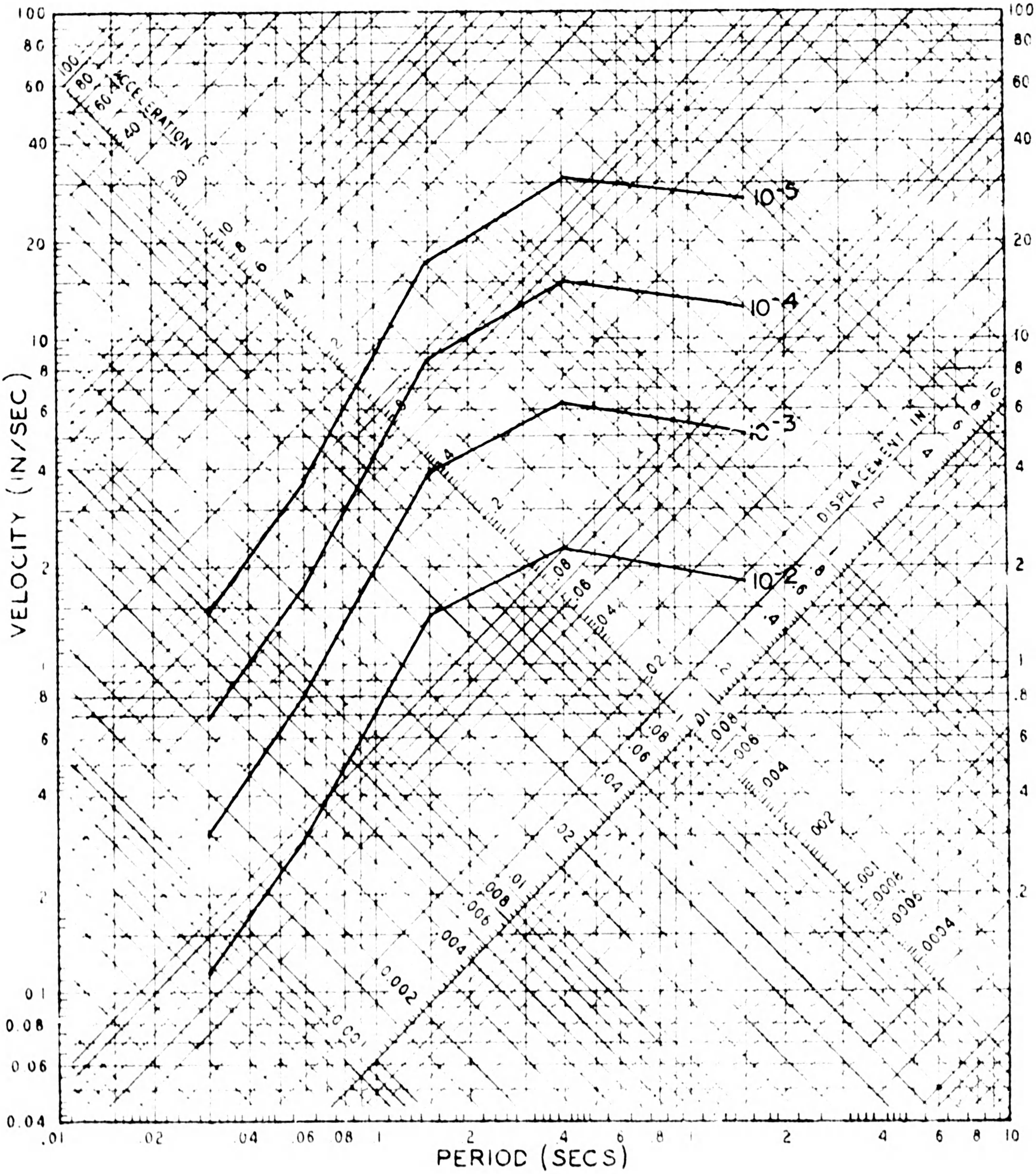
UNIFORM RISK RESPONSE SPECTRA FOR SEQUOYAH, WATTS BAR, BELLEFONTE, AND PHIPPS BEND PLANT SITES



I_{0max} - IXMM

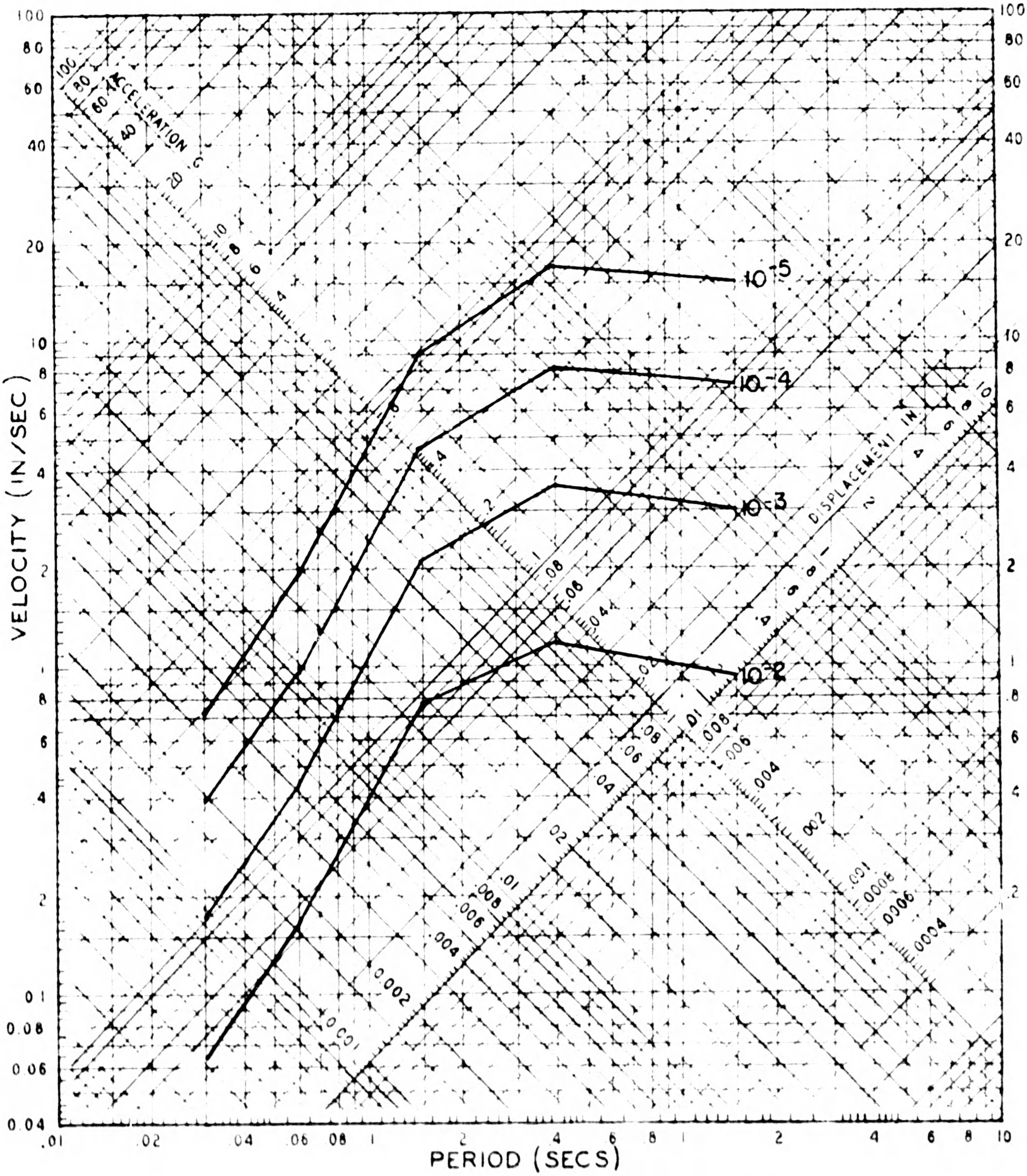
β - 1.312

DAMPING - 7%

CSC ATTENUATION

FIGURE Q6-16

UNIFORM RISK RESPONSE SPECTRA FOR SEQUOYAH, WATTS BAR, BELLEFONTE, AND PHIPPS BEND PLANT SITES



I_{0max} - VIII$_{MM}$

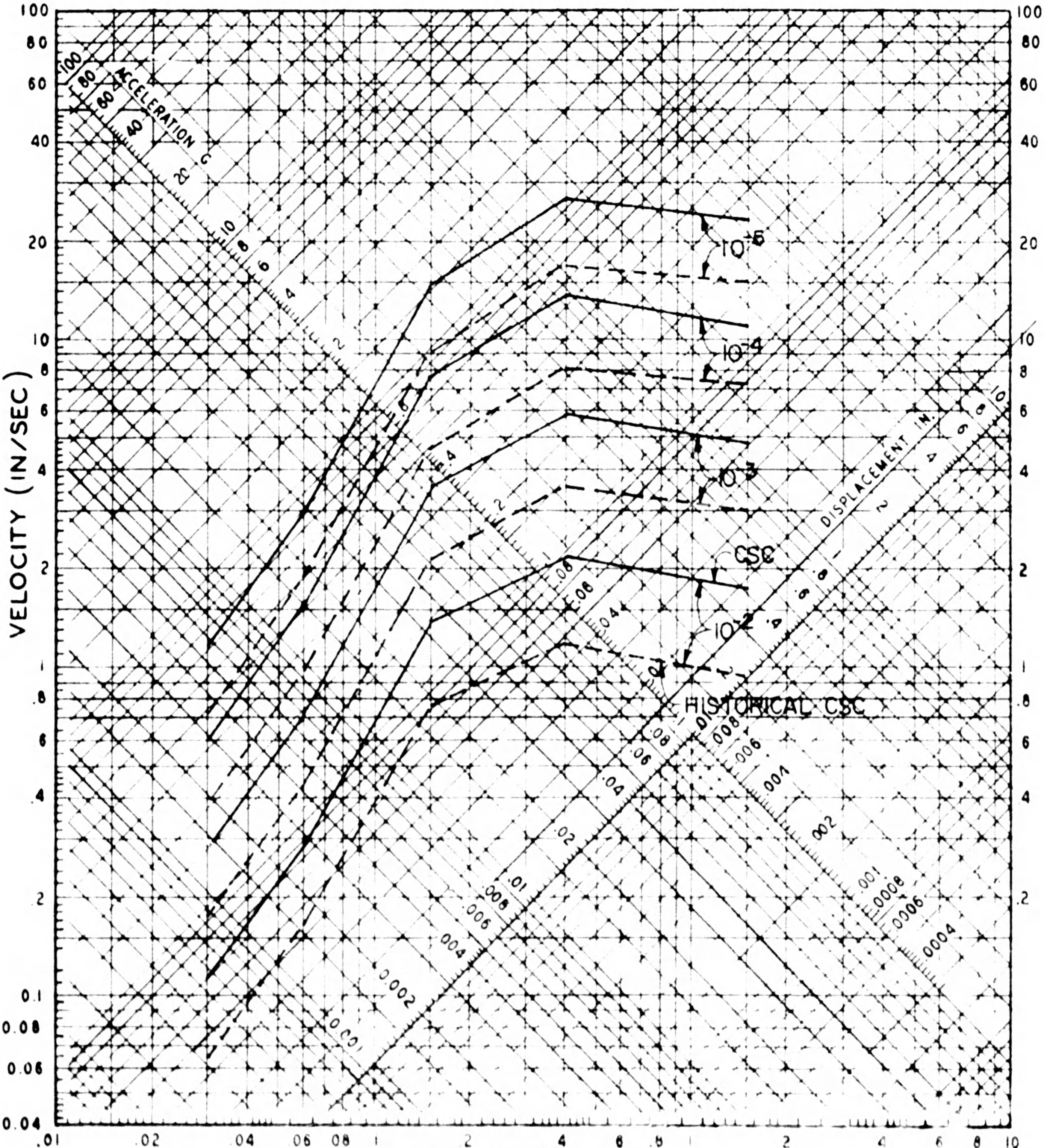
β - 1.312

DAMPING - 7%

HISTORICAL CSC ATTENUATION

FIGURE Q6-18

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA FOR CSC AND HISTORICAL CSC ATTENUATION



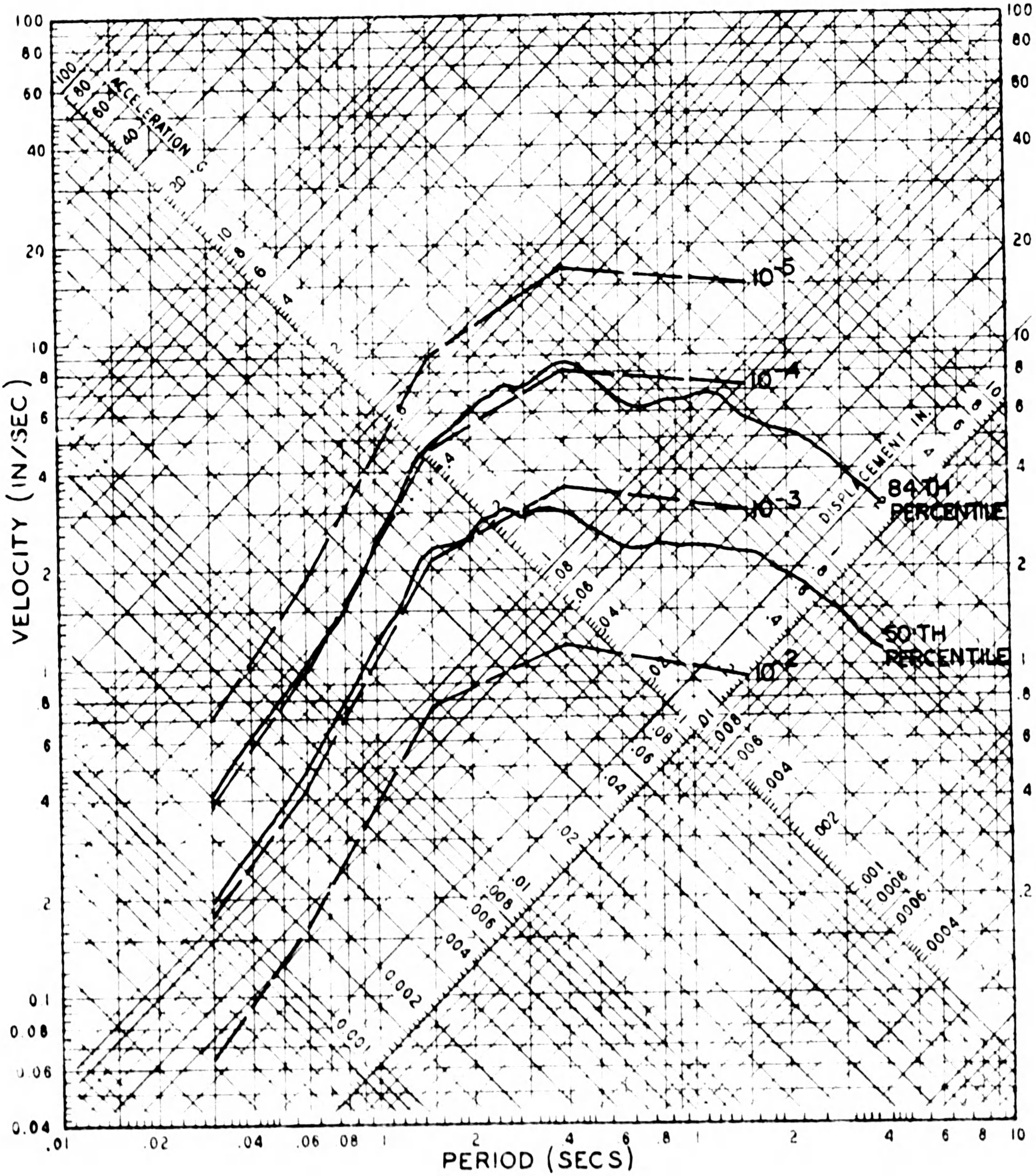
$I_{o_{max}}$ = $VIII_{MM}$

β = 1.312

DAMPING = 7%

FIGURE Q6-19

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA WITH THE 50TH AND 84TH PERCENTILE SITE SPECIFIC RESPONSE SPECTRA



I_{0max} - $VIII_{MM}$

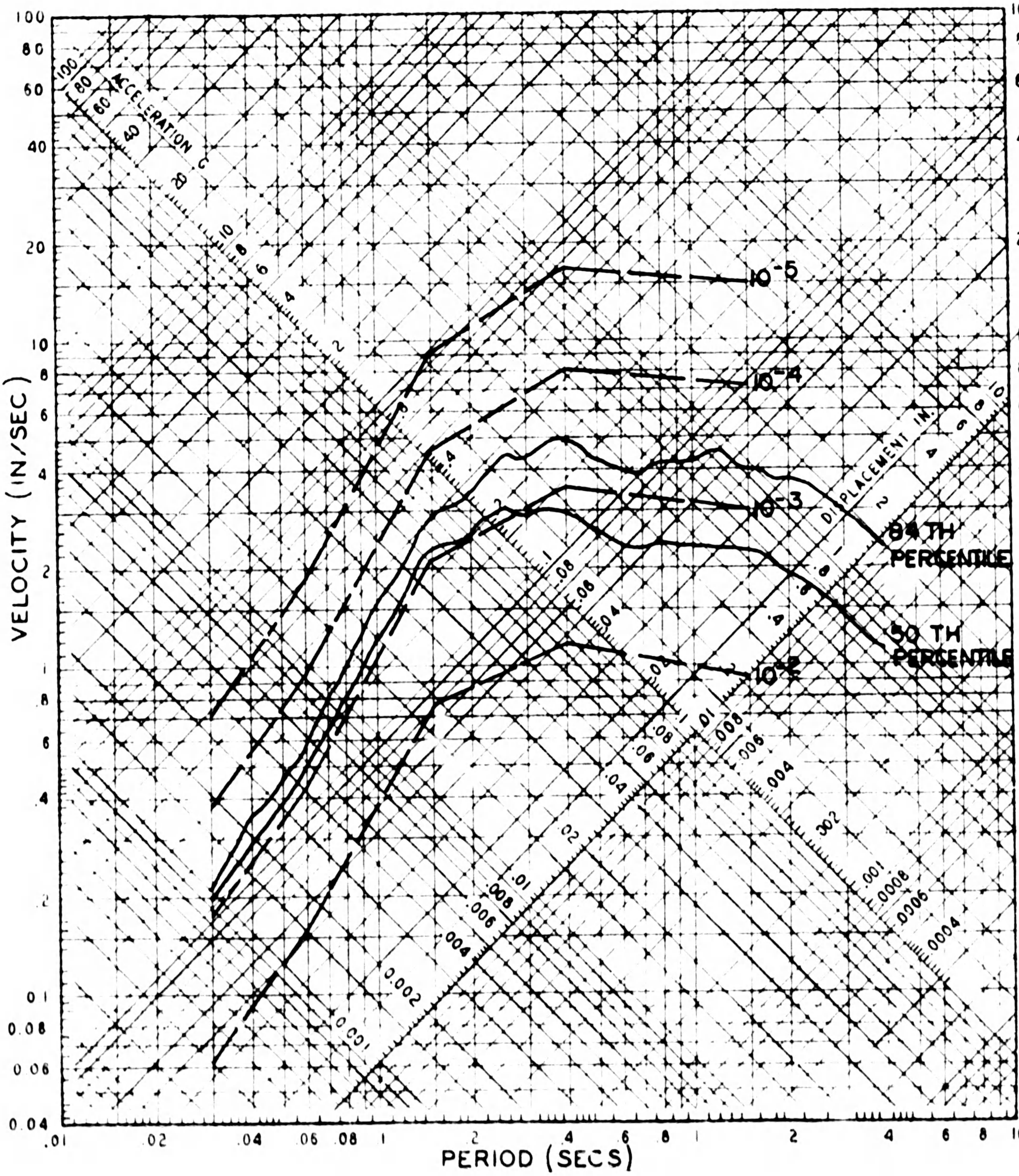
β - 1.312

DAMPING - 7%

HISTORICAL CSC ATTENUATION

FIGURE Q6-20

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA WITH THE 50TH AND 84TH PERCENTILE SITE SPECIFIC NORMALIZED RESPONSE SPECTRA



