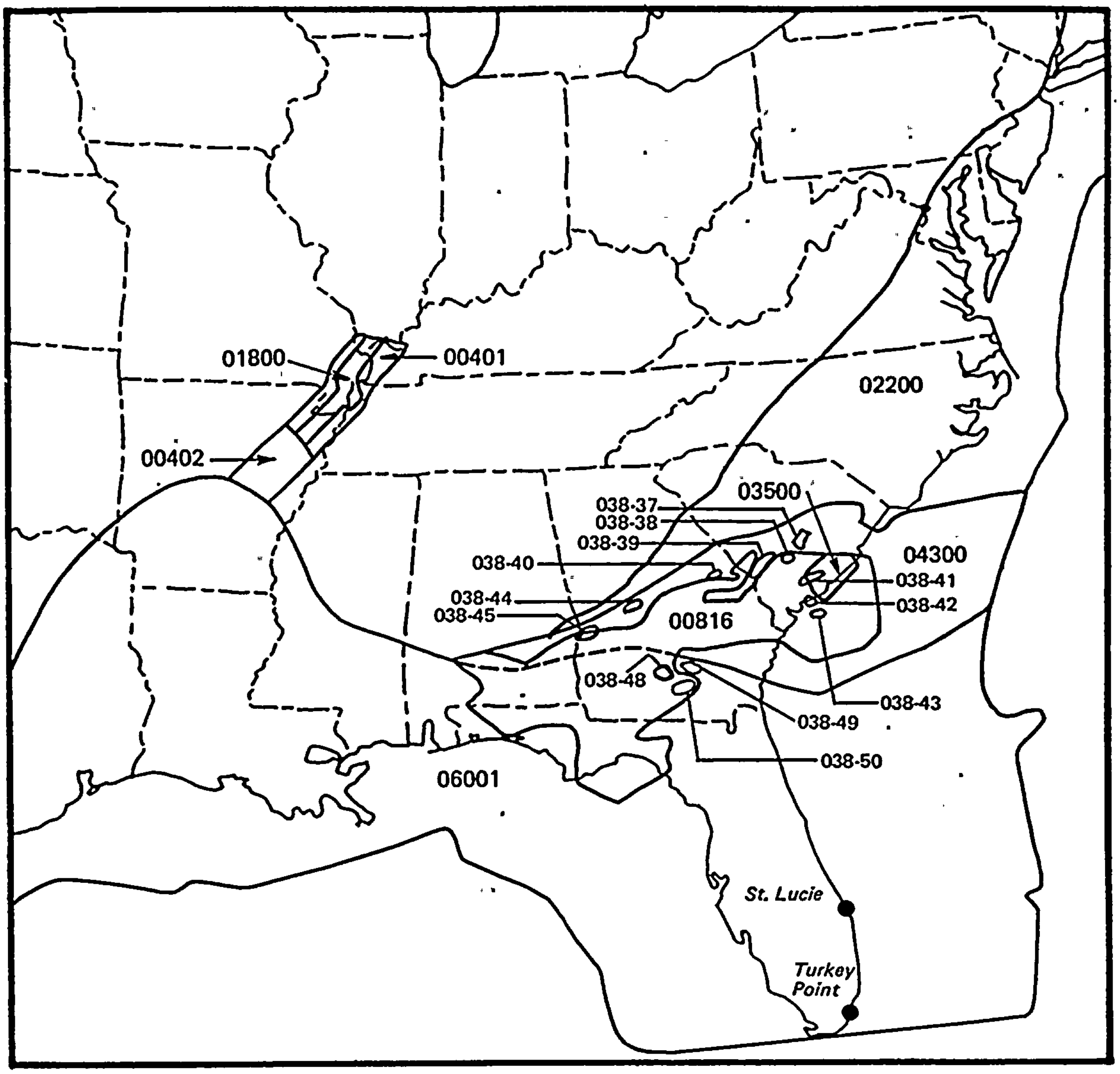
Seismic Source Zones Considered for the Florida Power and Light Company (Dames and Moore Model)

FIGURE 3



Source Zone Number	Name	Source Zone Contributing to Hazard St. Lucie	Turkey Point
00401	Reelfoot Rift (A)		
00402	Reelfoot Rift (B)		
00816	Mesozoic Basins	00816	00816
01800	Reelfoot Rift Faults		
02200	Reactivated Eastern Seaboard	02200	02200
03500	Charleston		
04300	Brunswick	04300	04300
06001	Southern Coastal Block	06001	06001
03837 to 03845	Mafic Plutons	03842 03848	03842 03848
03848 to 03850	Mafic Plutons	03849 03850	

NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

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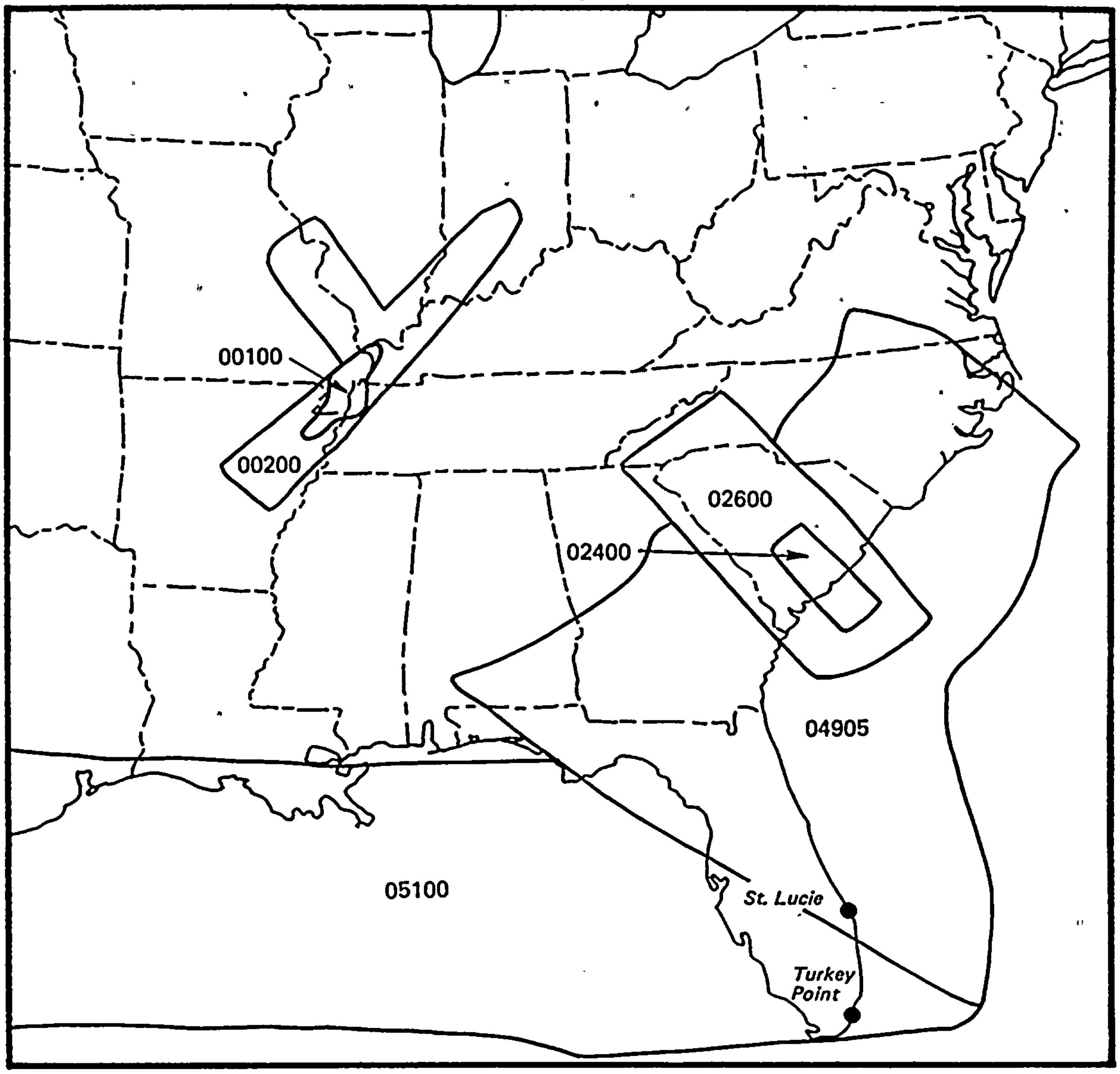
Seismic Source Zones Considered for the Florida Power and Light Company (Law Engineering Company Model)

FIGURE 4



Source Zone Number	Name	Source Zone Contributing to Hazard: St. Lucie	Turkey Point
00100	New Madrid		
00200	New Madrid Rift		
02400	Charleston	02400	02400
02600	South Carolina	02600	02600
04905	Appalachian Basement Background	04905	04905
05100	Gulf Coast to Bahamas Background	05100	05100

NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION.