I_{0max} - VIII$_{MM}$

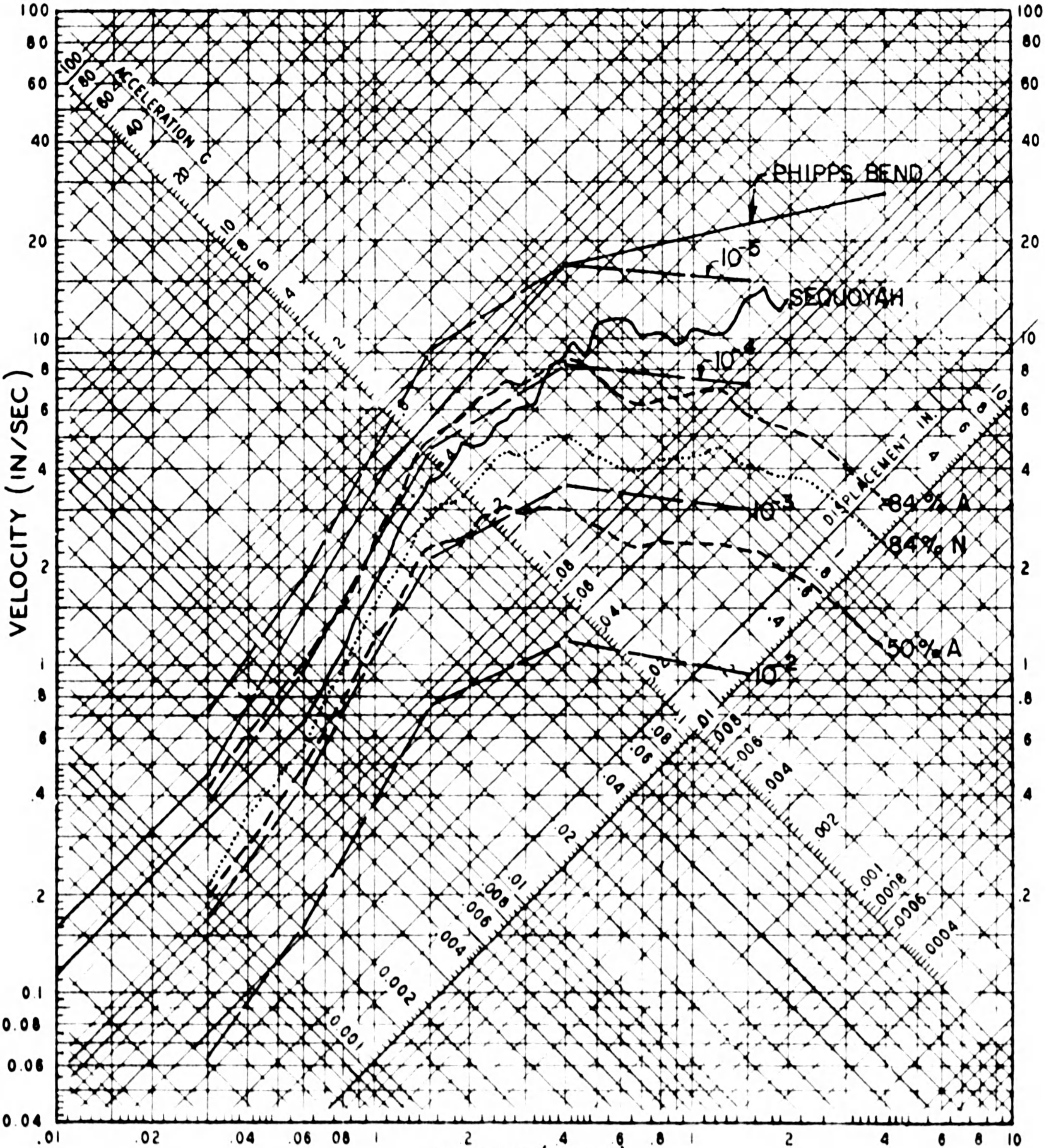
DAMPING - 7%

β - 1.312

HISTORICAL CSC ATTENUATION

FIGURE Q6-21

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA WITH VARIOUS SITE SPECIFIC SPECTRA AND THE SEQUOYAH DESIGN SPECTRUM FOR REINFORCED CONCRETE STRUCTURES



$I_{o_{max}}$ = VIII$_{MM}$

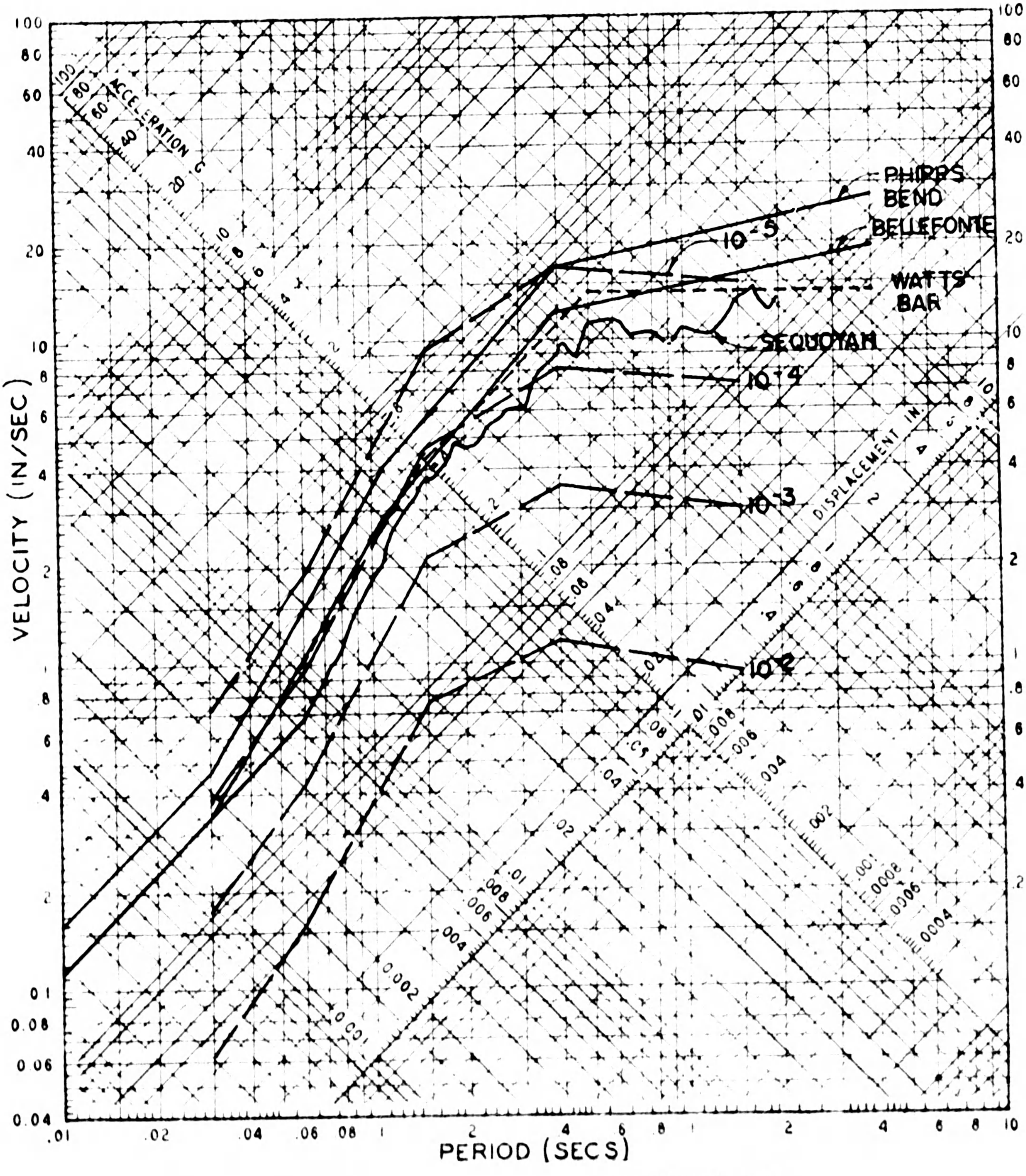
DAMPING = 7%

β = 1.312

HISTORICAL CSC ATTENUATION

FIGURE Q6-22

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA WITH THE SEQUOYAH, WATTS BAR, BELLEFONTE, AND PHIPPS BEND DESIGN SPECTRA FOR REINFORCED CONCRETE STRUCTURE



I_{0max} - VIIIMM

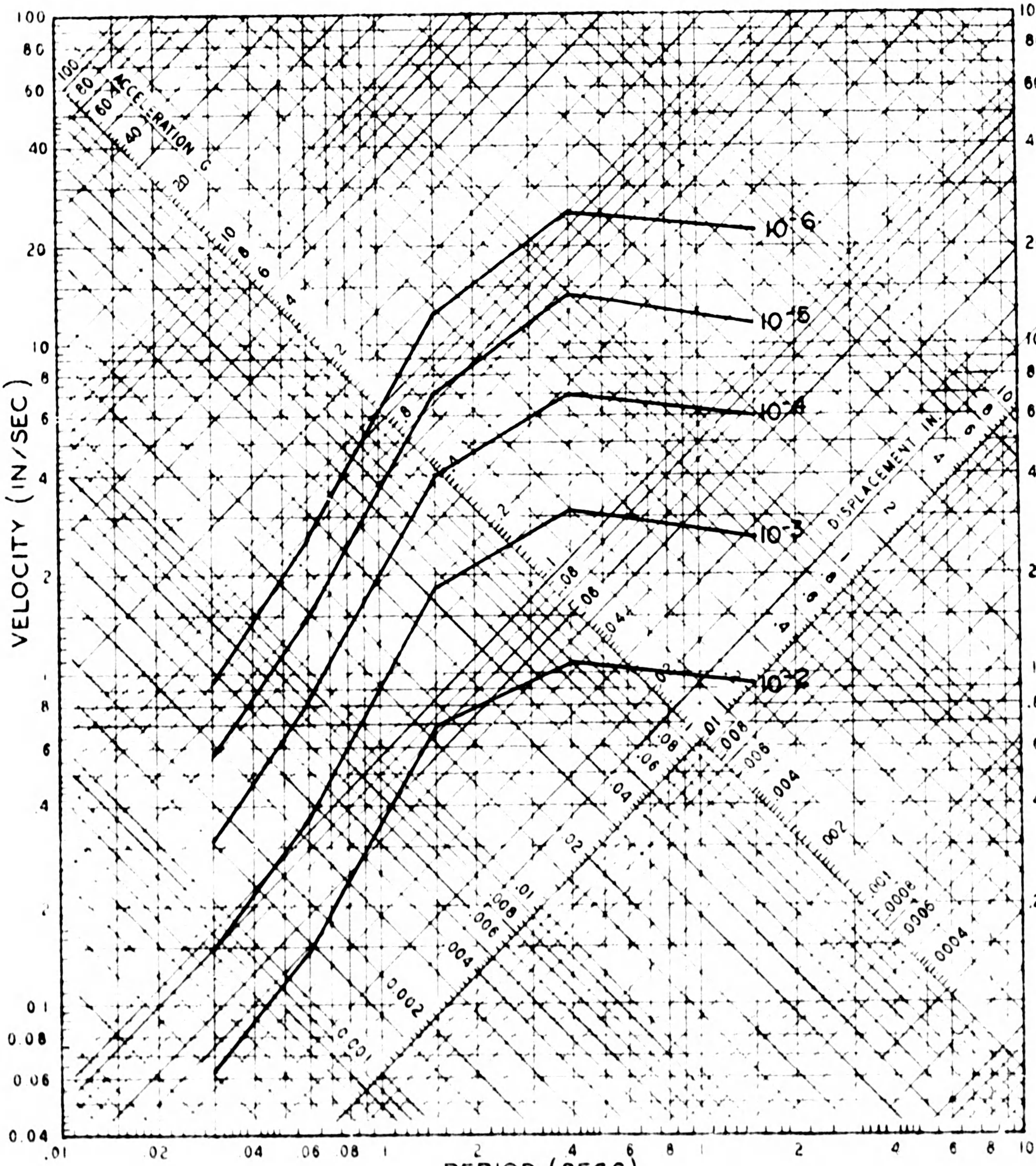
β - 1.312

DAMPING - 7%

HISTORICAL CSC ATTENUATION

FIGURE Q6-23

UNIFORM RISK RESPONSE SPECTRA FOR SEQUOYAH SITE

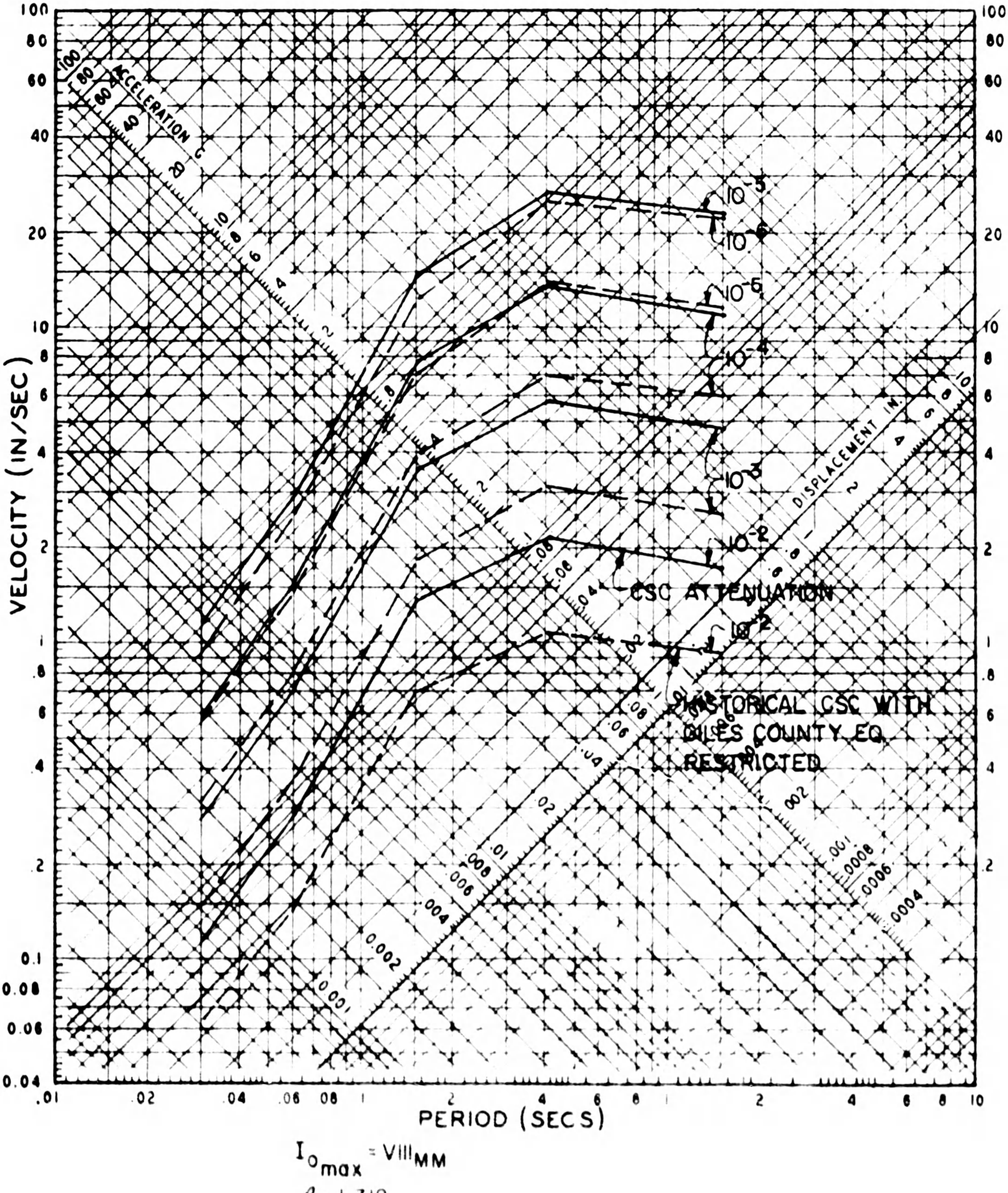


I_{0max} - $VIII_{MM}$ β - 1.312 DAMPING - 7%

HISTORICAL CSC ATTENUATION—GILES COUNTY EARTHQUAKE RESTRICTED

FIGURE Q6-24

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA FOR HISTORICAL CSC ATTENUATION WITH GILES COUNTY EARTHQUAKE RESTRICTED AND CSC ATTENUATION