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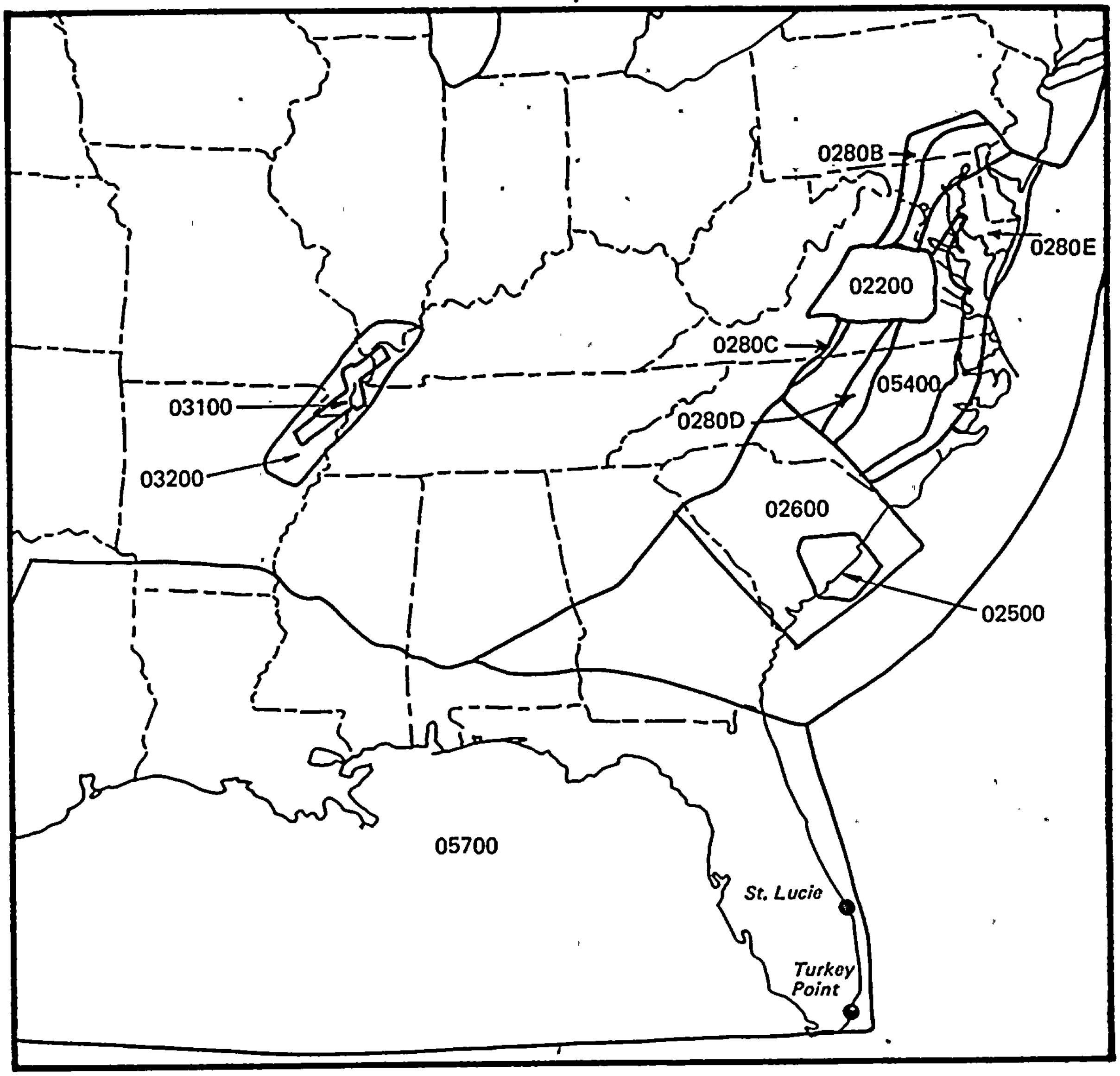
Seismic Source Zones Considered for the Florida Power and Light Company (Rondout Associates Model)

FIGURE 5



Source Zone		Source Zone Contributing to Hazard	
Number	Name	St. Lucie	Turkey Point
02500	Charleston	02500	02500
02600	South Carolina	02600	02600
03100	New Madrid		
03200	Reelfoot Rift		
05400	Southern Coastal Plain	05400	05400
05700	Gulf Coast Background	05700	05700
91100*	Combination 11		
92000* to 92400*	Combinations 920 to 924	92000 to 92400	92000 to 92400
92700*	Combination 927	92700	92700
92800*	Combination 928	92800	92800

*Geometry of Combination Sources Given in Table 1.

NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION.

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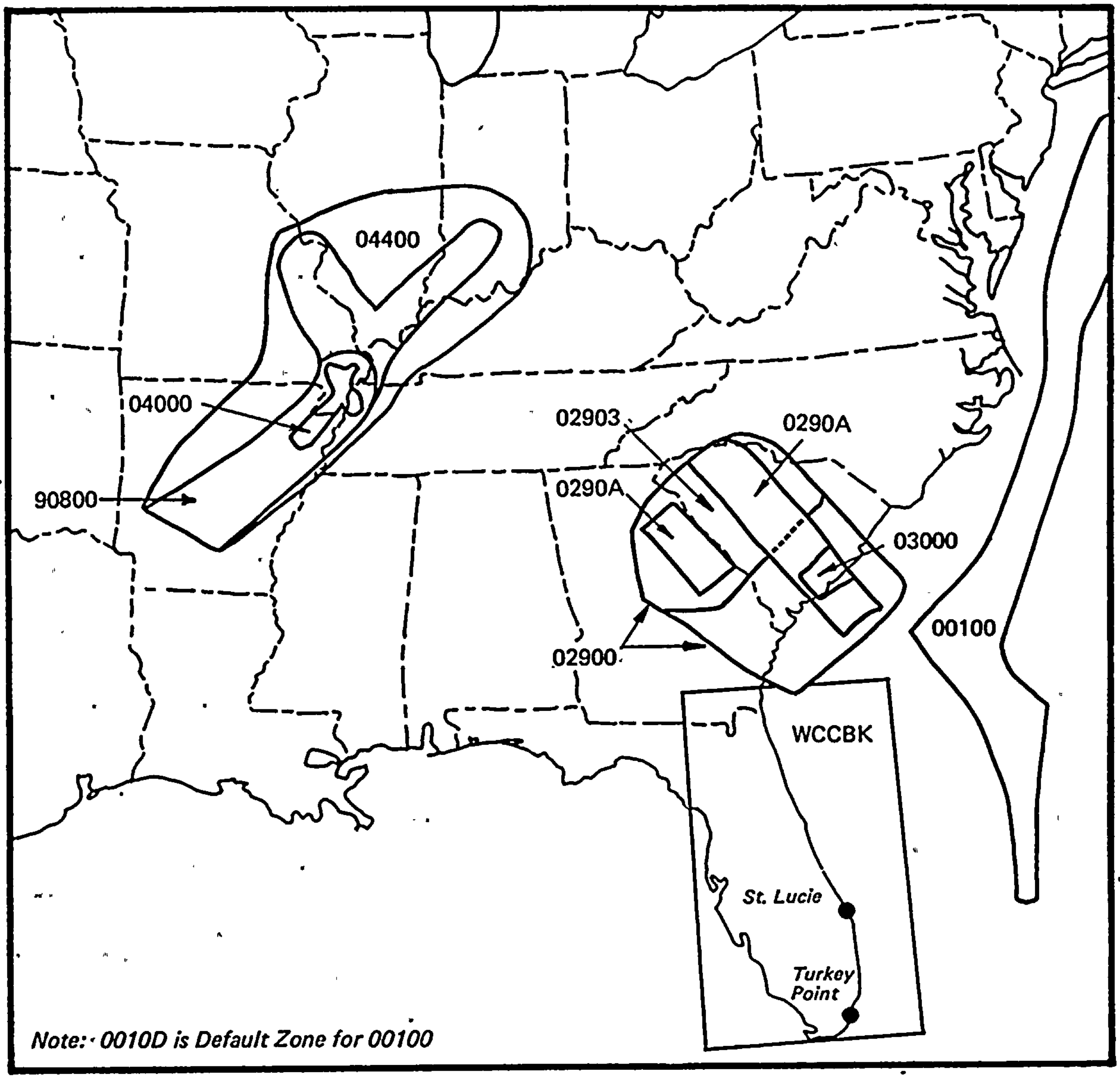
Seismic Source Zones Considered for the Florida Power and Light Company (Weston Geophysical Corp. Model)

FIGURE 6



Source Zone Number	Name	Source Zone Contributing to Hazard: St. Lucie	Turkey Point
00100	Continental Shelf Edge		
02900	South Carolina, Gravity Saddle (extended)	02900	<u>02900</u>
0290A	South Carolina, Gravity Saddle No. 2	0290A	<u>0290A</u>
03000	Charleston NOTA		
04000	Central Reelfoot Rift		
90800	Reelfoot Rift		
04400	New Madrid Loading Zone		
WCCBK	Background	WCCBK	WCCBK

NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

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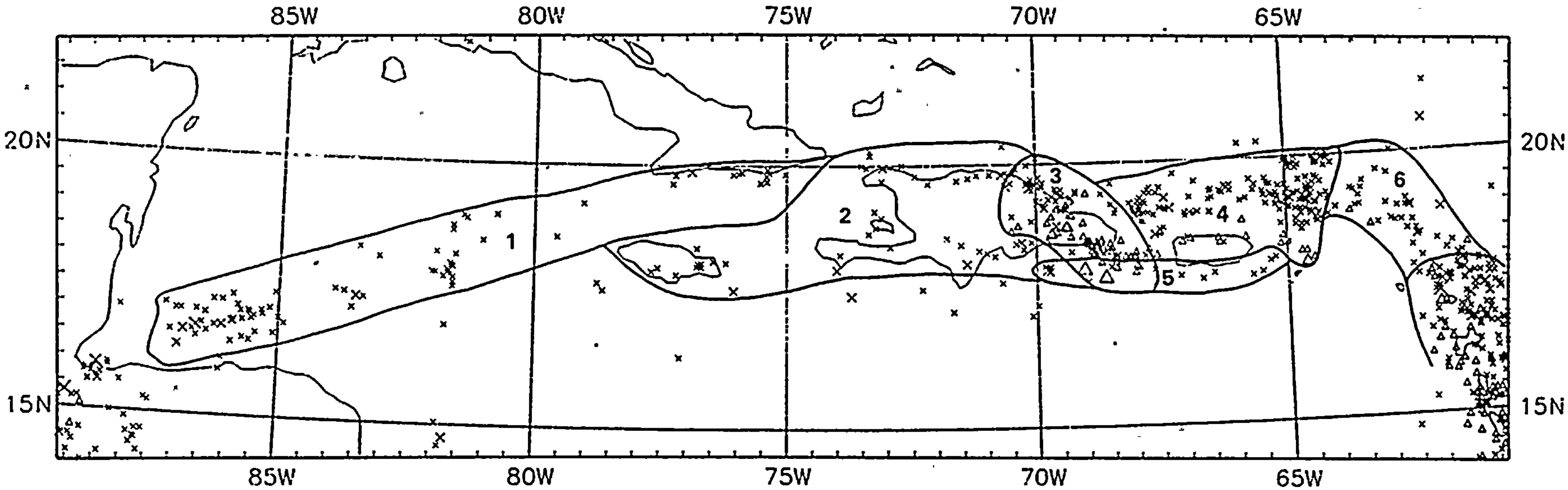
Seismic Source Zones Considered for the Florida Power and Light Company (Woodward Clyde Consultants Model)

FIGURE 7



Source Zone		Source Zone Contributing to Hazard	
Number	**Name**	**St. Lucie**	**Turkey Point**
1 CB001	Cayman Trough	<u>1</u>	1.
2 CB002	Jamaica–Western Hispaniola	<u>2</u>	2
3 CB003	Eastern Hispaniola		
4 CB004	Puerto Rico Trench		
5 CB005	Muertos Trench		
6 CB006	Greater Antilles– Lesser Antilles Transition		

NOTE: THE UNDERLINED SOURCES CONTRIBUTE TO LOW FREQUENCY (5hz AND LESS) GROUND MOTION

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Seismic Source Zones Considered for the Florida Power and Light Company in the Northern Caribbean

FIGURE 8

HAZARD RESULTS AT ST. LUCIE
EQUAL TEAM WEIGHTS

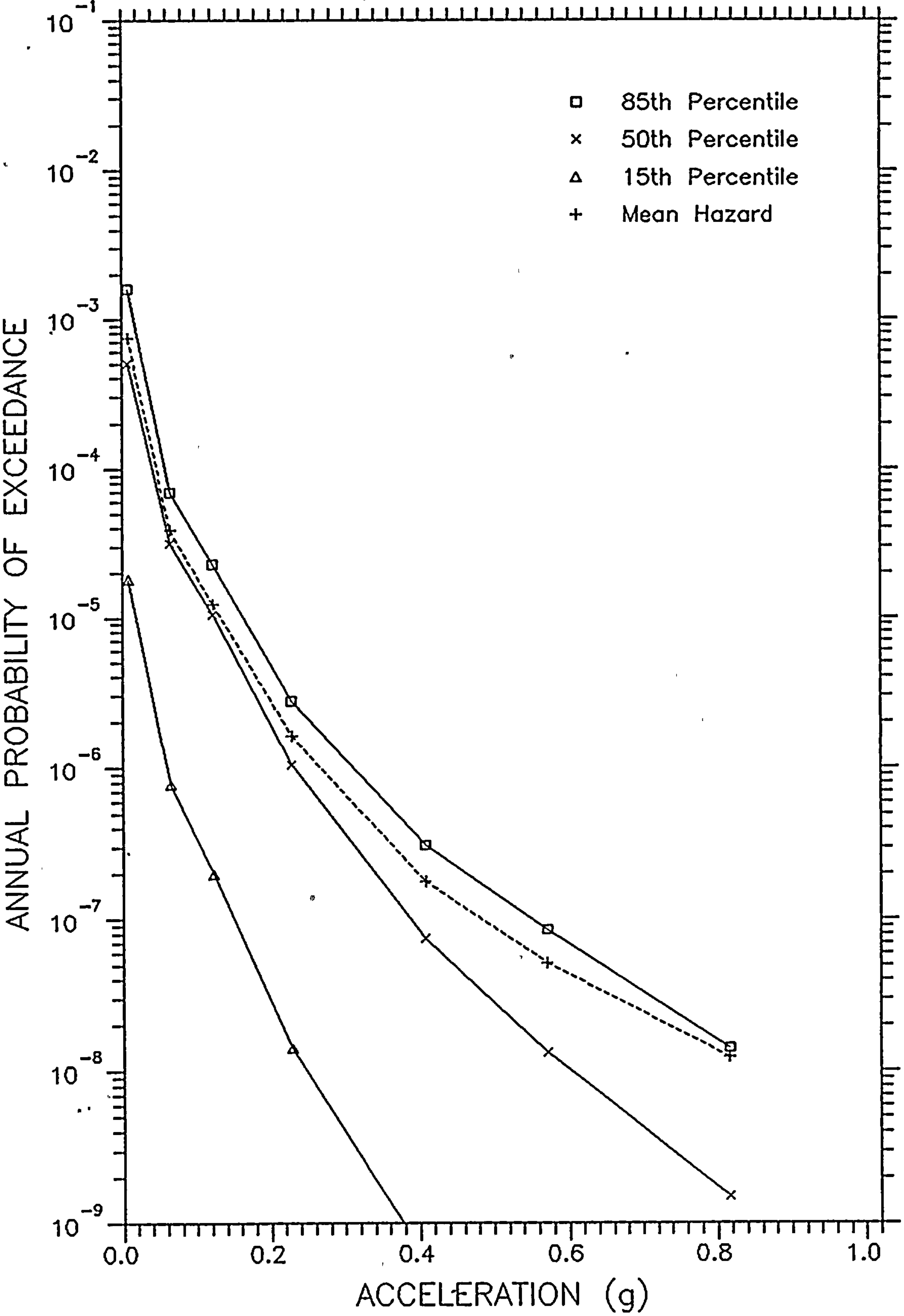