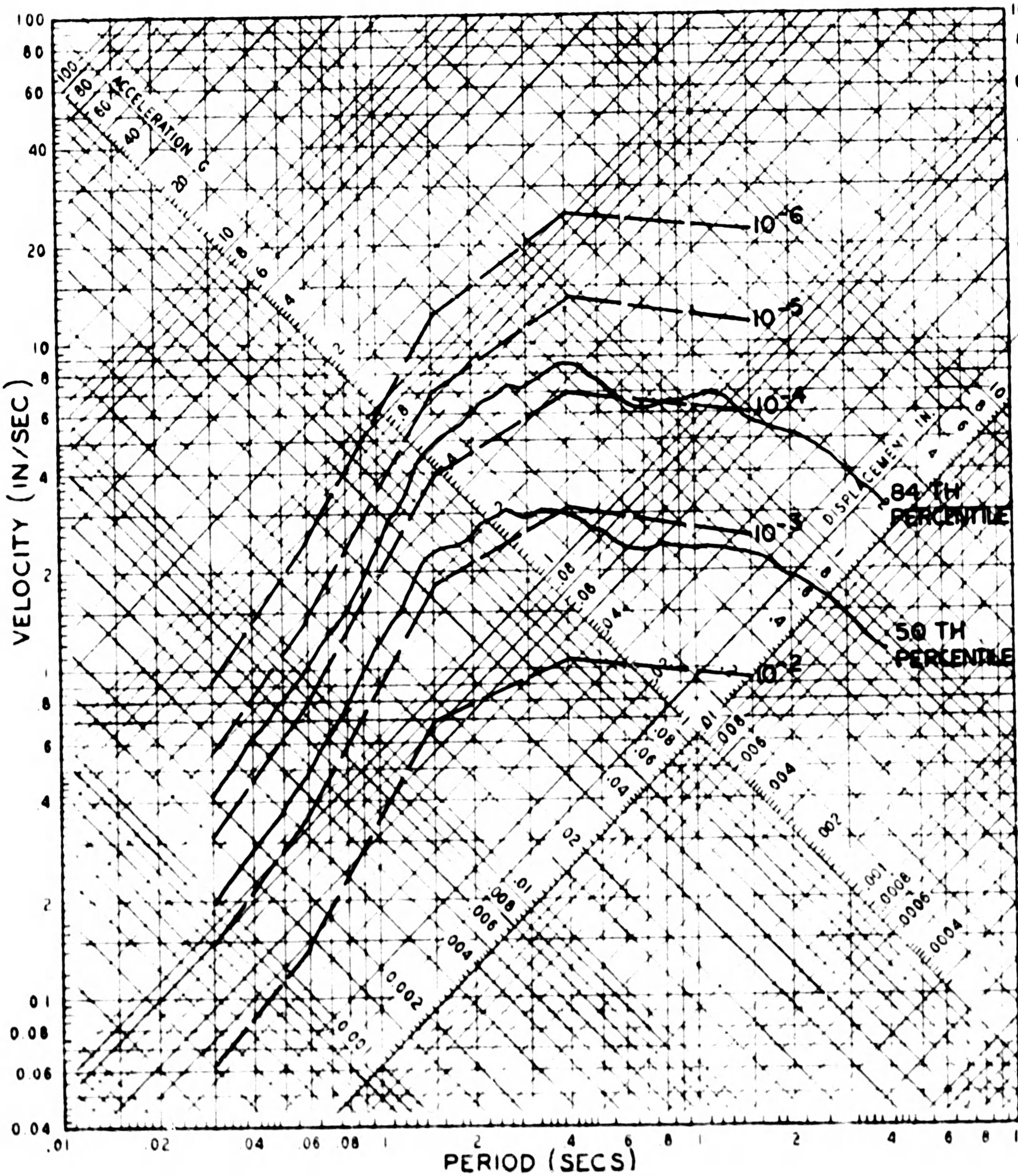
$I_{o_{max}}$ = VIII$_{MM}$

β = 1.312

DAMPING = 7%

FIGURE Q6-25

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA WITH THE 50TH AND 84TH PERCENTILE SITE SPECIFIC RESPONSE SPECTRA

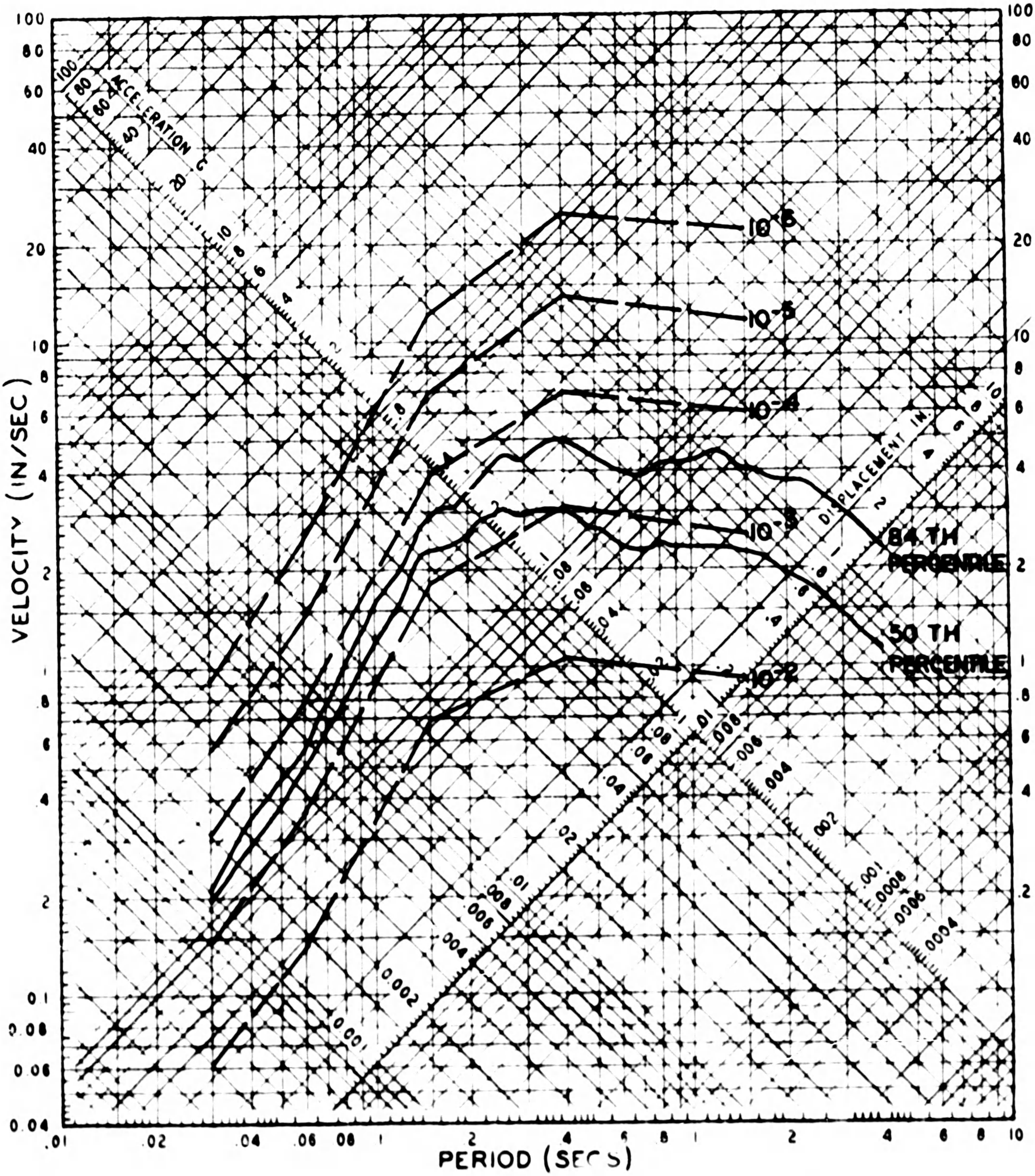


I_{0max} - VIII$_{MM}$ β - 1.312 DAMPING - 7%

HISTORICAL CSC ATTENUATION—GILES COUNTY EARTHQUAKE RESTRICTED

FIGURE Q6-26

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA WITH THE 50TH AND 84TH PERCENTILE SITE SPECIFIC NORMALIZED RESPONSE SPECTRA

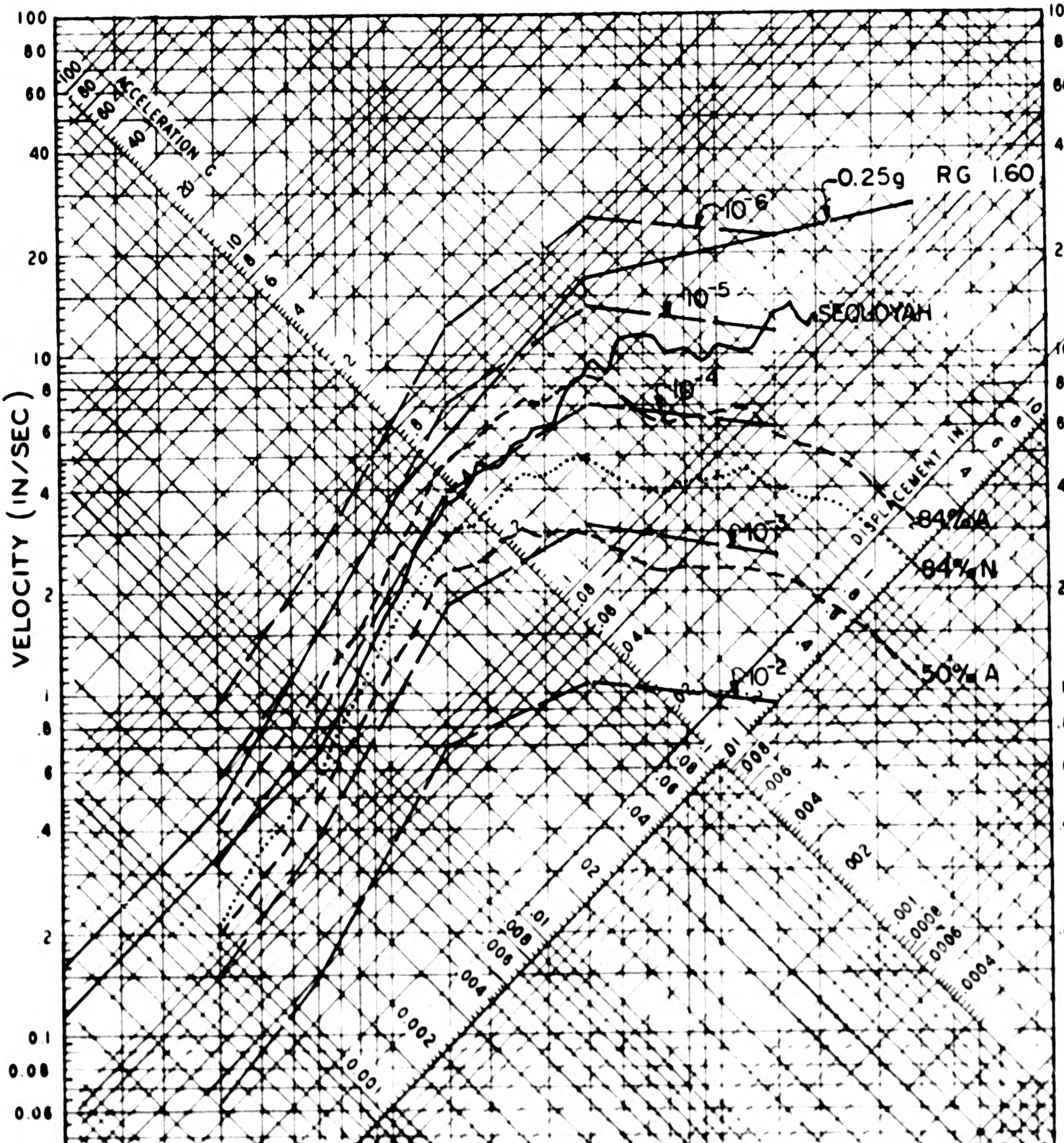


I_{0max} - VIII$_{MM}$ β - 1.312 DAMPING - 7%

HISTORICAL CSC ATTENUATION—GILES COUNTY EARTHQUAKE RESTRICTED

FIGURE Q6-27

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA WITH VARIOUS SITE SPECIFIC SPECTRA AND THE SEQUOYAH DESIGN SPECTRUM FOR REINFORCED CONCRETE STRUCTURES - GILES COUNTY EARTHQUAKE RESTRICTED



$I_{0_{max}}$ = $VIII_{MM}$ DAMPING = 7%

β = 1.312 HISTORICAL CSC ATTENUATION

FIGURE Q6-28

APPENDIX B

SUPPLEMENTS TO PHASE II REPORT

Justification of the Seismic Design Criteria Used for the Sequoyah, Watts Bar, and Bellefonte Nuclear Power Plants.

Additional Information for Phase II Report Concerning the Magnitude of the Giles County Earthquake and the Response Spectra from Strong Motion Records.

In the Phase II report, a magnitude range of 5.3 to 6.3 was used to select strong motion records on rock to represent the Giles County earthquake (discussed in section 4.6 and 4.7 of Phase II report). The average magnitude of the selected strong motion records is 5.7. The range of 5.3 to 6.3 was used based on discussions with the NRC staff and personal communication with G. A. Bollinger.

Originally, Bollinger (personal communication) used three methods to estimate the magnitude (M_b) of the Giles County earthquake. The first method using the "total felt area", resulted in a magnitude of 5.2. The second method, using the felt area of MM intensity IV, resulted in a magnitude of 5.8. The third method utilized a scaling procedure outlined by Nuttli (reference 1) using the November 9, 1968, southern Illinois earthquake. This method resulted in a magnitude of 6.2. This information was utilized in establishing the 5.3 to 6.3 magnitude range.

Recently, Nuttli, Bollinger, and Griffiths (reference 2) have performed additional studies which involved scaling from the November 9, 1968, southern Illinois earthquake. A magnitude of 5.8 for the Giles County earthquake is obtained from this scaling procedure. Hence, the most recent studies to determine magnitudes using the above mentioned methods yield magnitudes of 5.2, 5.8, and 5.8 for the Giles County earthquake. Nuttli, et al, indicate the best estimate of the magnitude is 5.8 since the felt area of intensity IV and the scaling procedure result in 5.8.

After careful examination of reference 2, TVA believes the magnitudes determined from the intensity IV felt area and the scaling procedure are conservative and the magnitude range of 5.3 to 6.3 used in the Phase II report is very conservative.

Reasons for our opinion are:

1. Nuttli, et al, question the use of the total felt area for the Giles County earthquake because of lack of data concerning the felt area (approximately 900,000 square kilometers). TVA's consultant, Weston Geophysical, performed a study (section 4.7 of Phase II report) of the total felt area. They obtained considerably more data which corroborated the total felt area used by Bollinger (Personal communication). Using the "felt area" method as previously discussed, a magnitude of 5.2 is obtained from this information. However, if the "total felt area" is arbitrarily doubled the same method yields a magnitude of 5.4. Relevant work on the southern Illinois earthquake (with an estimated "total felt area" of 1,600,000 square kilometers) yields magnitudes ranging from 5.3 to 5.5 for this earthquake.

2. As shown in figure 1, the isoseismals for the Giles County earthquake appeared to be drastically affected by the surficial geology. The isoseismals for the higher intensities are very elongated in the northeast and southwest directions along the valley. These intensities could reflect amplification of motion through the overburden in the valleys. Recorded earthquake motions have shown high amplications for thin layers of overburden (TVA Phase I report). The elongation of the higher intensities conservatively affect the magnitudes determined from the felt area of intensity IV and scaling from the southern Illinois earthquake. These elongated isoseismals are not a good indication of the magnitude of the earthquake.

Nuttli's original procedure (reference 1) used the minimum distance (reference 2) from the epicenter to the isoseismal curve in an attempt to avoid the effects of anomalous surficial geology. Nuttli's new approach (reference 2) fits the isoseismal curves by ellipses and uses the semiminor and semimajor axes to give a range of distances. He indicates the important aspect is that as long as one is consistent in defining the distances it would not make any difference. However, as shown in figure 2, it makes a great deal of difference for the Giles County earthquake.

Figure 2 shows that, for the southern Illinois earthquake, curves obtained from the minimum distance and eliptic methods are quite similar, while analysis of the Giles County earthquake, using the same methods, produces curves which differ substantially. The minimum distance for the Giles County suggests it is no larger than the southern Illinois earthquake (magnitude 5.3 to 5.5, MM intensity VII). This supports the information provided in our Phase I report which indicates the Giles County earthquake is a MM VII-VIII. Another supporting fact is that the total felt area of the southern Illinois earthquake is almost twice that of the Giles County earthquake.

The purpose of showing figure 2 is to illustrate that the elongation of the higher intensities definitely affects the scaling procedure in a very conservative manner. It is uncertain that the scaling procedure can be used to predict magnitudes of earthquakes which have isoseismals that differ substantially from the southern Illinois earthquake.

3. Figures 3 through 7 show the isoseismals for five of the central U.S. earthquake which Nuttli, et al, used in addition to the southern Illinois earthquake. These isoseismals differ greatly from those of the Giles County earthquake (figure 1). The former are fairly regular and do not reflect any specific correlation of intensity with surficial geology, except the intensity V area for the February 2, 1962, event. Also this intensity V area demonstrates the difficulty of drawing an ellipse to represent the area. Table 1 lists the central U.S. earthquake used in reference 2 with their instrumentally determined magnitude, total felt area, magnitude determined from total felt area, magnitude from the scaling procedure, and MM intensity. Both approaches give good results as long as the isoseismal shapes of the earthquakes compare favorably with the southern Illinois earthquake.

In summary, the magnitude estimates of the Giles County earthquake, as determined by the three approaches, are 5.2, 5.8, and 5.8. The 5.8 determinations are conservatively affected by the surficial geology in the northeast and southwest directions. Even so, the range calculated now from the different methods is 5.2 to 5.8. The range used in the Phase II report is 5.3 to 6.3. The twelve earthquakes (26 recordings) used in the Phase II report range from magnitude 5.3 to 6.2 with five earthquakes greater than 5.8. Therefore, the results obtained from the earthquakes are very conservative with 40 percent of the data representing a larger earthquake than the Giles County 1897 earthquake.

The mean response spectra (figures B-57 and B-58) shown in the Phase II report represent a mean assuming a Gaussian distribution. The mean of the peak acceleration of the strong motion earthquakes is 0.13 g. Figures B-57 and B-58 (Phase II report) show a comparison of the mean response spectra with the plants' design spectra. Figures A-37 and A-38 (Phase II report) show the mean, mean plus one standard deviation, and the maximum and minimum response spectra for the strong motion earthquakes. The mean plus one standard deviation spectra was not compared with the plant design spectra for the following reasons:

1. As discussed above, the magnitude range and the resulting average magnitude of the strong motion records is a very conservative definition of the Giles County earthquake. Therefore, the resulting mean response spectra are conservative and are more appropriate for comparison with the plants' design spectra.

2. The mean plus one standard deviation response spectra exceed the regulatory guidelines which are presently in effect. The present guidelines are to anchor the Regulatory Guide 1.60 response spectra to a mean acceleration value (references 3 and 4). The regulatory guide response spectra were developed by normalizing a set of strong motion records to 1.0g. From these records mean plus one standard deviation normalized response spectra were developed. These normalized response spectra shapes are then anchored to a mean acceleration of a specific site to define the design spectra.

   Examination of the response spectra, from the strong motion records used in the Phase II report show their shapes are representative of the regulatory guide spectra. Figures 8 and 9 show the regulatory spectra anchored to the mean acceleration (0.13g) of the strong motion records. Also, figures 8 and 9 show a comparison of the regulatory guide spectra with the plants' design spectra. These comparisons show the plants' design spectra are adequate.

In conclusion, TVA feels this additional information supports the conclusions drawn in the Phase II report that the Sequoyah, Watts Bar, and Bellefonte seismic design criteria are conservative and adequately ensure the health and safety of the public.

REFERENCES

1. Nuttli, O. W., "The Mississippi Valley Earthquake of 1811 and 1812: Intensities, Ground Motion, and Magnitudes," Bulletin of the Seismological Society of America, Vol. 63, 1973.

2. Nuttli, O. W., Bollinger, G. A., and Griffiths, D. W., "On the Relation Between Modified Mercalli Intensity and Body-Wave Magnitude," Preprint submitted to the Bulletin of the Seismological Society of America, 1978.

3. Nuclear Regulatory Commission, Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," 1973.

4. Nuclear Regulatory Commission, Standard Review Plan 2.5.1, "Basic Geologic and Seismic Information," 1975.

5. Nuttli, O. W. and Zollweg, J. E., "The Relation Between Felt Area and Magnitude for Central U.S. Earthquakes," Bulletin of the Seismological Society of America, Vol. 64, 1974.

6. Coffman, Jerry L. and von Hake, Carl A., 1974, "United States Earthquakes, 1972," U.S. Department of Commerce, U.S.G.S.

TENNESSEE VALLEY AUTHORITY

TABLE I

LIST OF CENTRAL U.S. EARTHQUAKES

Date	Felt Area, km^2 (1)	M_b (2) Instrumental Determination	M_b (3) Total Felt Area	M_b (2) Scaling	MM Intensity
February 2, 1962	90,000	4.3	4.5	4.0	VI
March 3, 1963	280,000	4.8	4.8	4.9	VI
October 21, 1965	420,000	4.9	4.9	4.9	VI
June 4, 1967	54,000	4.5	4.3	4.4	VI
November 17, 1970	92,000	4.4	4.5	4.4	VI
October 1, 1971	62,000	4.1	4.4	4.0	VI
*September 15, 1972	200,000	4.4	4.7	5.0	VI
*September 15, 1972	650,000 (4)	4.4	5.0	-	VI

(1) Reference 5.
(2) Reference 2.
(3) Reference 5. ($M_b = 2.65 + 0.098I + 0.054I^2$; $I \leq 6$).
(4) Reference 6.

*Two interpretations for the same event.

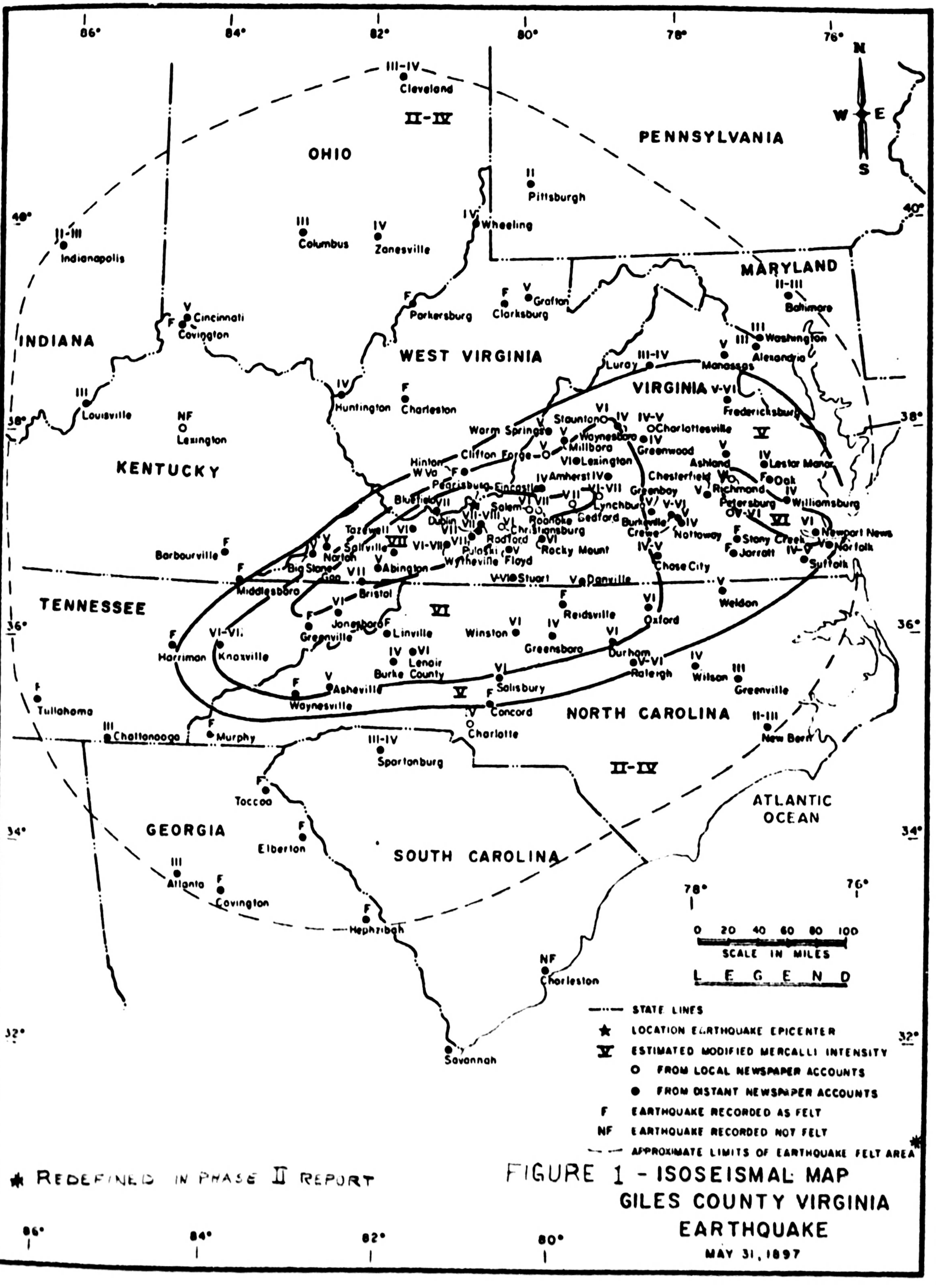


FIGURE 1 - ISOSEISMAL MAP
GILES COUNTY VIRGINIA
EARTHQUAKE
MAY 31, 1897

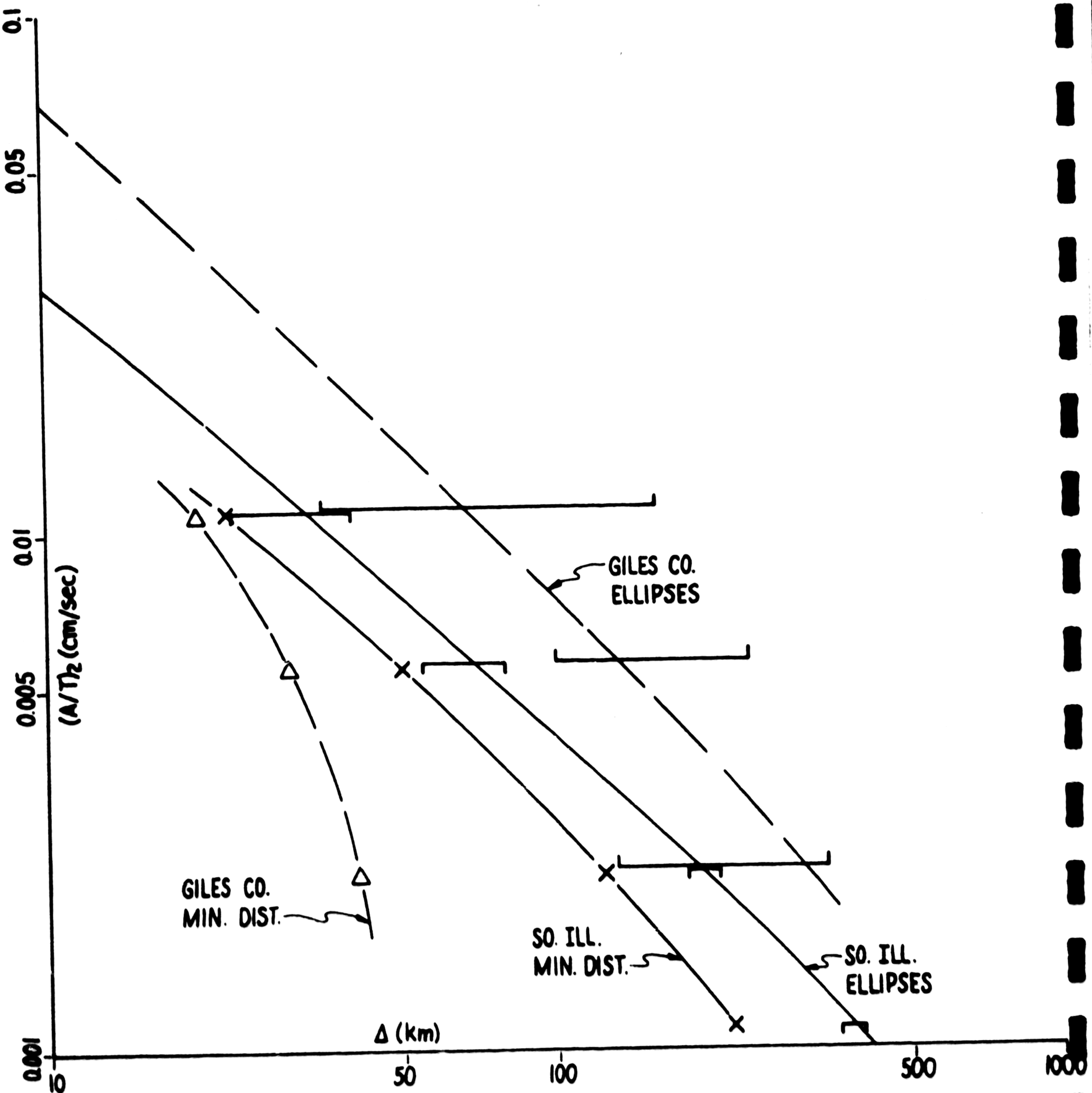


FIGURE 2 - ATTENUATION OF INTENSITY WITH DISTANCE
(AFTER NUTTLI ET AL)