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FIGURE 9

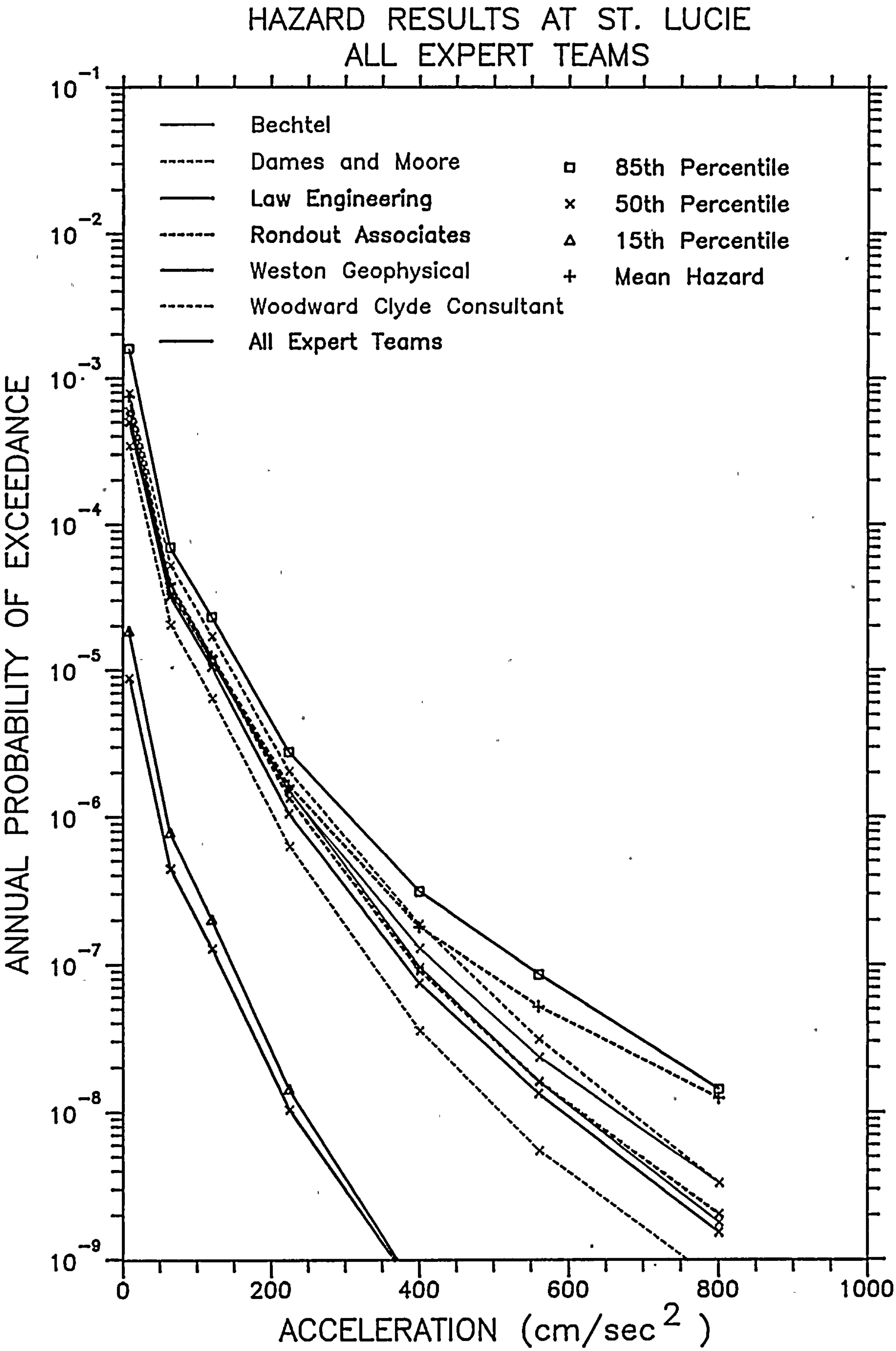

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FIGURE 10

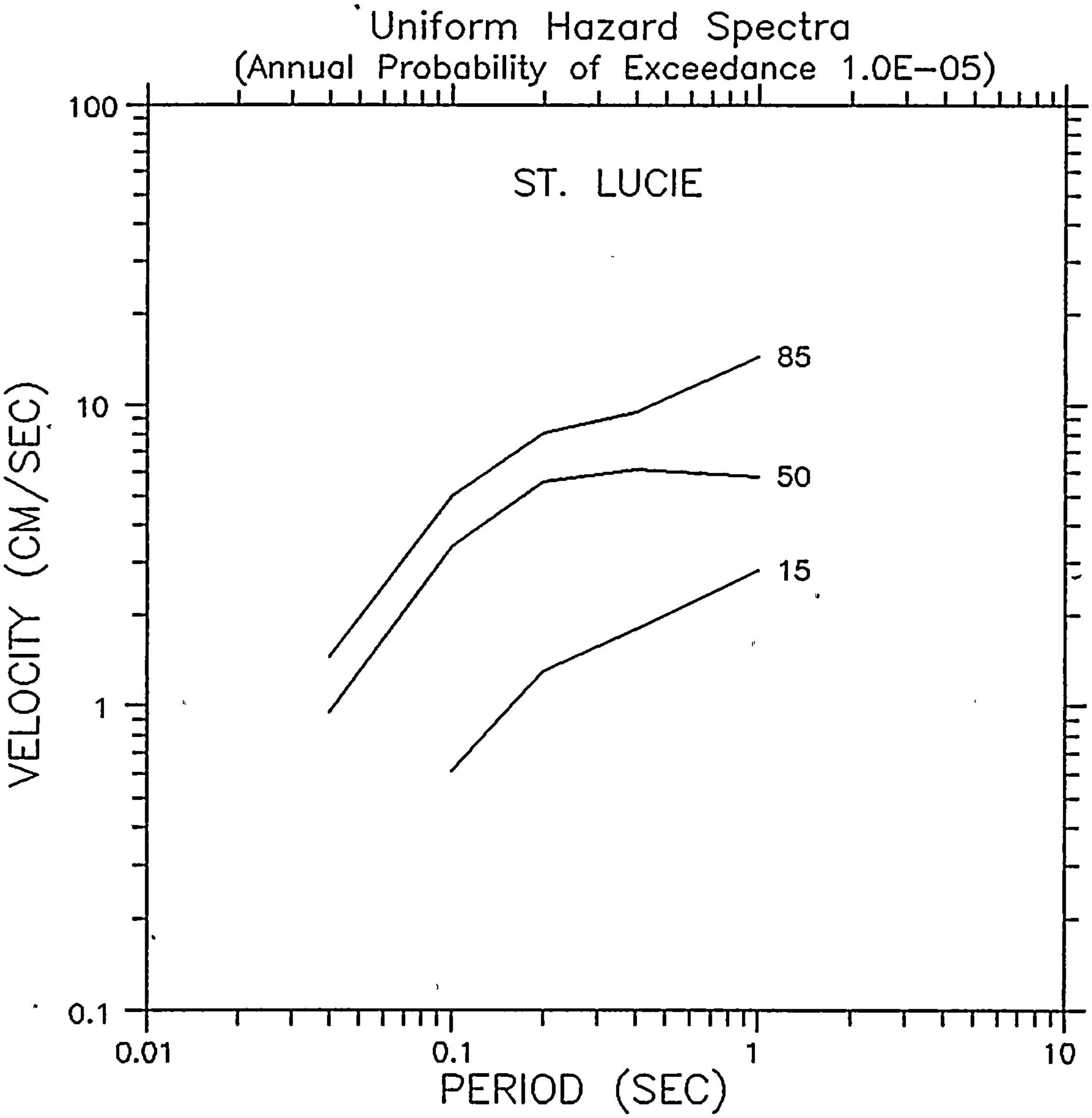

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FIGURE 11

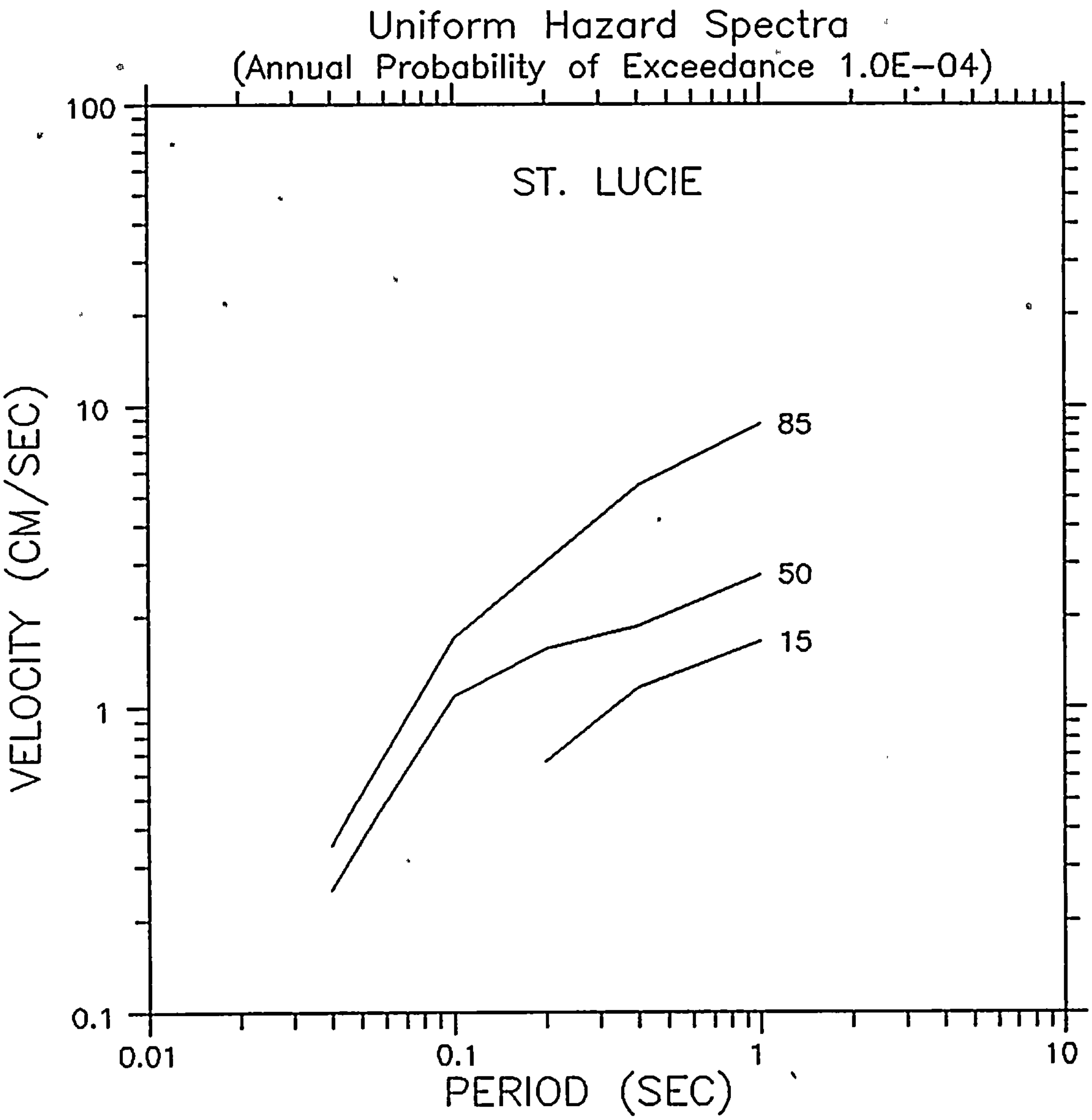