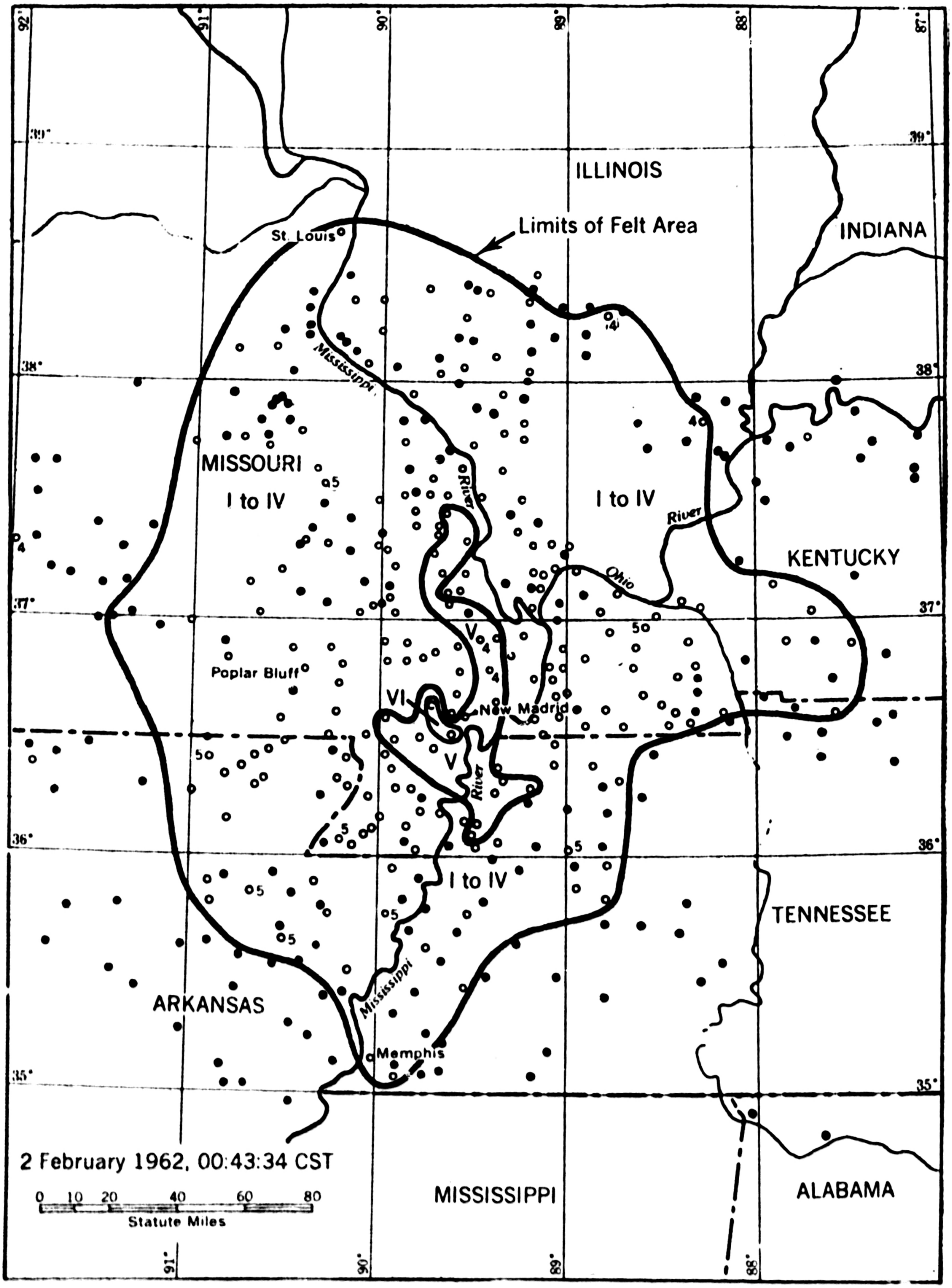


FIGURE 3 - ISOSEISMAL MAP OF FEBRUARY 2 1962 EARTHQUAKE

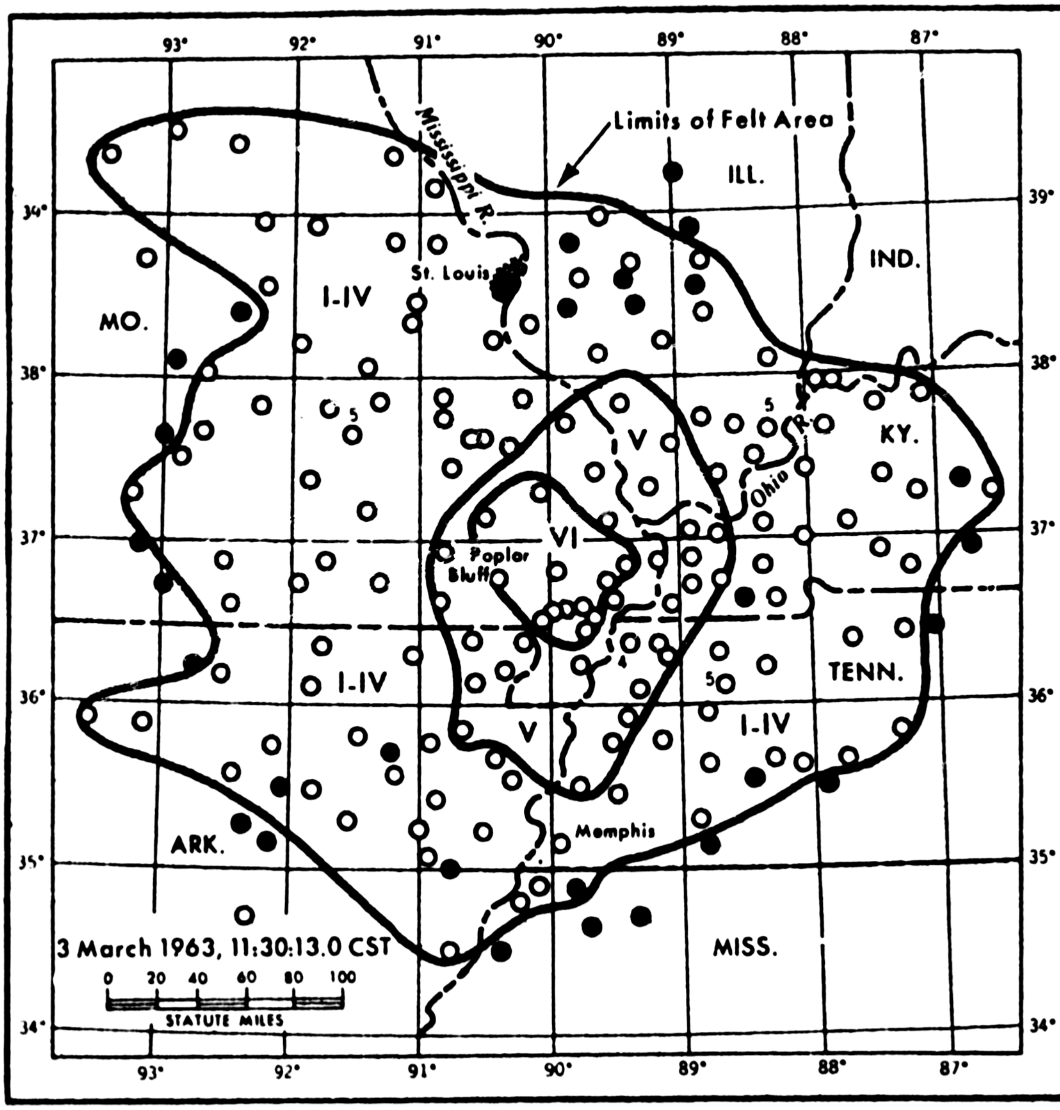


FIGURE 4 - ISOSEISMAL MAP OF MARCH 3, 1963 EARTHQUAKE

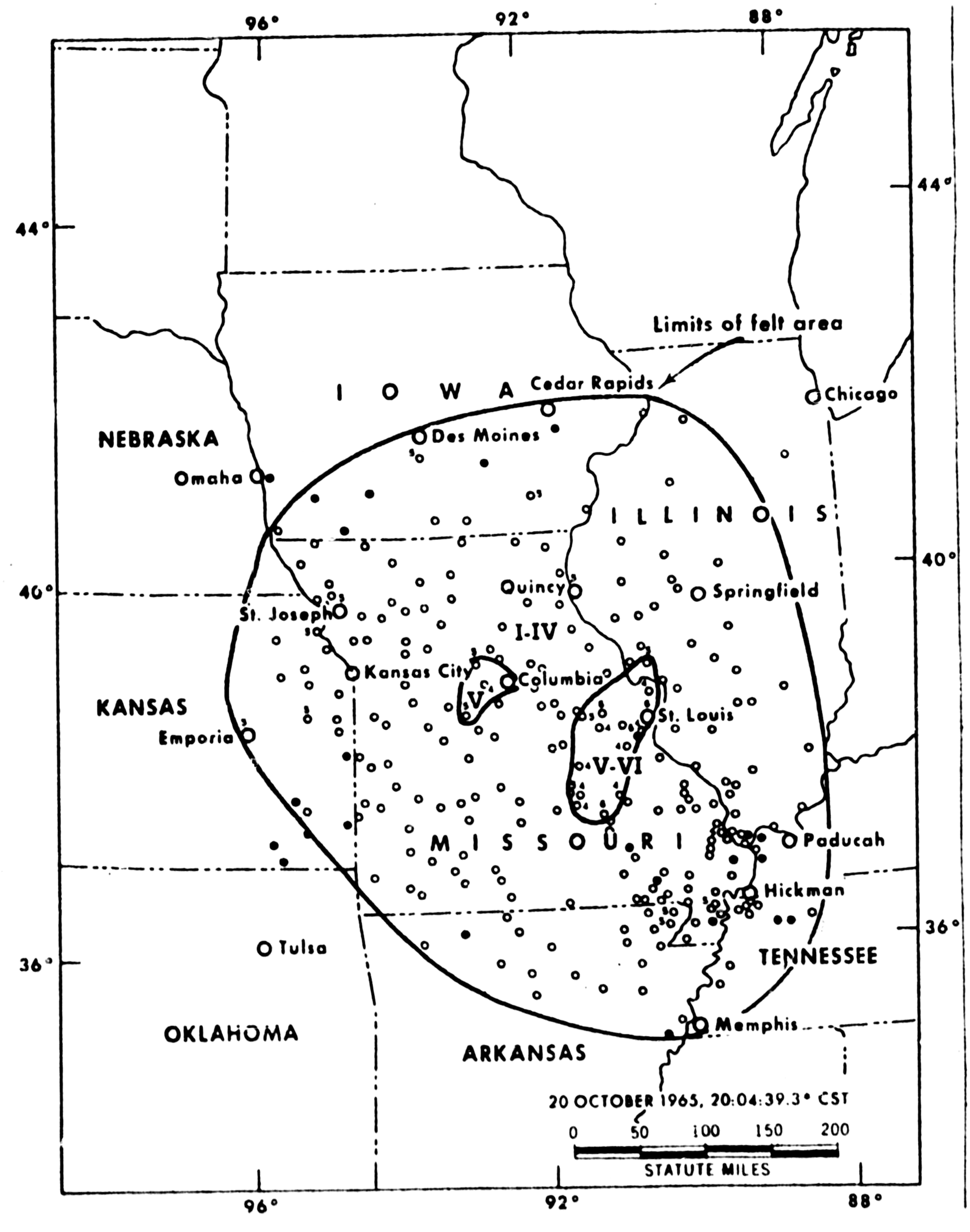


FIGURE 5 - ISOSEISMAL MAP OF OCTOBER 20, 1965 EARTHQUAKE

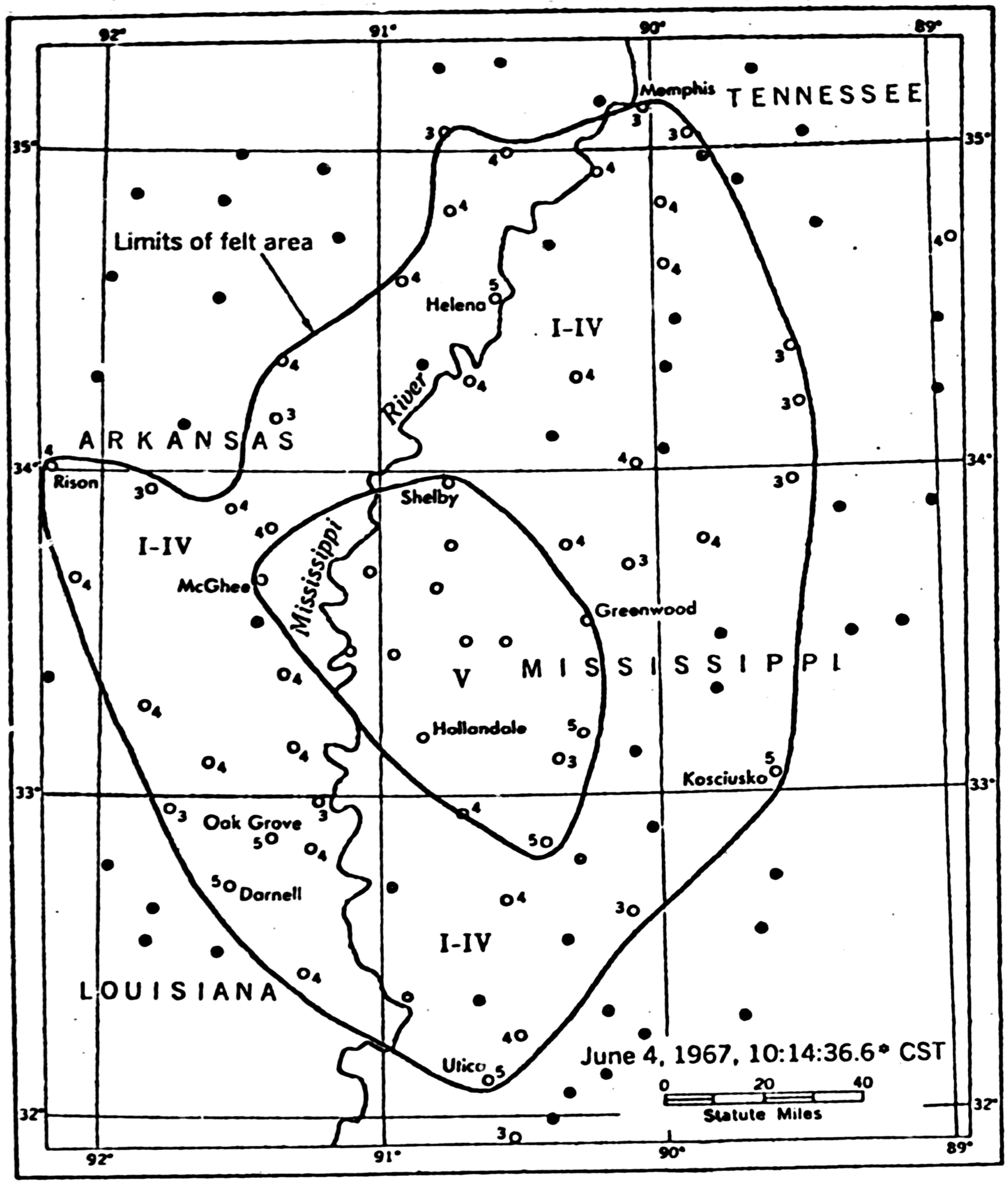


FIGURE 6 - ISOSEIMAL MAP OF JUNE 4, 1967 EARTHQUAKE

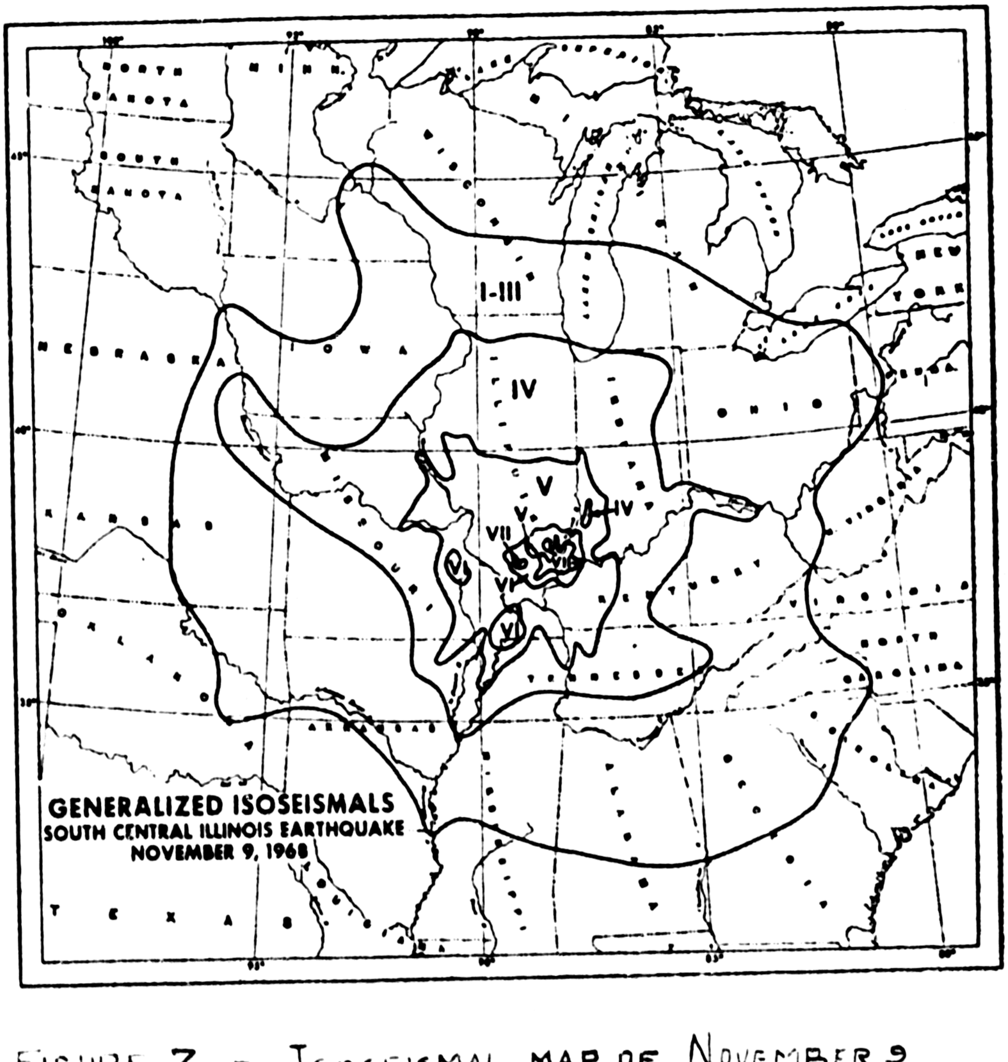


FIGURE 7 - ISOSEISMAL MAP OF NOVEMBER 9, 1968 EARTHQUAKE

COMPARISON OF SEQUOYAH, WATTS BAR, AND BELLEFONTE NUCLEAR PLANTS TOP OF ROCK DESIGN SPECTRA WITH 0.13G REGULATORY GUIDE 1.60 SPECTRUM

SEQUOYAH - 5% DAMPING
WATTS BAR - 5% DAMPING
BELLEFONTE - 7% DAMPING
REG GUIDE 1.60 - 7% DAMPING

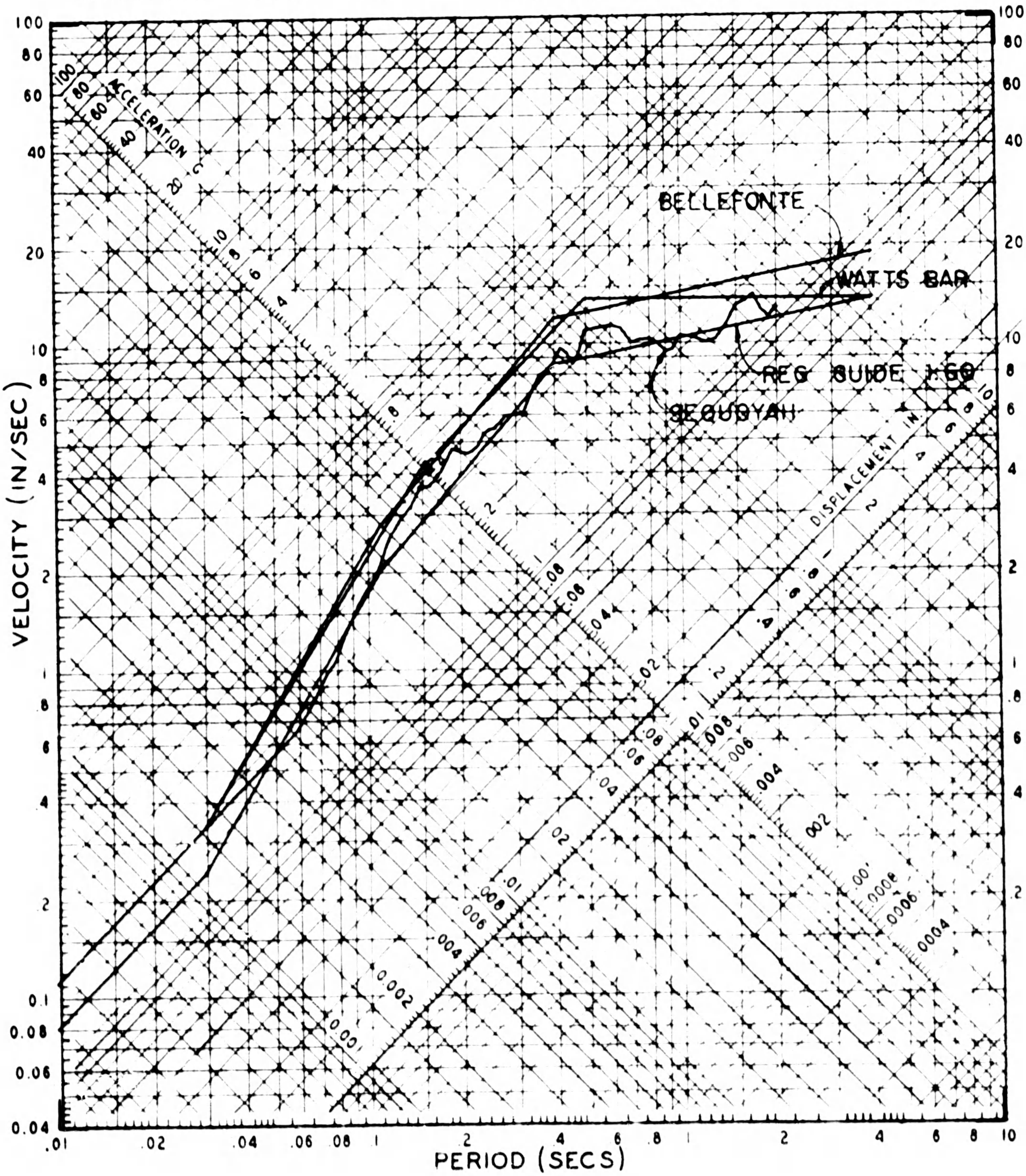


FIGURE 9

ERRATA

Page 17, first paragraph, reference should read:

"Prediction of Strong Motions for Eastern North America on the Basis of Magnitude" (reference 8).

Page 17, second paragraph - 4.0 seconds should be 4.85 seconds

Page 21, reference 8 should read:

"Prediction of Strong Motions for Eastern North America on the Basis of Magnitude. Weston Geophysical Corporation, Boston, Massachusetts, August 1978."

Table 4-4: Replace with new copy provided.

Figures 3-7, 3-8, 4-5, 4-6, A-1 through A-38, and B-1 through B-58:

The Watts Bar response spectra curves have a break point at 0.20 seconds. This should be at 0.15 seconds by extending the line from 0.50 seconds through 0.20 seconds to 0.15 seconds. The uncorrected curves result in a more conservative interpretation.

TABLE 4-4

PREDICTED MAXIMUM HORIZONTAL ACCELERATIONS

FOR SELECTED DESIGN EARTHQUAKES

m_{bLg} \ Distance	10 km Duration		15 km Duration		20 km Duration	
	4.85 Sec	2.51 Sec	4.85 Sec	2.51 Sec	4.85 Sec	2.51 Sec
5.6	.06g	.07g	.04g	.05g	.03g	.04g
5.8	.10g	.12g	.06g	.08g	.05g	.06g
6.0	.15g	.18g	.10g	.12g	.08g	.09g

APPENDIX C

JUSTIFICATION OF THE SUITE OF EARTHQUAKES USED IN THE TVA STRONG MOTION ANALYSIS

INTRODUCTION

The methodology used by the Tennessee Valley Authority (TVA) in the Phase II report submitted originally in August, 1978, to develop a site dependent response spectrum for the Sequoyah site, included the following elements based on recommendations made by the Nuclear Regulatory Commission.

1. The Gile County earthquake of May 31, 1897, an historical event with a maximum epicentral intensity VII-VIII, was considered to be best characterized as a magnitude 5.8 m_b.
2. A magnitude range of 5.3 to 6.3 was considered to be an appropriate representation of the size of the Giles Co. event. Also, this range was intended to be sufficiently broad in order to allow for an increased number of candidate strong motion records.
3. The strong motion accelerogram data base to be used in developing the response spectrum would include recordings at rock sites, at distances less than approximately 25 km for earthquakes in the magnitude range of 5.3 to 6.3.

TVA acquired 26 accelerograms that conformed to the prescribed criteria of magnitude, distance, and recording conditions. These records include 12 horizontal components recorded at 6 rock sites for 5 western United States earthquakes, and 14 horizontal components recorded at 2 rock sites for 7 Friuli, Italy, earthquakes. The average magnitude of the TVA strong motion data base was 5.7 ± 0.3 and the average epicentral distance was 15.8 $\pm$ 6.1 km.

Subsequent to the submittal of the Phase II report by TVA, it was observed that the magnitudes reported for the suite of earthquakes were local magnitudes, and a question was raised concerning the relationship of these M_L magnitudes to the m_b magnitude specified for the Giles Co. earthquake. It was also observed that average m_b magnitudes, based on observations at teleseismic distances (> 1000 km), were also available for the Friuli earthquakes and that these values were smaller than the corresponding M_L values by 0.1 to 0.6 magnitude units. These discrepancies raised the final question as to whether the suite of earthquakes used to develop the site dependent response spectrum was adequate, considering that the average m_b-Teleseismic magnitude was 0.3 to 0.4 units lower than the median value specified for the SSE.

The following discussion, which considers the initial characterization of the Giles Co. event, the magnitudes of the suite of earthquakes used by the TVA and the methods with which they were determined, and also the damage reports associated with the earthquakes, suggests that the data base used by the TVA is an adequate and conservative representation of the Giles Co. earthquake.

ESTIMATION OF THE MAGNITUDE OF THE GILES COUNTY EARTHQUAKE

Typically, in the eastern United States, the basis for the specification of design earthquakes are large historical events for which substantial or only partial intensity data is available.

Since the advent of instrumental seismology, it has been widely accepted that the size of an earthquake, or equivalently the amount of strain energy released in the earthquake process, is better characterized by an instrument-based magnitude calculation, rather than from observed damage reports. Hence, for the last few decades, earthquakes are routinely scaled by magnitude. Furthermore, since the implementation of seismographic networks, earthquake catalogs have become enriched with numerous small and microseismic events (i.e., mag < 4.0). For risk evaluation studies it has become necessary to merge the lengthier historical earthquake data base composed of moderate to large size events, characterized in terms of intensity, with the shorter instrumental data base featuring small magnitude events that have no intensity information, as well as a fairly substantial set of moderate size earthquakes for which both intensity and magnitude data are available. The effort to homogenize the earthquake catalogs has essentially revolved around estimating the magnitudes of historical events by applying empirical relationships developed using regression analysis on the more recent earthquakes for which both the magnitude and the distribution of intensity reports are known.

Initially, relationships were of the linear form, correlating magnitude with maximum epicentral intensity. These original studies indicated that there exists only a poor correlation between magnitude and maximum epicentral intensity. The poorly correlated relationships with large standard deviations of 0.5 on the magnitude inferred from maximum intensity (Nuttli, 1978), results from factors such as variation in focal depth of earthquakes, inconsistent assignment of maximum intensity, and local site response characteristics. More recently, several studies (Nuttli and Zollweg, 1974; Street and Turcotte, 1977: Nuttli, Bollinger, and Griffiths, 1978; Street and Lacroix, 1979) have correlated magnitude to parameters other than maximum epicentral intensity. Parameters that exhibit better correlations with magnitude, (i.e. standard deviations of 0.2 to 0.3 on predicted magnitude), include the total perceptible area, the area confined by the intensity IV isoseismal, or the form of the fall-off of intensity with distance curve. Using such relationships and the documented total perceptible area, and also the perceptible area within the Intensity IV isoseismal, the magnitude of the Giles Co. event is calculated to be in the range of 5.1 to 5.9. The lower magnitude results from applying equations based of the total area, while the larger magnitudes are output from the equations based on the area within the intensity IV isoseismal. The nearly 1 magnitude unit variation in these calculations may result from an underestimated total perceptible area due to a poor population distribution, or equally likely from an over estimated area confined by intensity IV, through misinterpretation of lower intensities as intensity IV. It should be noted that increasing the perceptible area of the Giles Co. event by a factor of 2., and also decreasing the area within the intensity IV isoseismal by the same factor of 2., both equations based on total area and area of intensity $\geq$ IV result in the same magnitude of m_b ~5.5.

A comparison of the felt area of the Giles Co. earthquake with more recent earthquakes which have both instrumental m_b magnitudes and isoseismal maps shows that the prescribed magnitude of 5.8m_b is conservative; the event may have a smaller magnitude by 0.5 units but in all likelihood could not be 0.5 units larger than 5.8. Table 1 lists the perceptible areas of events which also have instrumental m_b magnitudes in a comparison with the felt areas of the Giles Co. event and its inferred magnitude. This table illustrates that applying formulae relating total felt area to magnitude underestimated the instrumental magnitude for all cases by 0.2 to 0.4 units, and that equations based on area of intensity $\geq$ IV either over or underestimated the magnitudes by .1 to .3 units. For this reason, the magnitude of the Giles Co. event based on total area (5.1) is not considered to be an accurate representation.

Based on the felt areas presented in Table 1, it is concluded that the Giles Co. event is best characterized as a 5.5 ($\pm$ 0.2) m_b (Lg). The events of September 5, 1944 and November 1, 1935 with magnitudes of 5.7 m_b (Lg) and 6.0 m_b (Lg), respectively, are larger events than the Giles Co. earthquake, and thereby constitute an upper bound limit for the size of the Giles Co. event. The earthquakes of August 12, 1929 and

December 20, 1940 with magnitudes 5.2 and 5.4, respectively, are somewhat smaller events than the Giles Co. Hence, the estimation of the Giles Co. event to be a 5.5 ($\pm$ 0.2) m_b (Lg) event appears justifyable.

For the reasons presented above, the use of 5.8m_b as the median value in the range of magnitude of 5.3 to 6.3 m_b, as recommended by the NRC, to characterize an event that is likely to have a magnitude in the range of 5.3 to 5.7 m_b is conservative. Events in the higher half of the range constitute earthquakes that are significantly larger than the Giles Co. event, while events in the lower half of the range, 5.3 to 5.8, seem to be an appropriate estimate of the size of the SSE.

INTENSITIES OF THE UNITED STATES AND FRIULI EARTHQUAKES USED IN THE STRONG MOTION ANALYSIS

Additional evidence that further supports the contention that the United States and Friuli, Italy, earthquakes used in the Strong Motion Analysis conservatively represents the Giles Co. event is obtained from a comparison of the damage reports associated with the earthquakes. Table 2 lists the earthquakes and their magnitude, intensity, and a brief description of the damage reported. Based on the damage reports and cultural effects in this table, all events used in the strong motion analysis are equally large to much larger than the Giles County earthquake. This fact provides further justification of the appropriateness and conservatism of the suite of strong motion records used by TVA.

DETERMINATION OF MAGNITUDES FOR THE EARTHQUAKES USED IN THE STRONG MOTION ANALYSIS

The original tabulation of the earthquakes used in the strong motion study, which is repeated in Table 2, reported Local Magnitudes (M_L) for all events. The Friuli earthquakes reported M_L magnitudes as determined at seismograph station Roma Monte-Porzio, while the United States earthquakes have M_L magnitudes calculated at California seismological observatories at Pasadena or Berkeley. The M_L magnitude of these events conformed to the criteria of being in the range of 5.3 to 6.3; also the mean magnitude of these events of 5.7 ($\pm$ 0.3) nearly equalled the conservative size of 5.8 prescribed for the Giles County event.

Subsequent investigations into the assignment of magnitudes for the strong motion earthquakes revealed some problems. First, the strong motion earthquakes had M_L magnitudes, while the Giles County event was characterized by an m_b magnitude. Secondly, the Friuli events had m_b-teleseismic magnitudes that were lower than the corresponding M_L magnitudes by .1 to .6 magnitude units. Finally, some of the events had surface wave magnitudes, M_S, that also differed from the m_b-teleseismic and M_L magnitudes.

In order to resolve these problems, it is necessary to describe the methodology used to calculate the various types of magnitudes. The following discussion describes these methodologies.

RICHTER LOCAL MAGNITUDE - M_L

The local magnitude was originally developed by Richter (1935) to scale the size of California earthquakes. This magnitude is based on the measurement of the maximum trace amplitude, for any seismic phase or frequency, for an earthquake recorded on a standard Wood-Anderson torsion seismograph. This instrument has the standard response characteristics of 0.8 seconds natural period, 0.8 damping factor and magnification of 2800 for the periods of 0 to 0.5 seconds. The magnitude of an event is determined by comparison of trace amplitude to an arbitrarily chosen zero magnitude event which has the characteristics of maximum trace amplitude of 1 micrometer at an epicentral distance of 100 km as recorded on the Wood-Anderson seismograph.

The form of the M_L magnitude equation is:

$$M_L = \log_{10} A(\Delta) - \log_{10} A_0(\Delta)$$

Where A is the maximum amplitude on the Wood-Anderson seismogram for an earthquake of Magnitude M_L at a distance Δ. A_0 is the amplitude of the zero magnitude event.

The magnitude of the United States and Friuli, Italy, events were determined through this methodology. It should be noted that the M_L magnitude is only justifyably applied for the California region where it was developed, or for other regions where it is demonstrated that the regional seismic wave attenuation characteristics approximate that of the California region. For regions with differing seismic wave attenuation characteristics, calibration functions need to be developed and applied as corrections to the M_L calculations. Karnik (1969) describes the types of calibration functions that have been developed for the central Europe area in order to correctly calculate Local Magnitudes in this region. The M_L magnitudes for the Friuli events as reported by Procházková, Schenková, and Karnik (1979) and also listed in Table 2 are therefore accepted to be homogeneous with the M_L magnitudes of the United States events.

BODY WAVE MAGNITUDE - m_b

Body wave magnitudes are calculated from seismic phases that pass through the interior of the earth and are recorded at teleseismic distances (usually greater than 1000 km). The form of the m_b magnitude equation was defined by Gutenberg (1945) to be:

$$m_b = \log_{10} (A/T) - \bar{Q} (\Delta,h)$$

Where A/T = Amplitude to Period ratio.

$\bar{Q}$ = Calibration function based on distance and depth as well as the seismic phase used.

Due to the long distances at which m_b magnitudes are determined, significant scatter in the reported magnitudes of events has been observed. Variations in attenuation effects all along the travel path as well as lack of precise control of seismograph calibration for all the worldwide stations are responsible for the wide scatter in m_b for a given event. Table 3 lists the statistics of m_b magnitudes for the seven Friuli, Italy, events used in the strong motion analysis. This table also lists M_L magnitudes as determined from a standard Wood-Anderson seismograph at Roma Monte-Porzio. Table 3 shows that mean m_b values are lower than corresponding M_L as determined at one station. Such a comparison would be more meaningful if a similar number of M_L observations were available. The several other M_L observations for the Friuli events as recorded at other European stations (Delhaye et al, 1978) would, however, still suggest that the mean m_b magnitudes are substantially lower (by 0.4 units) than the M_L magnitude.

It should, however, also be observed that the standard deviations of the m_b magnitudes of the 7 Friuli events, assuming a normal distribution, range from 0.3 to 0.5 magnitude units. These large values indicate, that although the mean teleseismic m_b is smaller than the M_L, approximately 25% of the reporting stations had observed m_b-teleseismic magnitudes which are equal to or greater than the corresponding M_L magnitudes. Due to this fact, the size of the events, should not be evaluated based on a solitary parameter such as mean m_b-teleseismic, but rather on an evaluation of the various scaling parameters such as mean m_b, the scatter in m_b observations, M_L, M_s, and also intensity.

Relationships between the m_b and M_L have been empirically determined using the worldwide data set of earthquakes for which both types of magnitudes are available. Figure 1 illustrates that as a best estimate m_b and M_L should approximate each other (to .3 units) in the range of magnitude of interest; 5.3 to 6.3. Figure 1 also suggests that in this range m_b is slightly larger than M_L.

The anomalously low m_b values for the Friuli events is possibly attributable to a high attenuation effect in the near source region that reduced the amplitude of the body waves as they emanated from the earthquake focus. Without proper research conducted to explain the broad range of m_b-teleseismic magnitudes reported for the Friuli events, these magnitudes observed at distances greater than several thousand kilometers are not considered to be as reliable as the local magnitudes observed at distances of several hundred kilometers, for the purpose of establishing the size of the events.

Furthermore, the m_b-teleseismic magnitude, besides exhibiting large scatter in worldwide determinations, is based on a low amplitude seismic body wave that has little engineering significance, while the Local Magnitude M_L, already discussed, and the m_b based on the Lg-phase, to be described, are based on the local recording of the seismic phases responsible for damage and the felt intensity, namely maximum amplitude seismic shear waves and fundamental and higher mode surface waves in the frequency range of 1 to 10 Hz. For these reasons, the size of events should be established, for engineering purposes, on the basis of locally determined magnitudes and observed damage and intensity reports, preferentially over the more distantly determined m_b-teleseismic magnitudes.

SURFACE WAVE MAGNITUDE - M_S

Several of the Friuli events had surface wave magnitude determinations. The M_s is calculated by measuring the amplitude of 20 second period (Love and Rayleigh) surface waves recorded at long distances (greater than 2,000 km). This scale is useful for measuring the size of large, shallow events, since these are the types of earthquakes for which surface waves are well developed. The major advantage of using this scale is that there is little regional variation in attenuation of 20s waves, therefore, this magnitude is valid for all regions of the world.

Generally m_b and M_s agree at magnitude 6 3/4. Above this value, M_s is greater than m_b, while below 6 3/4, M_s is smaller than m_b.

Again it is pointed out that for the Friuli events, all of which were below 6 3/4, there exists an anomalous trend in that m_b is substantially lower than M_s, which further supports the notion of a near source attenuation of body waves which results in the reduced m_b magnitudes.

BODY WAVE MAGNITUDE FOR THE CENTRAL AND EASTERN UNITED STATES - m_b (Lg)

Nuttli (1973) developed a magnitude scale, based on the measurement of the Lg phase, which is a higher mode short period surface wave; typically the Lg is the seismic phase that has the maximum amplitude for central and eastern United States earthquakes. The equations developed by

Nuttli (1973) were empirically scaled to be equivalent to the m_b magnitude, previously described, based on teleseismically observed body waves. Data for his empirical study included four central United States events that were both recorded at local and teleseismic distances.

The impetus for developing the m_b scale for the central and eastern United States was the observation of much larger perceptible areas for similar size earthquakes in this region relative to California. This phenomenon is attributed to slower attenuation of seismic surface waves in the east. Considering this difference in attenuation, the M_L could not be justifyably applied in this region, therefore, the m_b based on the Lg phase evolved as the scale applicable in the east due to its proper dependence on the observed attenuation of this Lg phase.

A parallel can be drawn between the M_L and the m_b (Lg) magnitude scales. Both are based on measuring the maximum trace amplitude on a seismogram; in the case of m_b (Lg), the maximum amplitude sustained over several cycles of motion. For engineering purposes, this is translated into a magnitude based on the peak velocity observed at a site. These magnitudes (m_b(Lg) and M_L) are different from the m_b-teleseismic, in that the latter is not based on the phase which is a peak motion on a seismogram. The difference between m_b (Lg) and M_L, besides the fact that they are each based on the particular attenuation characteristics of the central and eastern Unites States, and California respectively, is the type of seismic phase that is employed for the calculations. The M_L is based on the maximum horizontal velocity at any frequency for any phase. The horizontal component was used since at the time of the development of the scale, a network predominated by Wood-Anderson Torsion seismographs, which record horizontal motion, was operating in California. The m_b (Lg) on the other hand is based on the vertical component of the Lg phase. The vertical component was used since in the central and eastern United States the majority of seismograph sites were equipped with vertical component short period seismometers which recorded vertical motions. Typically, the Lg at a frequency near 1 Hz. provides the maximum trace amplitude on seismograms recorded by eastern networks.

For engineering purposes, it is reiterated, that the magnitude scales based on the measurement of the maximum near source ground motion, e.g., M_L and m_b (Lg) appear to be better indicators of the size of an event, then do scales based on a distant recording of a low amplitude body wave, m_b-teleseismic, which is subjected to various and not easily defined filtering effects that modify the seismic phase over long travel paths.

SUMMARY AND CONCLUSIONS

The important aspects of the previous discussion on the adequacy of the suite of accelerograms used by TVA to represent the Giles Co. earthquake include the following:

1. A magnitude of 5.8 m_b (Lg) is a conservative assessment of the size of the Giles Co. event, when compared to more recent events for which intensity data and instrumental magnitudes are available.
2. Specification of a range of magnitudes of 5.3 to 6.3 is extremely conservative in that it can be demonstrated, using intensity data, that the Giles Co. event is not likely to be larger than 5.8, while the same intensity data may be representative of earthquakes smaller than 5.8 by a few tenths of a magnitude unit.
3. Damage reports of all the events used by TVA in the strong motion analysis are equivalent to or greater than the damage reported for the Giles Co. event to 3 intensity units.
4. M_L - magnitudes of the events used by TVA conform to the conservative range and median value prescribed for the Giles Co. event.
5. m_b-teleseismic magnitudes of the events used by TVA, determined teleseismically, are approximately 0.1 to 0.6 units smaller than M_L magnitudes. These m_b magnitudes, observed at numerous distant

stations, throughout the world, exhibit much scatter due to filtering effects in the source region, along the entire travel path, and also due to not well calibrated recording instruments. These m_b-teleseismic magnitudes based on observation of small amplitude body waves at long distance, are considered to be less useful than the local magnitude, M_L, which is based on the maximum motion, for defining the size of an earthquake for engineering purposes. It is noted that the m_b specified for the Giles Co. event is based on the central and eastern United States magnitude scale which is a measure of the maximum sustained motion of Lg phase on a seismogram; not on body waves recorded at long distances.

6. Relationships between m_b and M_L indicate that for a large data set of earthquakes for which both m_b and M_L are available, m_b approximates M_L in the range of interest, e.g. mag. 5.3 to 6.3. For this reason, it seems justified to use the M_L magnitude determinations of the United States and Friuli earthquakes to represent the size of the Giles Co. event, which is specified in terms of m_b, (based on Lg), instead of the m_b (based on teleseismic body waves), which for the case of the Friuli events exhibit large scatter, that is not adequately explained.

Based on the above it is concluded that the suite of records used by TVA in their strong motion analysis conservatively represents the size of the Giles County design basis earthquake.

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TABLE 1

MAGNITUDES AND PERCEPTIBLE AREAS OF SOME E. U.S. EARTHQUAKES

EVENT	LOCATION	PERCEPTIBLE AREAS (km^2) TOTAL(A_T)	INT. IV (A_{IV})	m_b - MAGNITUDES INSTRUMENTAL[1]	INFERRED FROM[4] A_T	A_{IV}
Aug 12, 1929	Attica, N.Y.	540,000	112,000[1]	5.2	5.0	5.3
Nov 01, 1935	Timiskaming, Can.	2,630,000	724,000[1]	6.0	5.6	6.2
Dec 20, 1940	Ossippe, N.H.	794,000	89,000[1]	5.4	5.2	5.1
Sep 05, 1944	Cornwall-Massena	1,445,000	346,000[1]	5.7	5.4	5.8
Jun 15, 1973	Quebec-Maine Border	251,000	45,000[1]	5.0	4.7	4.8
May 31, 1897	Giles Co., Va.	698,000	337,000[2]		5.1	5.8
		895,000	351,000[3]		5.2	5.8

[1] After Street and Lacroix (1979)

[2] After Law Eng. and Testing Co., Report on Evaluation of Intensity at Giles County, Virginia, Earthquake of May 31, 1897, pp. 94., 1975.

[3] After Hopper and Bollinger (1971)

[4] Using perceptible areas of reference 1, 2, 3 above and empirical relationships of Nuttli, Bollinger, and Griffiths (1978).