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FIGURE 12

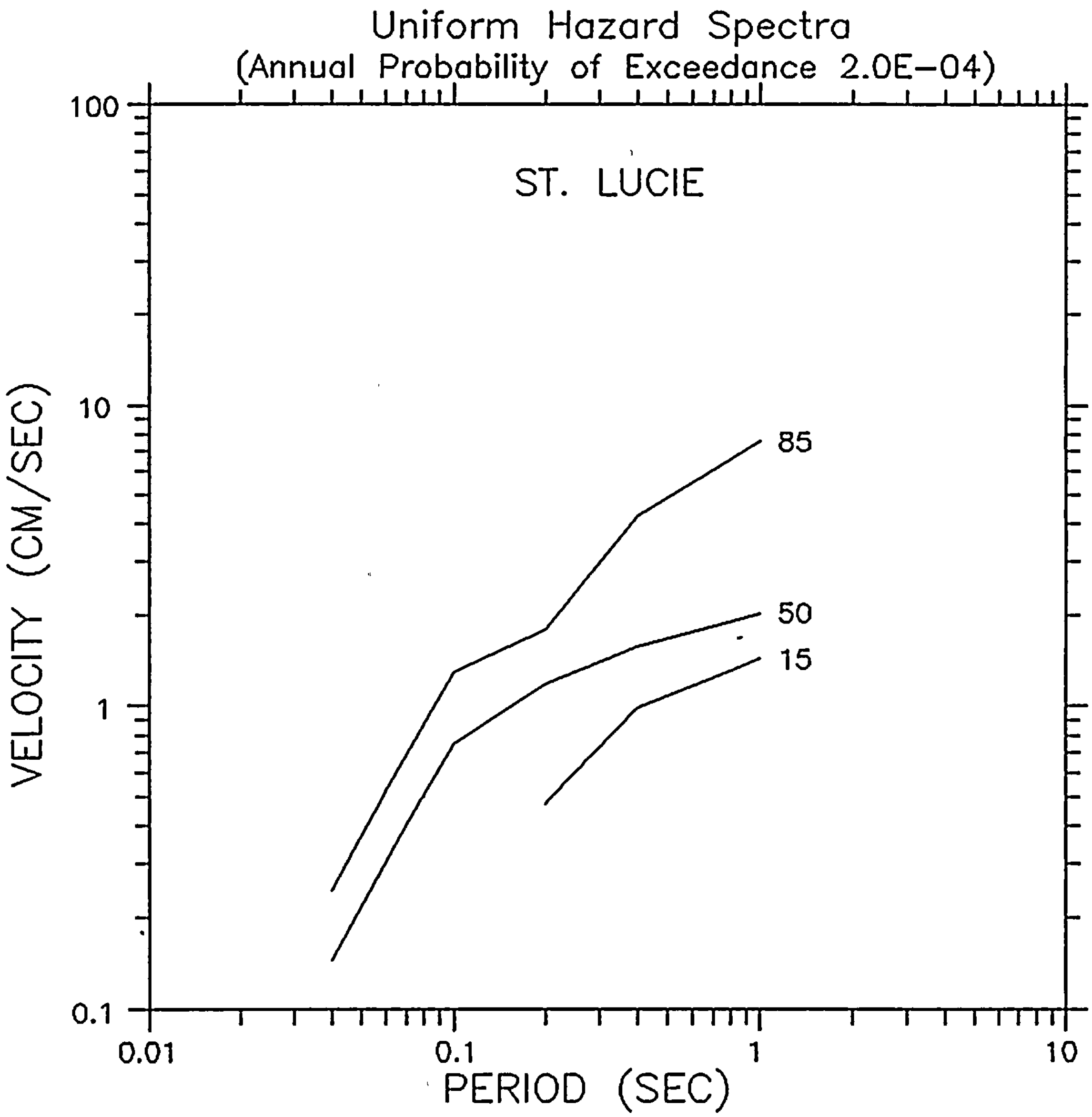

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FIGURE 13

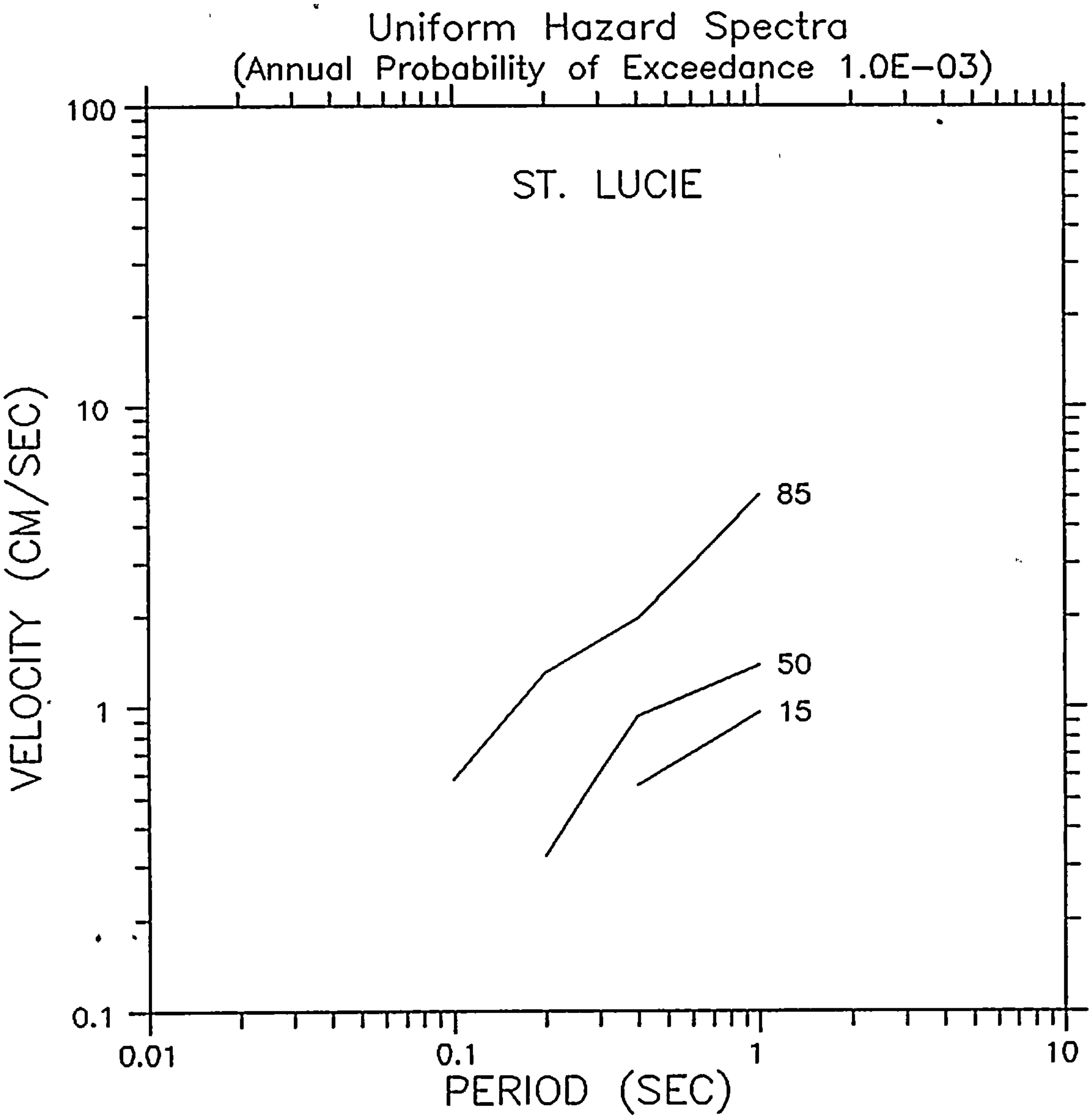

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FIGURE 14

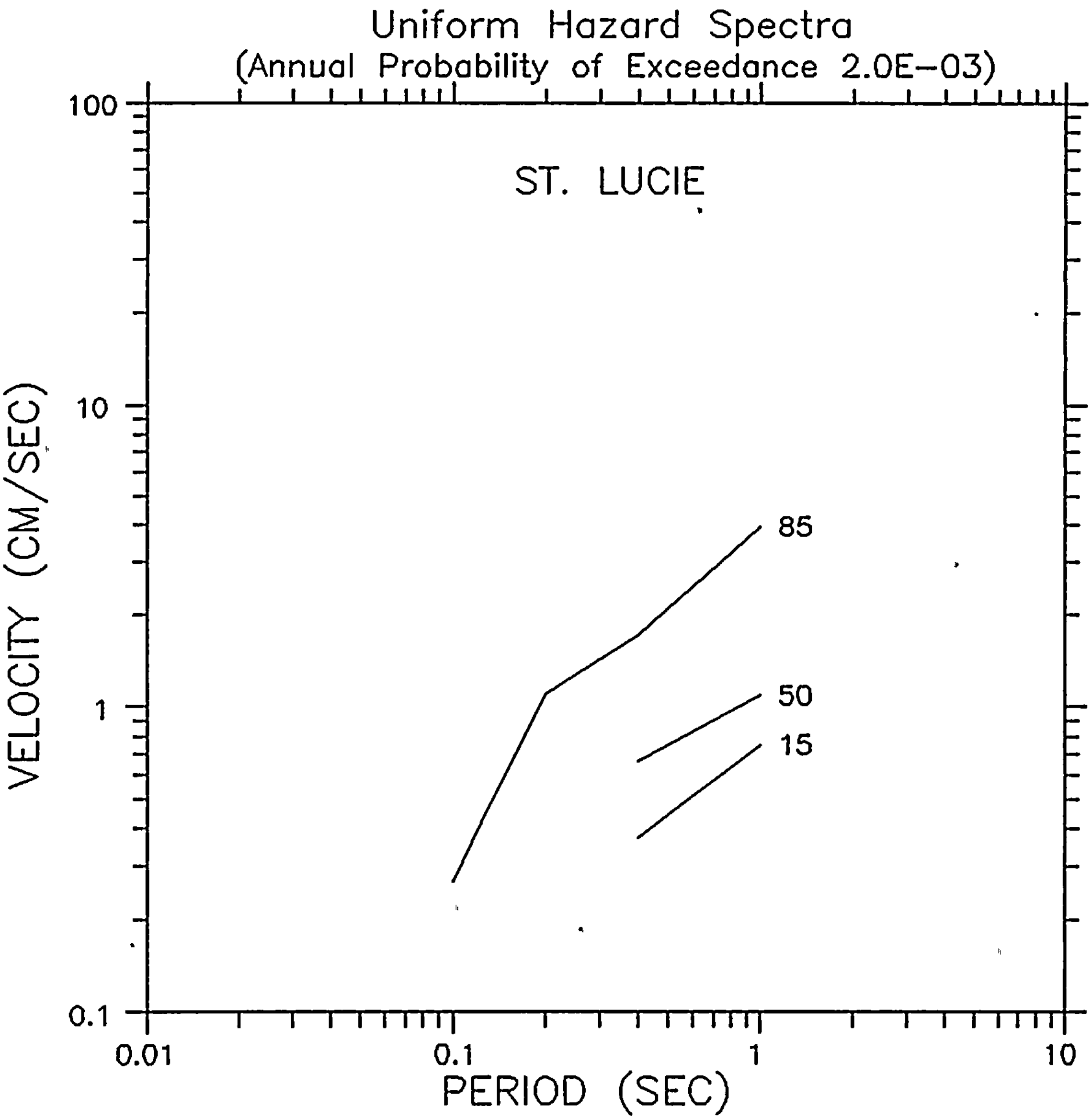

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FIGURE 15

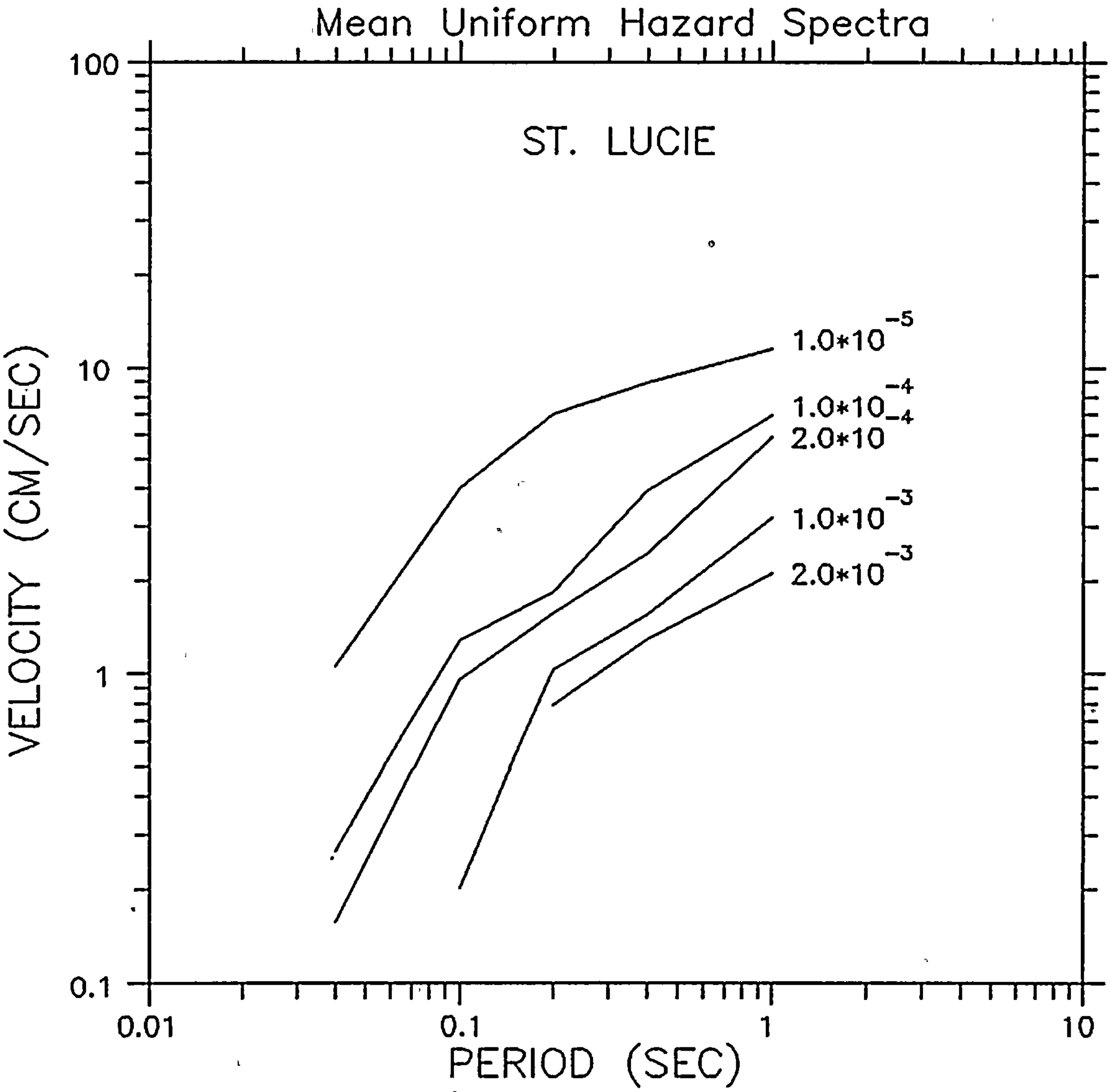

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FIGURE 16

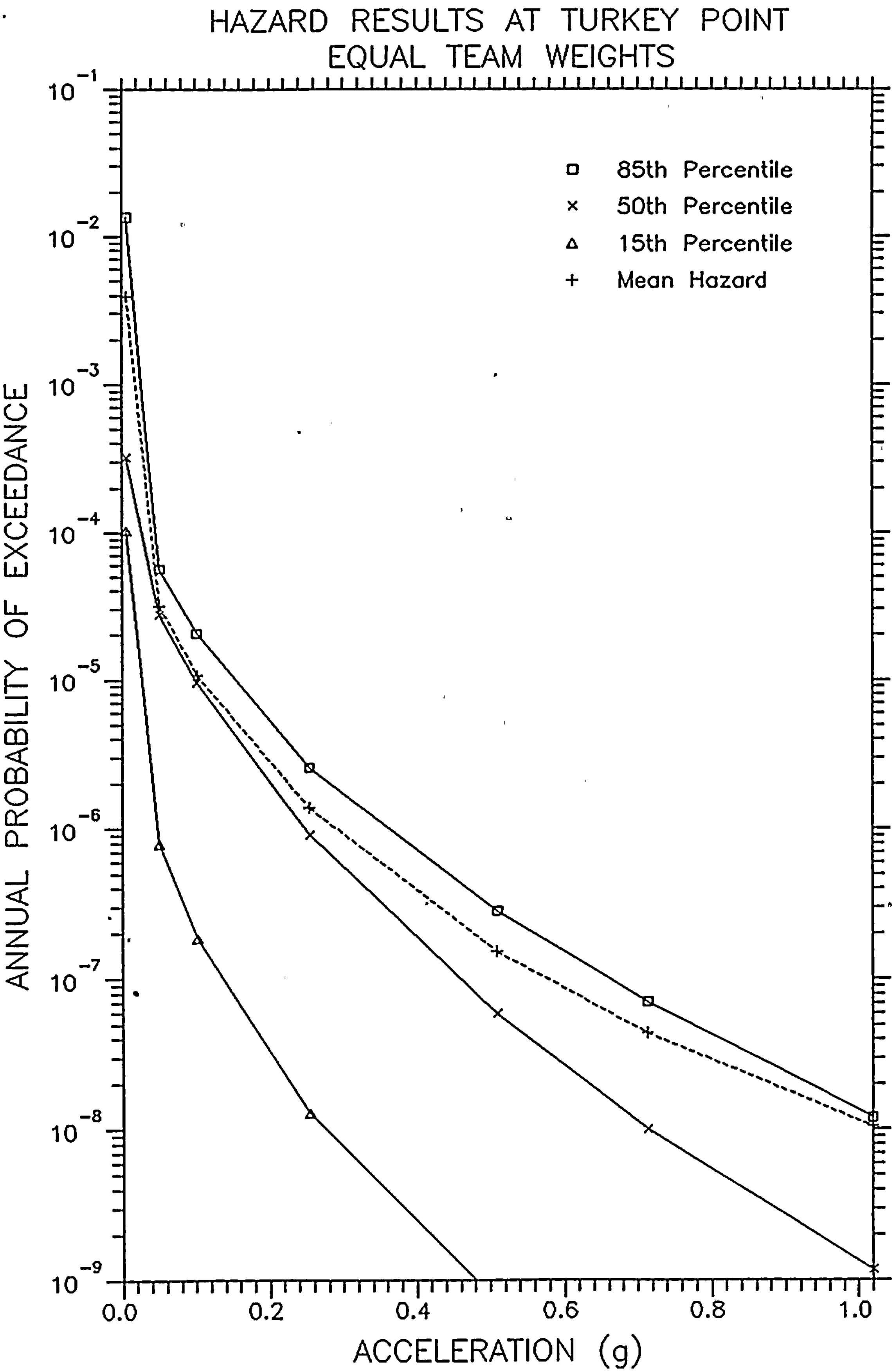

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FIGURE 17

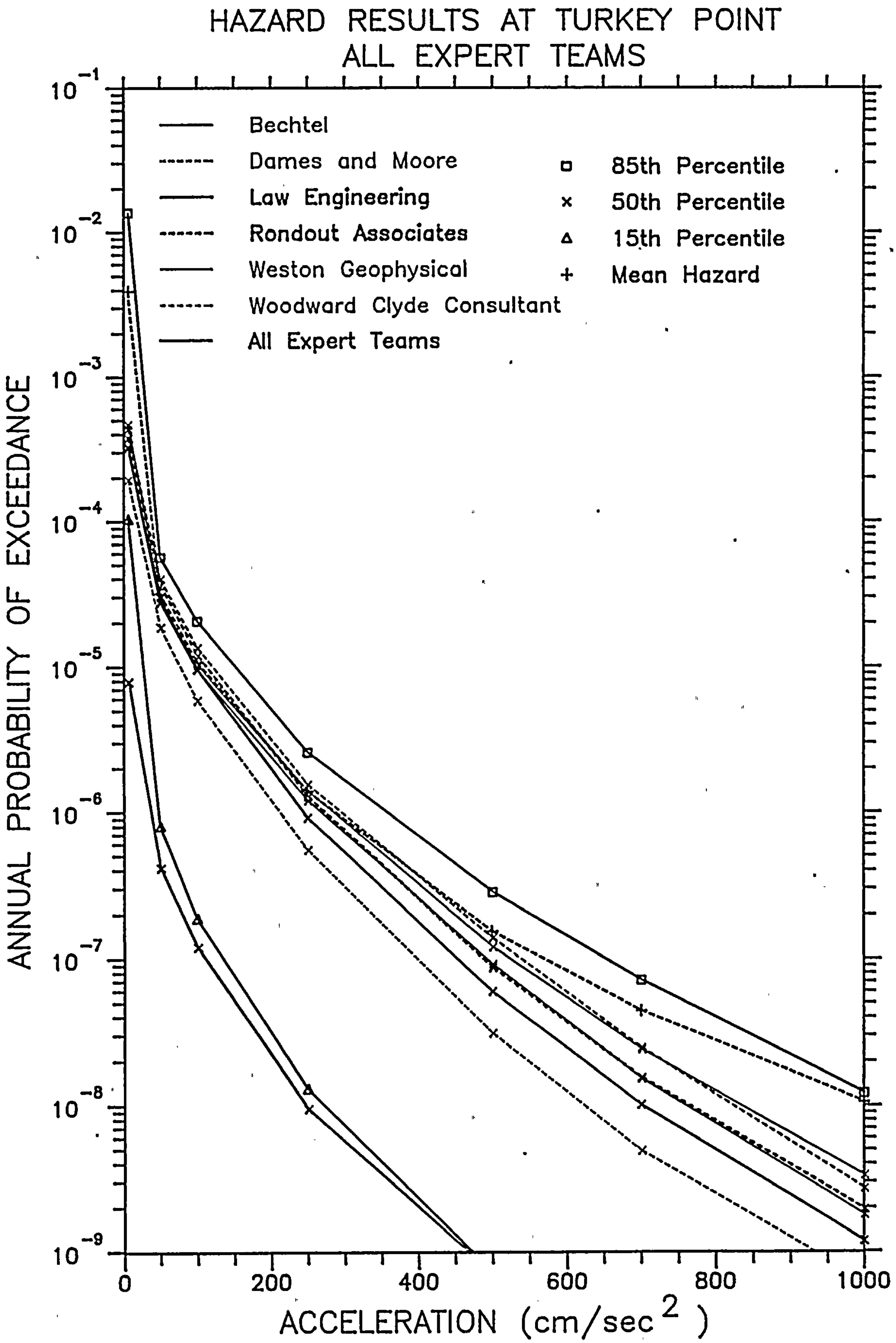

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FIGURE 18