TABLE 2

EARTHQUAKE	MAGNITUDE M_L	INTENSITY	DAMAGE REPORTED
Giles County, Va.	5.8[1]	VII-VIII	Muddied springs; many cracked chimneys; some top chimney bricks thrown down.
Helena, Montana	6.0	VIII	Many buildings damaged in earlier event of May 18, 1935 were destroyed; 2 killed. Severe building damage; ground cracks.
San Francisco, Cal.	5.3	VII	Landslides; extensive highway pavement cracks; minor building-chimney damage; 40 minor injuries.
Parkfield, Cal.	5.6	VII	Minor surface faulting; highway pavement cracks and buckling; minor bridge damage.
Lytle Creek, Cal.	5.4	VII	Landslides; ground cracks; twisted and overturned chimneys; widespread minor damage.
Oroville, Cal.	5.7	IX	Extensive, normal surface faulting; widespread, minor structural damage. Cracked walls, chimneys; broken plaster.
Friuli, Italy May 6, 1976	6.2	X	905 killed, 2,286 injured; widespread destruction of property, utilities. Extensive surface faulting; landslides.
Friuli, Italy May 9, 1976	5.5	IX	Further destruction of previously structurally damaged buildings.
Friuli, Italy May 11, 1976	5.3	VIII	Several injured; additional structural damage.

TABLE 2 (CONT.)

EARTHQUAKE	MAGNITUDE	INTENSITY	DAMAGE REPORTED
Friuli, Italy Sept. 11, 1976 2 Shocks-4 min. apart	5.5 5.9	VIII	Several killed, injured; additional structural damage; landslides.
Friuli, Italy Sept. 15, 1976	6.1	VIII	Several killed, additional structural damage.
Friuli, Italy Sept. 15, 1976	6.0	IX	More injured, extensive structural damage.

[1] m_b magnitude, inferred from area confined by intensity IV isoseismal.

TABLE 3

BODY-WAVE MAGNITUDES OF THE FRIULI EARTHQUAKES

DATE 9176	ORIGIN TIME GMT	$\bar{m}_b$	σ	RANGE	NO. OF OBS.	M_L [1]	SOURCE [2]	REMARKS
06 May	20:00	5.96	.415	5.0-6.8	58	6.2	EDR 9-76	Max. Int. X; 6.5 M_s
09 May	00:53	5.06	.324	4.5-5.9	32	5.5	EDR-8-76	Max. Int. IX
11 May	22:44	5.24	.497	4.5-6.7	25	5.3	EDR-9-76	Max. Int. VIII
11 Sep	16:31	5.21	.357	4.6-5.9	27	5.5	EDR 15-76	"Considerable Damage"
11 Sep	16:35	5.35	.336	4.7-6.4	32	5.9	EDR 15-76	"Additional Landslides Damage"
15 Sep	03:15	5.70	.468	4.6-6.4	36	6.1	EDR 16_76	"Considerable Damage" M_s 6.0
15 Sep	09:21	5.44	.437	4.2-6.3	40	6.0	EDR 16-76	M_s 5.9

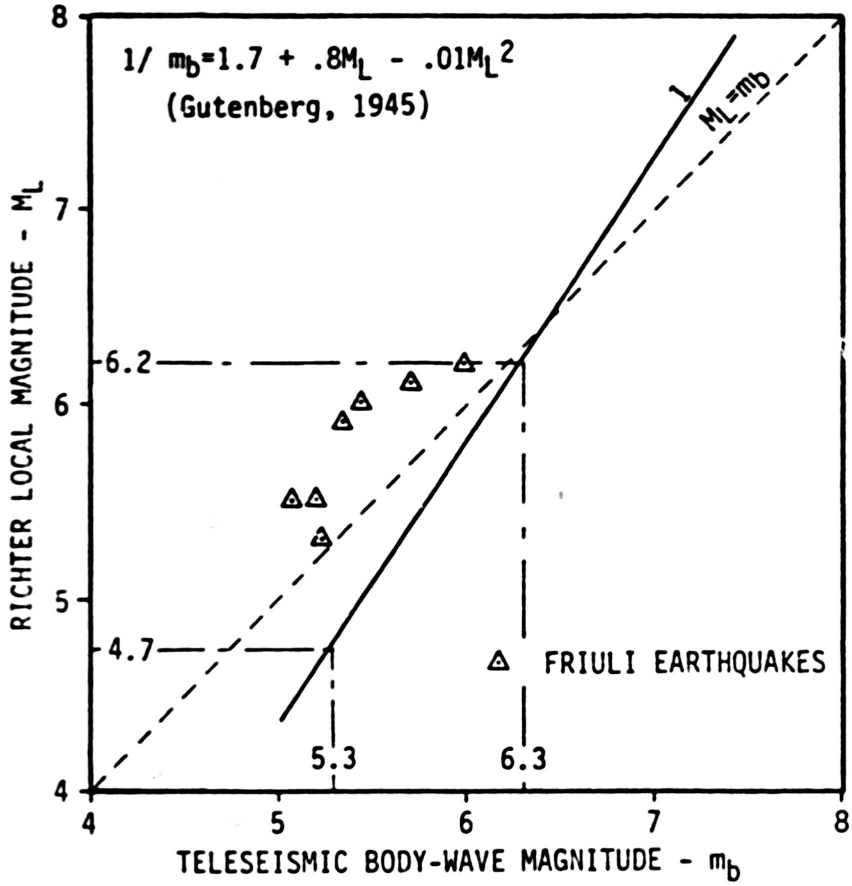
Statistical body wave magnitudes of the above seven Friuli Earthquakes at the following probability levels.

$P = .50 \quad m_b = 5.42$
$P = .84 \quad m_b = 5.83$
$P = .90 \quad m_b = 5.94$

[1] M_L Local Magnitude determined at RMP, Roma Monte Porzio Seismograph station.

[2] m_b-teleseismic data taken from Earthquake Data Reports, Geological Survey, Department of Interior.

RELATIONSHIPS BETWEEN MAGNITUDE SCALES



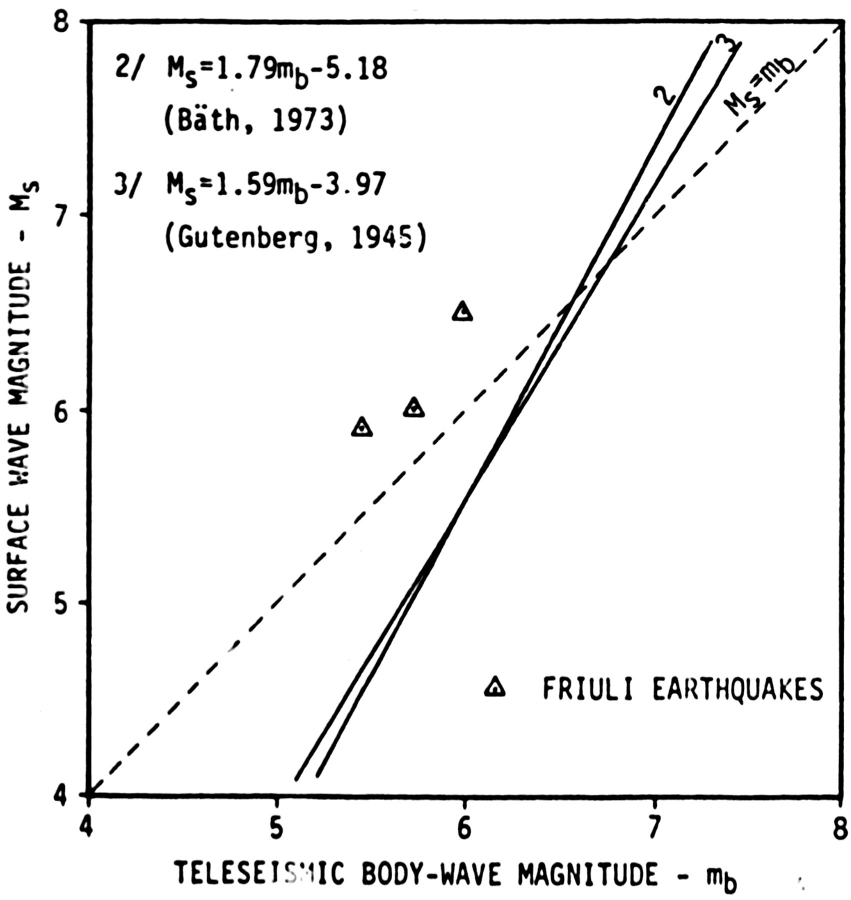


FIGURE 1

APPENDIX D

THE ACTUAL M_L AND m_b MAGNITUDES
OF AND THE EFFECTS OF VARIATIONS
IN THE SUITE OF EARTHQUAKES

The suite of twenty-six earthquake records used in developing the site specific response spectra are described in our Phase II Report. The NRC staff has commented on the use of M_L instead of m_{bLg} as the magnitude measure used to select events in the magnitude range of 5.3 to 6.3. The justification and documentation for this is contained in appendix C. This appendix is concerned with simply delineating the M_L and m_b magnitudes of the suite of earthquakes used, and the impact on statistical measures of magnitude and peak acceleration if events are deleted from, replaced in, or added to the suite of earthquakes used.

The suite of twenty-six earthquake records used to develop the site specific response spectra are listed in table D-1. Table D-1 also gives the M_L, m_b, and M_s magnitude values assigned, the epicentral distances, and peak accelerations for each event. The criteria for selecting these site specific records are:

1. Epicentral distance approximately less than 25 kilometers,
2. Magnitude (M_L) between 5.3 and 6.3, and
3. Rock site.

In addition to the twenty-six records which meet these criteria, four other records just fall beyond (on the high side) these criteria limits. These records are from the Lake Huges Nos. 4 and 9 stations (two records each) during the February 9, 1971, San Fernando earthquake. This event has a M_L of 6.4 just larger than the 6.3 limit and a m_b of 6.2 which is less than the 6.3 limit. The Pacona Dam records from the San Fernando event could be considered on this same basis but are not because the topography of the recording site is not typical or indicative of our nuclear plant sites. These events are also listed in table D-1.

Six of the original twenty-six records have m_b values less than 5.3 while their M_L values are larger than 5.3. If m_b is used to select the earthquakes rather than M_L, these events would then fall below the magnitude limit. These events are the May 9, 1976, Friuli earthquake (m_b = 5.1, M_L = 5.5), May 11, 1976, Friuli earthquake (m_b = 5.2, M_L = 5.3), and September 11, 1976, 16:31 GMT Friuli earthquake (m_b = 5.2, M_L = 5.5).

The Helena and San Francisco earthquakes have M_L values assigned but do not have m_b values assigned. The Helena earthquake of October 31, 1935, is assigned a 6.0 magnitude by Pasadena (California Institute of Technology). This 6.0 is normally reported as a M_L magnitude. The San Francisco earthquake of March 22, 1957, is assigned a 5.3 M_L magnitude by Berkely (University of California). In general the numerical values of m_b and M_L are approximately equal. A m_b for Helena would most likely fall within the stated range and a m_b for San Francisco may or may not. Thus, San Francisco is considered as a candidate for deletion if the selection criteria is based on m_b. Also, for calculation purposes in table D-2, the values of m_b and M_L are assumed to be equal for these events.

The impact of deleting, replacing, or adding records to the suite of earthquakes is given in table D-2. The resulting range of actual magnitude, average magnitude (based on normal distribution), and 50th and 84th percentile peak accelerations (based on lognormal distribution) for various permutations of the original twenty-six records and four possible additional records are enumerated in table D-2. The impact of these possible changes is not significant.

Combining the results presented in table D-2 and the results of the sensitivity study given in our response to questions 3 and 4, TVA concludes the original suite of earthquake records are representative of the desired site specific event.

There is no need to alter the suite of earthquakes to make it more representative. Indeed, the possible changes considered above would make the set an even more conservative representation of the 1897 Giles County, Virginia earthquake.

TABLE D-2

VARIOUS EARTHQUAKE COMBINATIONS AND THEIR AVERAGE MAGNITUDES AND 50TH AND 84TH PERCENTILE PEAK ACCELERATIONS

Case	Number of Records	Magnitude M_L Range	Magnitude M_L Average	Magnitude M_b Range	Magnitude M_b Average	Peak Acceleration (g), Percentile 50th	Peak Acceleration (g), Percentile 84th
Original 26	26	5.3-6.2	5.7	5.1-6.0	5.5	0.10	0.22
Original 26 -Fruili 054, 063, 132	20	5.3-6.2	5.8	5.3-6.0	5.6	0.14	0.24
Original 26 -Friuli 054, 063, 132 -San Francisco	18	5.4-6.2	5.8	5.3-6.0	5.6	0.14	0.25
Original 26 -Fruili 054, 063, 132 + Lakes Huges Nos. 4 and 9	24	5.3-6.4	5.9	5.3-6.2	5.7	0.14	0.23
Original 26 -Friuli 054, 063, 132 -San Francisco + Lake Huges Nos. 4 and 9	22	5.4-6.4	5.9	5.3-6.2	5.7	0.14	0.24
Original 26 + Lake Huges Nos. 4 and 9	30	5.3-6.4	5.8	5.1-6.2	5.6	0.11	0.21

which the largest historical earthquake is assumed to reoccur "at the site" of the plant. This approach is the most conservative approach defined by the guidelines of 10 CFR Part 100, Appendix A. In attempting to resolve the NRC concerns with the seismic design bases, TVA performed several major studies. From these studies TVA concludes:

1. The Giles County event (the controlling event in the applicable tectonic province) is overrated and soil biased. The differences between soil and rock sites and the reduction of acceleration with depth should be considered when using this event in developing the plants design spectra.
2. For converting site intensity to ground acceleration, we consider the Murphy-O'Brien intensity-acceleration relationship as the most appropriate.
3. The present design spectra are acceptable when compared to various site specific spectra developed either from site specific records or on the basis of magnitude. These comparisons show the plant spectra envelop the magnitude spectra and the normalized 84th percentile spectra from site specific records and falls between the actual 50th and 84th percentile spectra from the site specific records. We conclude the plant spectra are acceptable.
4. Based on field studies, Sequoyah is a relatively quiet site and has low response characteristics. Thus, it is overly conservative to automatically impose an 84th percentile philosophy when selecting an acceptable percentile level for the site specific spectra. The selected percentile level should either be the 50th percentile or possibly a value between the 50th and 84th percentile. Thus, we conclude the plant spectra are acceptable.

5. Extensive probabilistic analyses were performed to determine uniform risk response spectra. Based on these analyses, TVA concludes the probability of exceedance for the OBE and SSE design spectra is acceptable.

6. Based on a regional geophysical-geological study, TVA concludes there is sufficient evidence to show that the 1897 Giles County, Virginia earthquake should not be migrated to the Sequoyah, Watts Bar, or Bellefonte plant sites. We feel this adds one more level of conservatism since we believe the plant design spectra are acceptable based on the other evidence presented.

Based on the results of all the studies and investigations submitted, TVA concludes the seismic design bases used at Sequoyah, Watts Bar, and Bellefonte are conservative and adequately ensure the health and safety of the public.

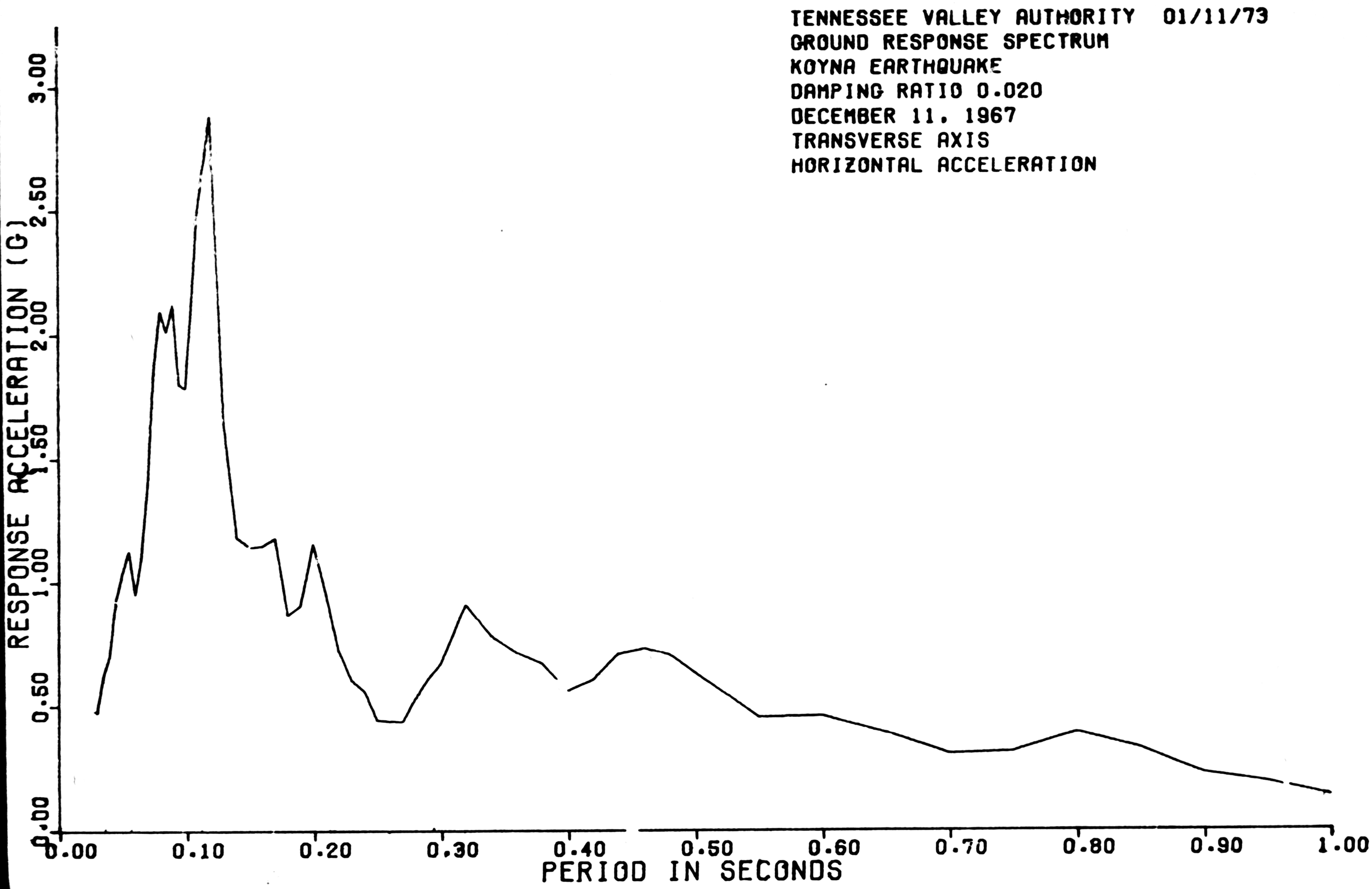

TENNESSEE VALLEY AUTHORITY 01/11/73
GROUND RESPONSE SPECTRUM
KOYNA EARTHQUAKE
DAMPING RATIO 0.020
DECEMBER 11, 1967
TRANSVERSE AXIS
HORIZONTAL ACCELERATION
RESPONSE ACCELERATION (G)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
PERIOD IN SECONDS