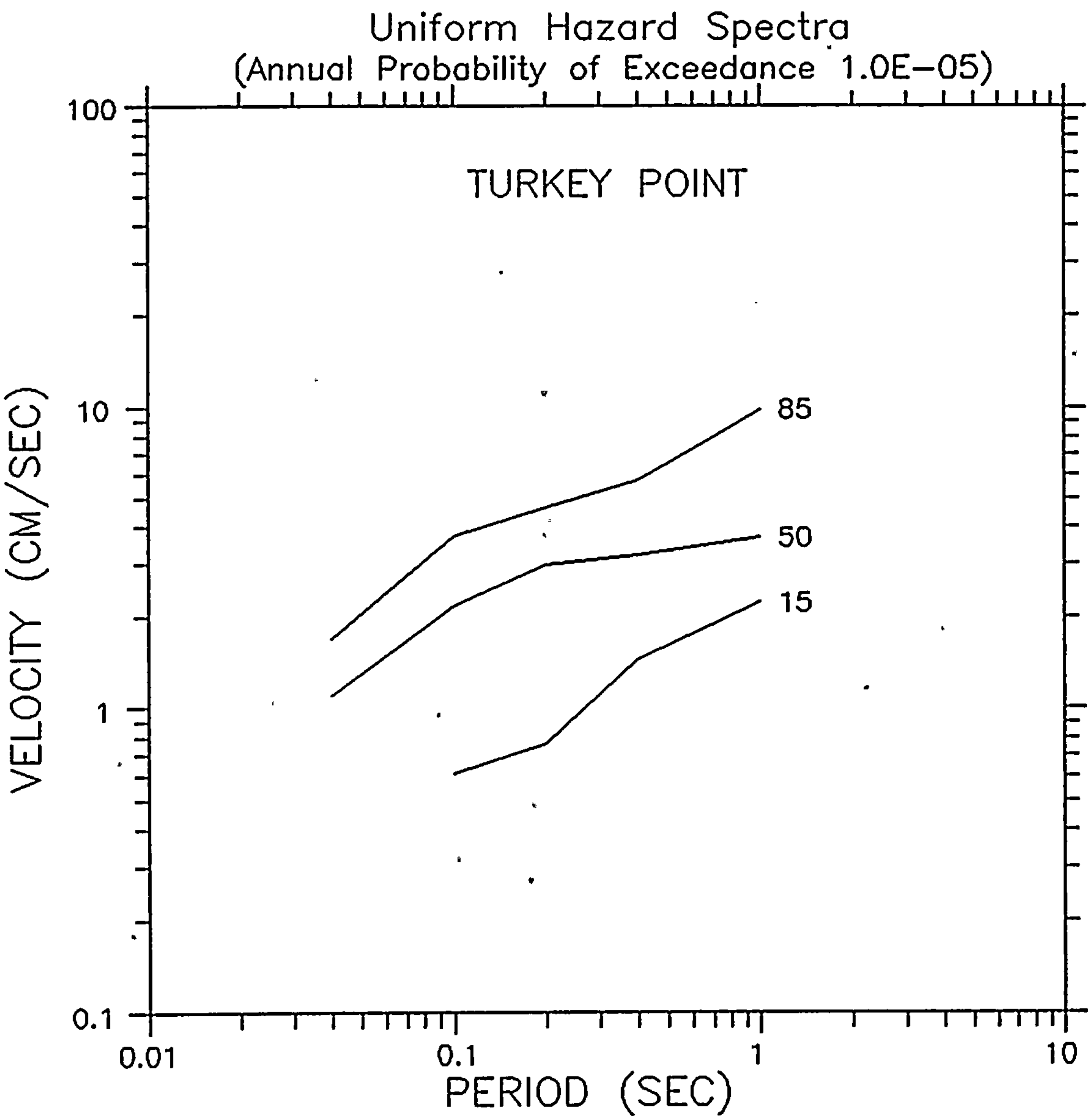

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FIGURE 19

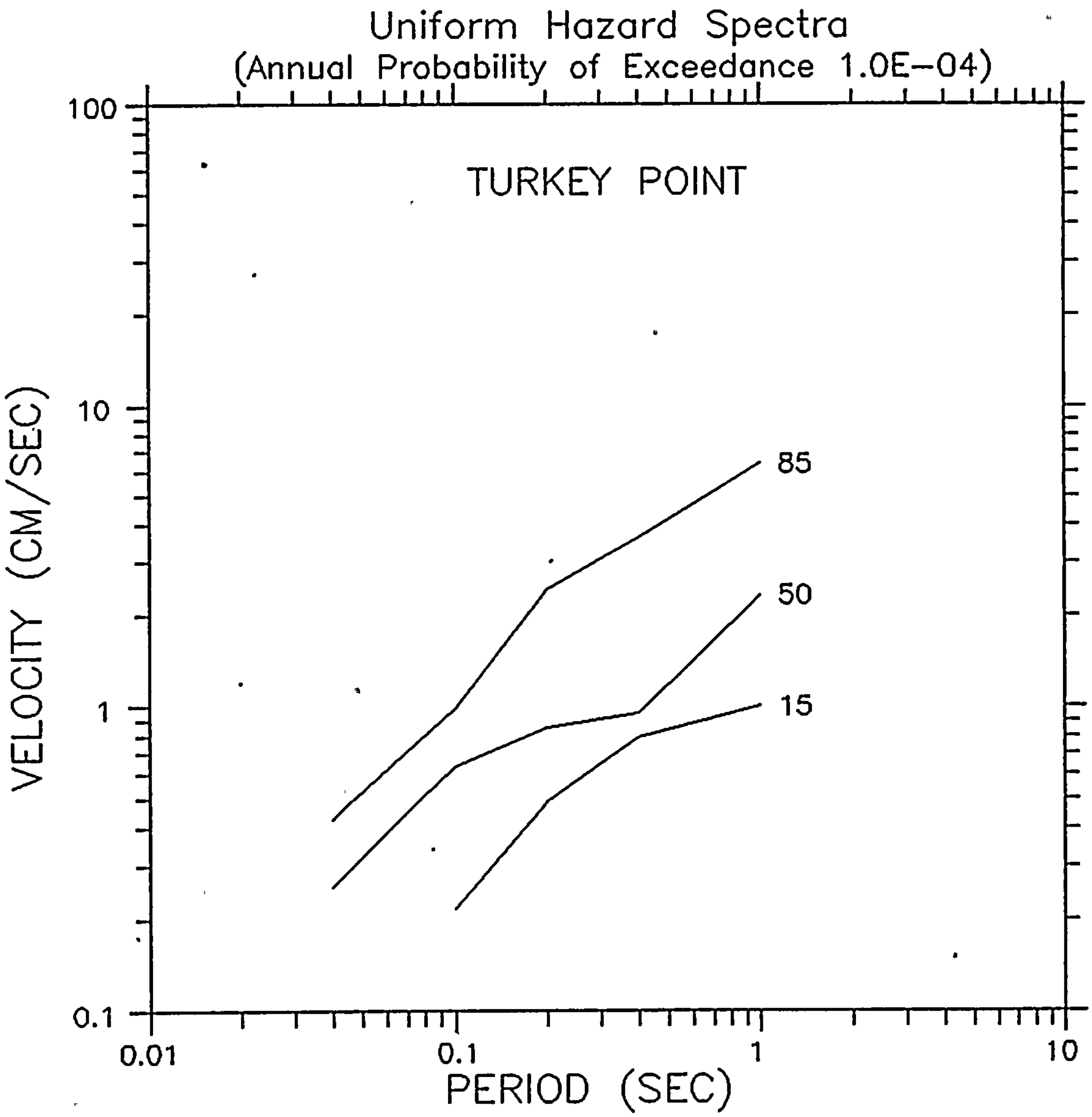

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FIGURE 20

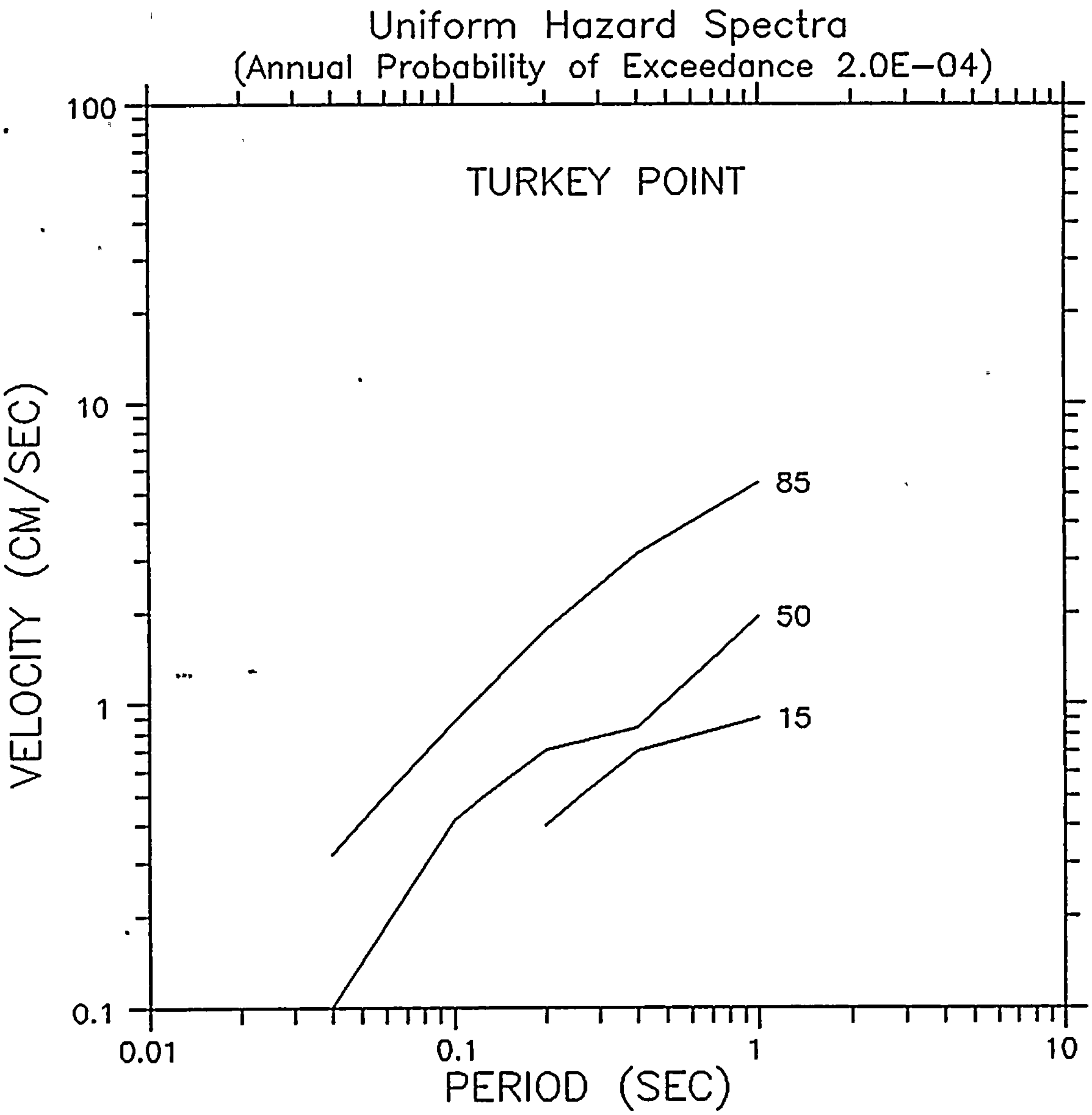

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FIGURE 21

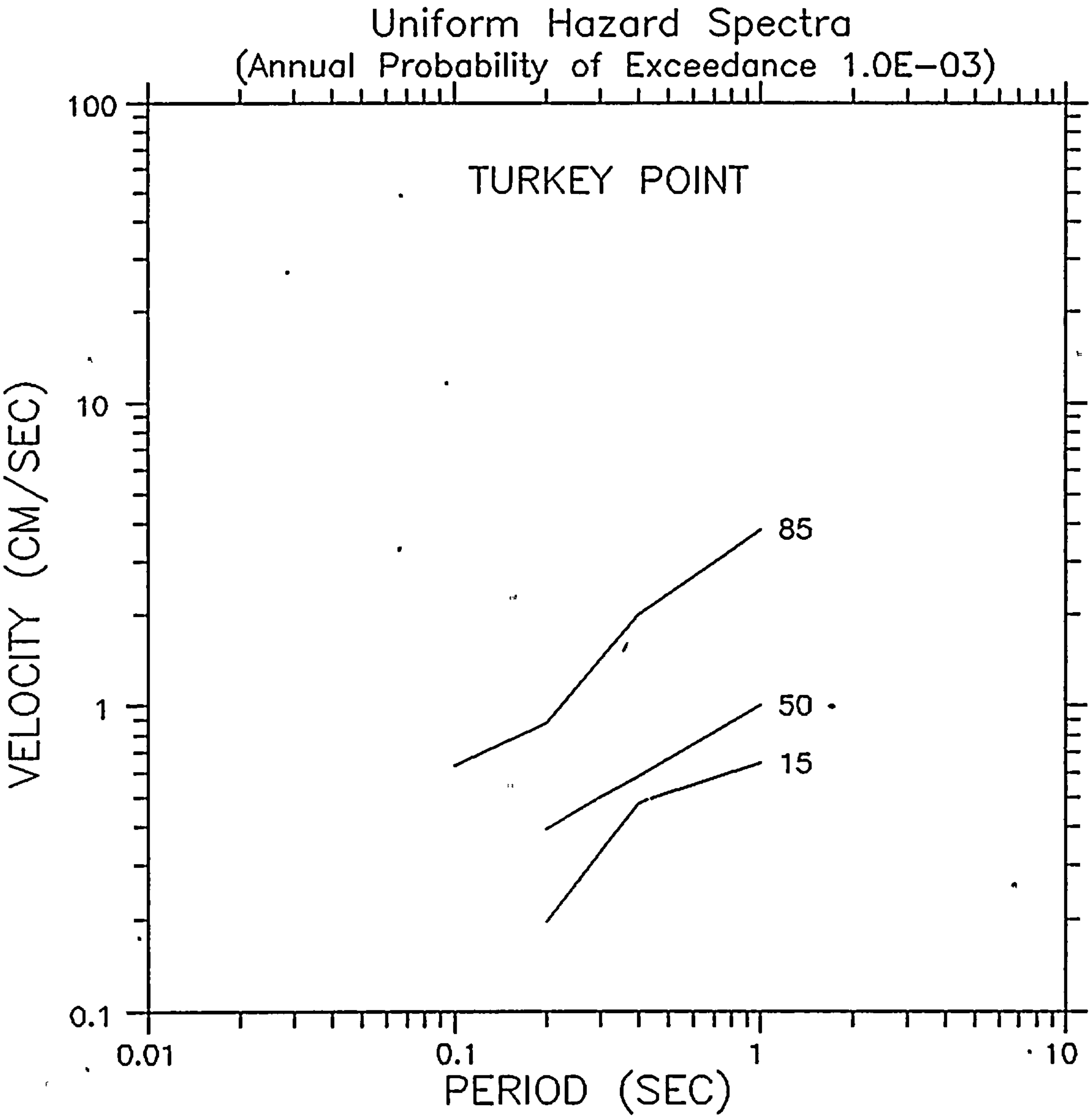

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FIGURE 22

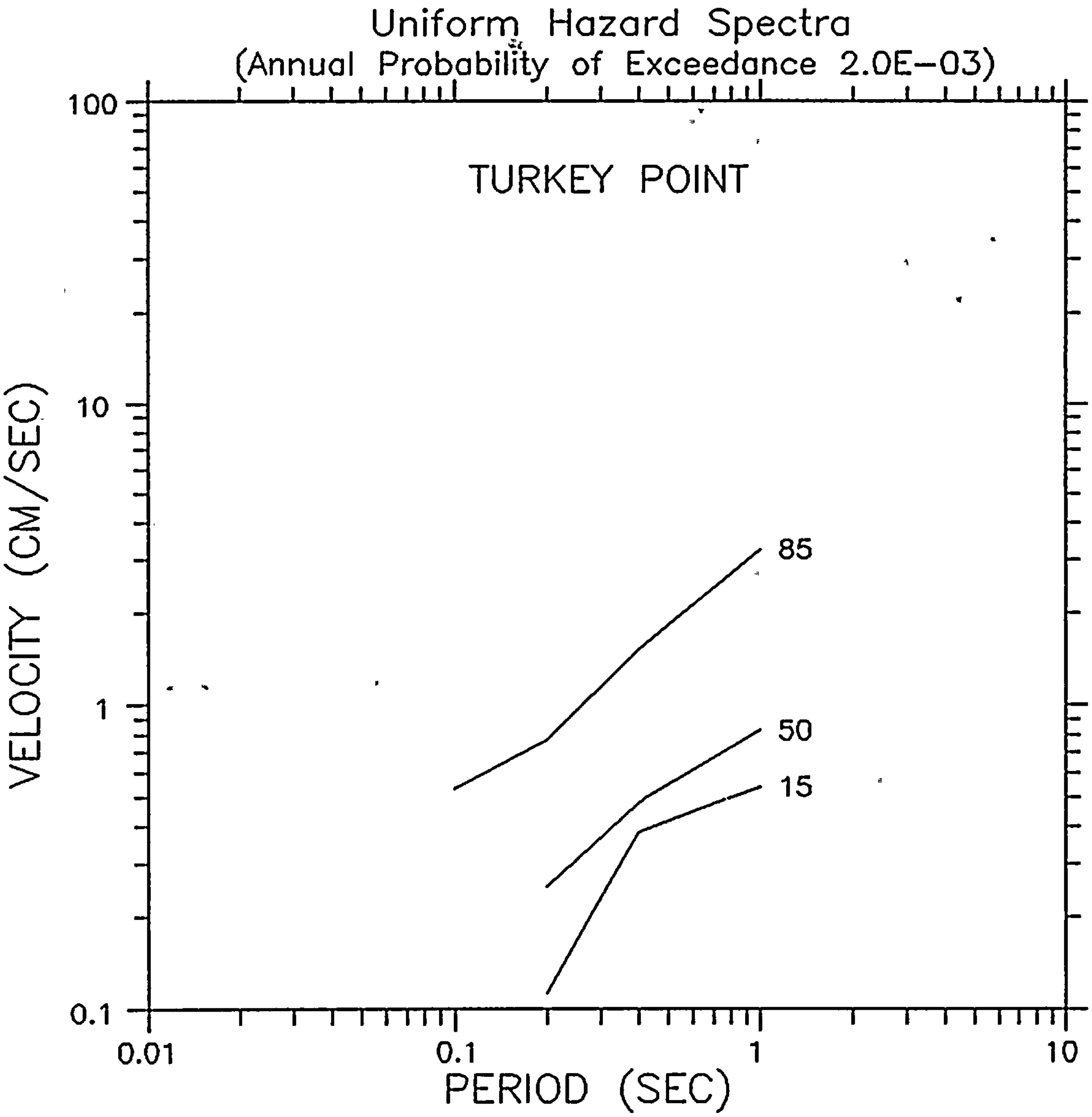

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FIGURE 23

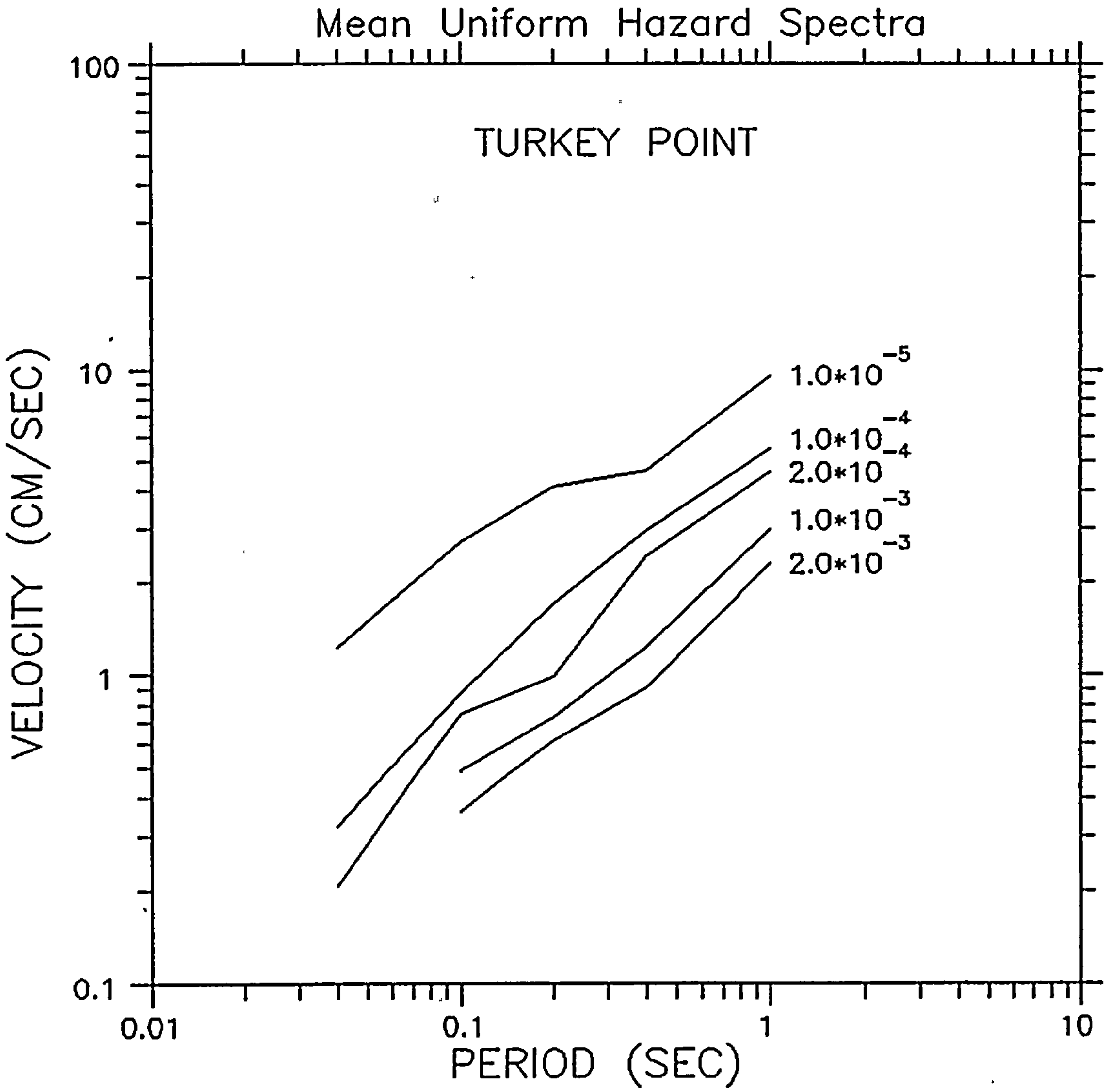

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FIGURE 24