FIGURE Q2-1

MAXIMUM, MINIMUM, 16TH, 50TH, AND 84TH PERCENTILE RESPONSE SPECTRA FOR THIRTEEN UNITED STATES AND ITALY EARTHQUAKES
LOGNORMAL DISTRIBUTION- 7% DAMPING

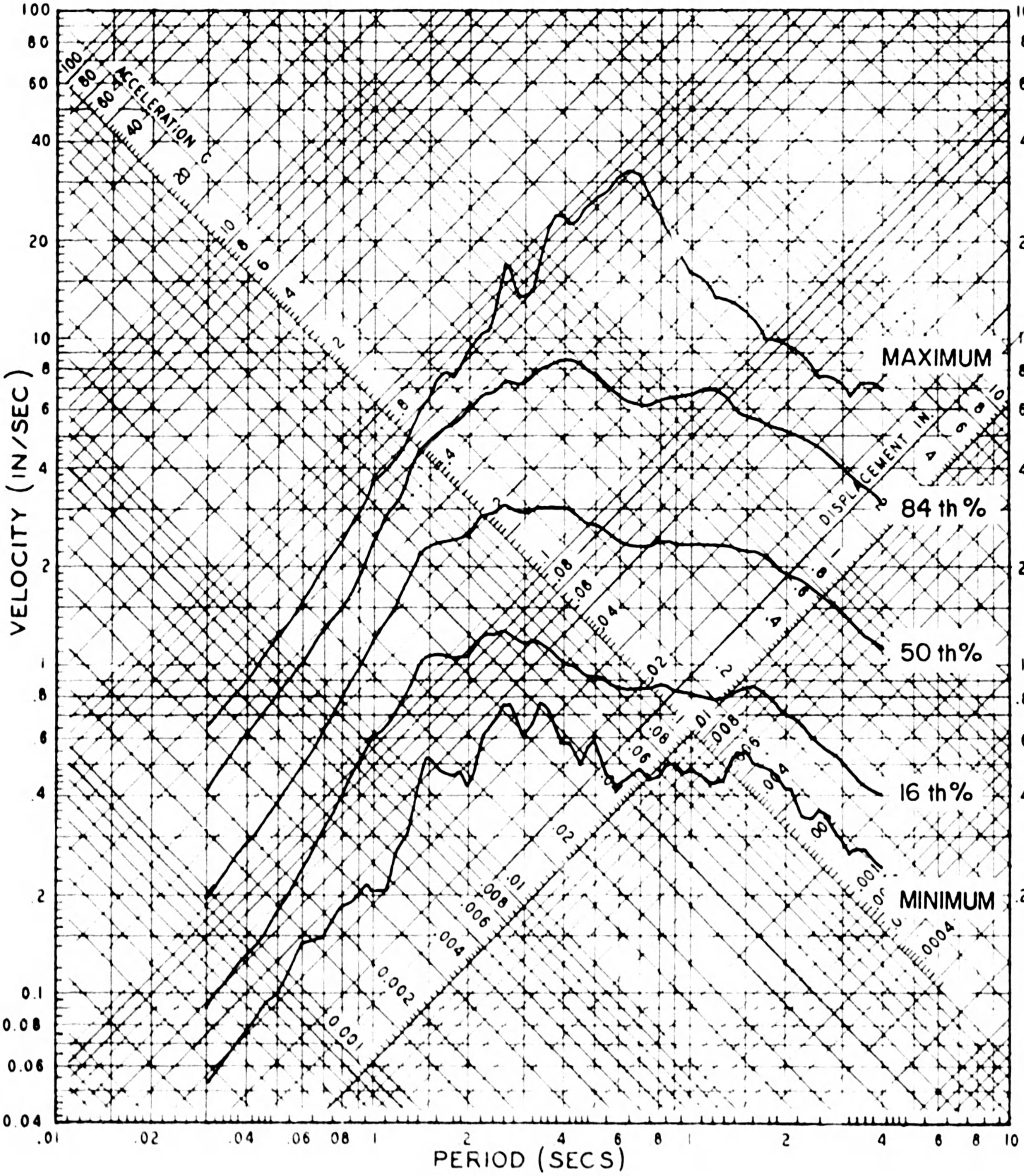


FIG. Q3-2

SENSITIVITY STUDY - 16TH, 50TH, AND 84TH PERCENTILE NORMALIZED SPECTRA FOR ORIGINAL 13 EARTHQUAKES, ORIGINAL PLUS 4 HIGH PAIRS, AND ORIGINAL PLUS 4 LOW PAIRS.
LOGNORMAL DISTRIBUTION - 7% DAMPING

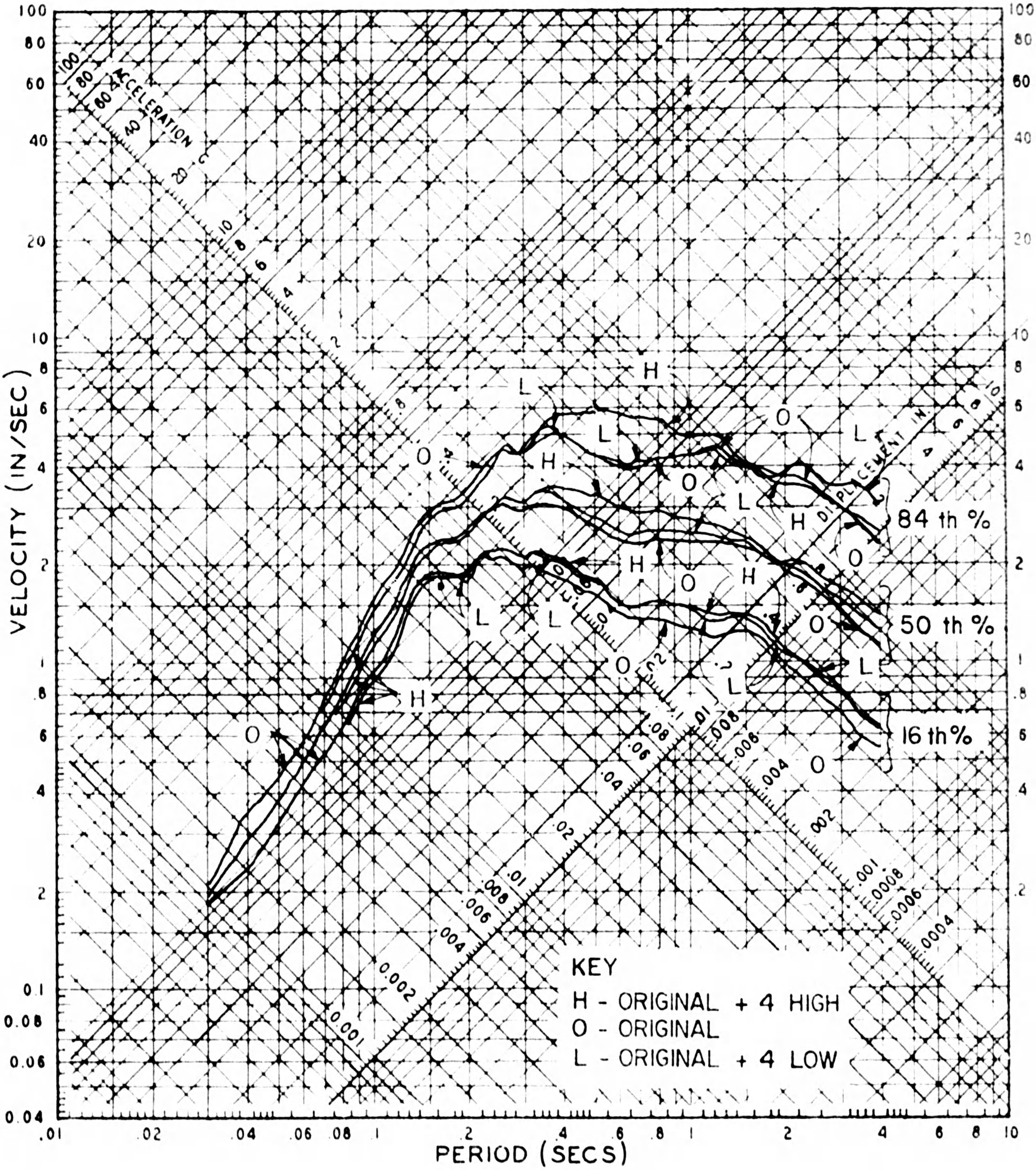


FIG. Q3-30

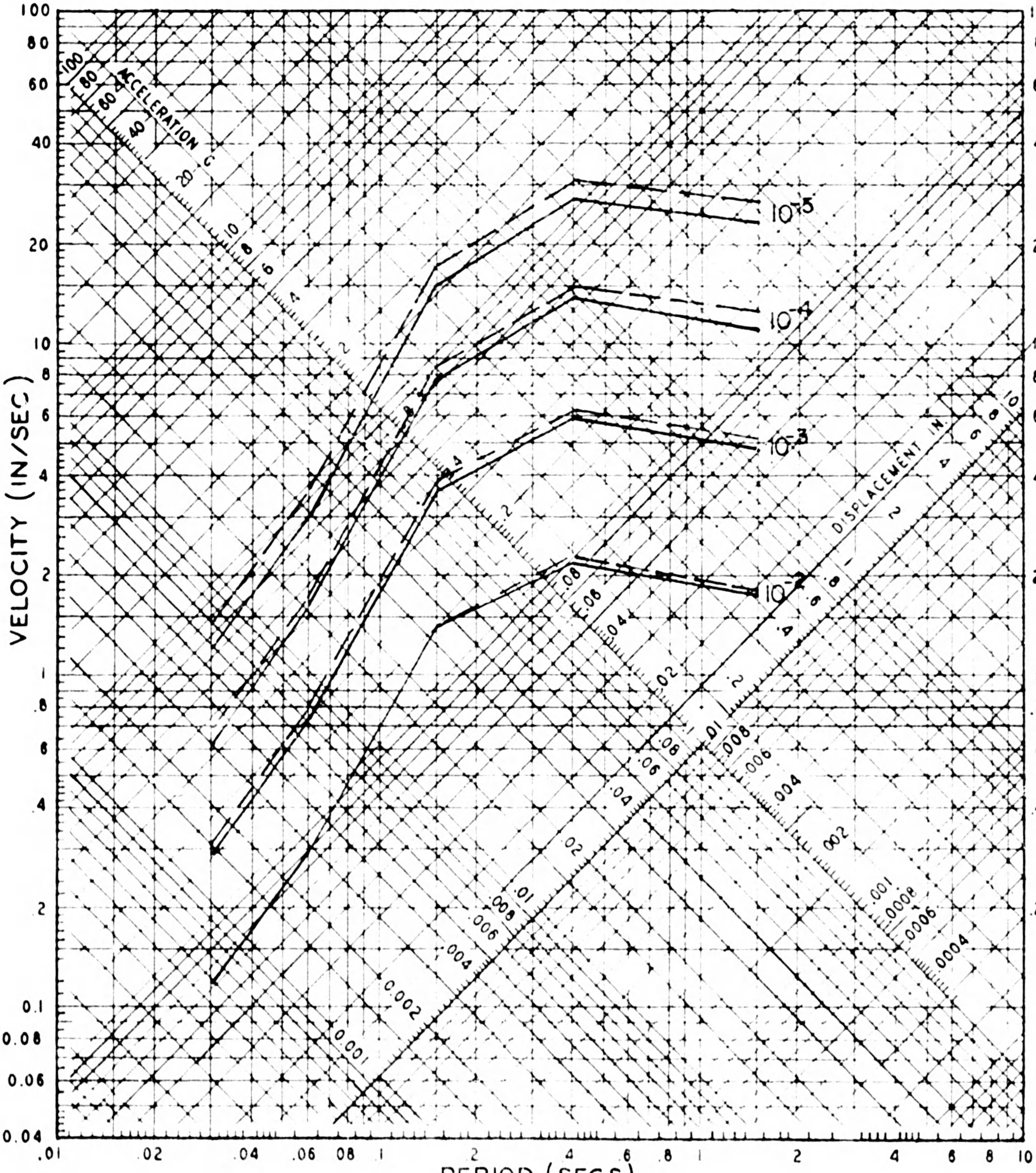
TABLE Q6-1

NUMERICAL VALUES FOR THE VARIOUS ATTENUATION RELATIONSHIPS USED IN THE SEISMIC RISK ANALYSIS

Period (Seconds)	Program Constants					Standard Errors			
						Intensity Unlimited	Intensity Limited		
T	k*	ln k	C_1	C_2	C_3				
			CSC Attenuation						
0.03	1.042	0.041	2.22	0.55	-0.69	1.026	0.785	0.790	0.832
0.06	1.297	0.260	2.24	0.55	-0.69	1.034	0.796	0.801	0.842
0.15	2.437	0.891	3.07	0.55	-0.69	1.047	0.813	0.818	0.858
0.40	1.196	0.179	2.36	0.55	-0.69	1.144	0.934	0.938	0.973
1.50	0.237	-1.440	0.74	0.55	-0.69	1.183	0.981	0.985	1.019
4.00	0.0450	-3.101	-0.92	0.55	-0.69	1.255	1.067	1.071	1.102
			Historical CSC Attenuation						
0.03	1.042	0.041	3.08	0.55	-0.94	0.836	0.693	0.696	0.720
0.06	1.297	0.260	3.30	0.55	-0.94	0.847	0.705	0.708	0.732
0.15	2.437	0.891	3.93	0.55	-0.94	0.862	0.725	0.727	0.750
0.40	1.196	0.179	3.22	0.55	-0.94	0.977	0.858	0.860	0.880
1.50	0.237	-1.440	1.60	0.55	-0.94	1.022	0.909	0.911	0.930
4.00	0.0450	-3.101	-0.061	0.55	-0.94	1.105	1.002	1.004	1.020

*k values are for 7 percent damping.

COMPARISON OF UNIFORM RISK RESPONSE SPECTRA WHEN THE SATP $I_{o_{max}}$ = $VIII_{MM}$ & IX_{MM}



——— $I_{o_{max}}$ = $VIII_{MM}$, β = 1.312

– – – $I_{o_{max}}$ = IX_{MM}, β = 1.312

FIGURE Q6-17

COMPARISON OF SEQUOYAH, WATTS BAR, AND BELLEFONTE NUCLEAR PLANTS TOP OF ROCK DESIGN SPECTRA WITH 0.13G REGULATORY GUIDE 1.60 SPECTRUM

SEQUOYAH - 1% DAMPING
WATTS BAR - 1% DAMPING
BELLEFONTE - 4% DAMPING
REG GUIDE 1.60 - 4% DAMPING

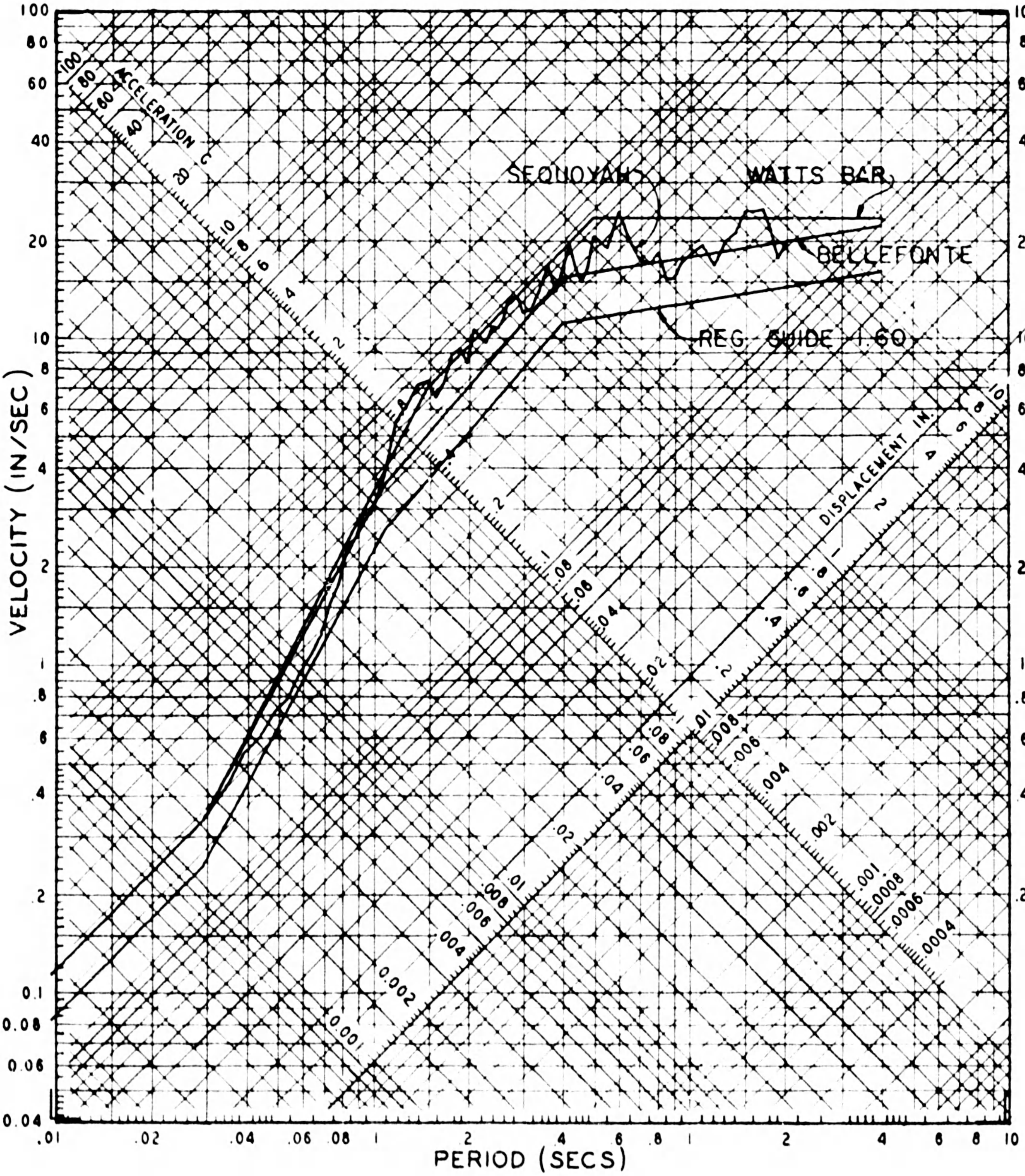


FIGURE 8