Woodward-Clyde Consultants

SITE - SPECIFIC TOP-OF-GROUND MOTIONS FOR ERCW PIPELINE

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SITE SPECIFIC TOP-OF-GROUND MOTIONS FOR ERCW PIPELINE

INTRODUCTION AND SUMMARY

Site specific ground motions were developed for the Watts Bar site by considering that an earthquake of magnitude approximately equal to m_{bLg} 5.8 earthquake could occur randomly anywhere within a 25 km radius of the site. The analysis was performed by averaging the peak accelerations and response spectra from a suite of accelerograms obtained at recording stations having soil conditions comparable to those along the ERCW pipeline. The median and 84th percentile peak accelerations resulting from this analysis are 0.10g and 0.22g, respectively.

EARTHQUAKE MAGNITUDE

As no recordings presently exist for earthquakes of m_{bLg} approximately equal to 5.8 in the eastern United States, recordings from the western United States and Italy were used in the analysis. Nuttli and Herrmann (1982) indicate the general relationship between the m_{bLg} magnitude scale used for eastern United States earthquakes and the M_L magnitude scale. They report (Herrmann and Nuttli, 1982) that m_{bLg} magnitudes are equal to M_L magnitudes. Consequently, for this analysis, events of M_L magnitude are used.

DATA SELECTION

Table 1 lists the currently available horizontal accelerograms recorded at soil sites during earthquakes of magnitude M_L 5.8 $\pm$ 0.5 within a distance range of 0 to 25 km. The distance criterion used was the closest distance to fault rupture when known; otherwise epicentral distance was used. The records

listed in Table 1 were obtained from instruments located in free field instrument shelters or on the ground floor of buildings.

The ERCW pipeline route is underlain by 20 to 50 feet of sands and gravels with an average thickness of about 25 feet overlying about 15 feet of weathered shale. Below the weathered shale the geology consists of interbedded shales and limestones of the lower Conasauga Formation. The range of measured shear wave velocities is shown in Figure 1. The shear wave velocity profile is characterized by a large velocity contrast at the alluvium-bedrock interface.

The soil conditions at all of the recording stations listed in Table 1 were examined for similarities to the soil conditions along the ERCW pipeline route. Of the 33 recording stations listed in Table 1, six were found to have shear wave velocity profiles with a significant velocity contrast at shallow depths. Descriptions of the subsurface conditions and shear wave velocity profiles at each of the six stations are given in Appendix A. Figure 2 shows a composite of all of the station shear wave velocity profiles compared with the measured velocity profiles along the ERCW pipeline.

Table 2 lists the selected data set comprised of 15 recordings (30 accelerograms) obtained during M_L 5.8 $\pm$ 0.5 earthquakes at the selected recording stations. Figure 3 shows the distribution of the data with respect to magnitude and distance.

RECORD PROCESSING

The sources of the accelerograms listed in Table 2 are the California Institute of Technology (CIT), the United States Geological Survey (USGS), and the Comitato Nazionale per

L'Enorgia Nucleare, Italy (CNEN). All of the records except those from CNEN were obtained in corrected form. The Friuli data set was obtained in uncorrected form from CNEN. The Friuli accelerograms were then corrected using the processing techniques employed by CIT and USGS. The general procedure is described by Trifunac (1970) and Trifunac and Lee (1973). The choice of long period filter values was based on the recommendations of Basili and Brady (1978). Based on recent experience with near source recordings, an interpolation time step of 0.01 seconds was used.

DATA ANALYSIS

The statistical analysis of the data was performed on the log of spectral acceleration. Studies (Esteva, 1969; Donovan, 1973; McGuire, 1974; Campbell, 1981) have shown that the variability in recorded ground motions are best modeled by a log normal distribution. The median and 84th percentile peak accelerations are computed using the expressions:

$$(a_{max})_{med} = e^{(\ln a)}$$

$$(a_{max})_{84th\%} = e^{(\ln a + S[\ln a])}$$

where lna is the mean of the natural log of the data set and S[lna] is the standard error of the log of the data set.

The statistical analysis models the random occurrence of an earthquake near the site. Given that an earthquake has occurred randomly within a 25 km radius of the site, the probability of the earthquake occurring within a particular distance band is equal to the ratio of the areas within the annular ring formed by the distance band to the total area of the circle. These probabilities are compared below with the percentage of the data falling in each distance band.

Distance Band (km)	Probability of Random Event in Distance Band	Portion of Site Specific Data Set in Distance Band
0-5	0.04	0.0
5.1-10	0.12	0.200
10.1-15	0.20	0.333
15.1-20	0.28	0.200
20.1-25	0.36	0.267

These results indicate that the data set is biased towards distances less than 15 km. Accordingly, a weighted statistical analysis was performed, with the records in each distance band assigned a weight equal to the probability of a random event occurring in their distance band. The weights are computed by the equation:

$$w_i = \frac{P(R_i)}{P(D_i)}$$

where w_i is the weight assigned to each record in distance band i, $P(R_i)$ probability of a random event in distance band i and $P(D_i)$ is the portion of the data set which actually falls within distance band i. As the data set does not contain any data in the first band, the weights for each band were renormalized by dividing by the factor $1 - P(R_1)$.

In developing the statistical spectra at longer periods, not all records were used as many of the accelerograms were processed with long period motion filter corner frequencies in the range of 0.3 to 0.5 H_z (periods of 2 to 3 seconds). The number of spectra averaged at various periods is tabulated below.

Period Range	Number of Spectra
0.04 - 2.0 sec.	30
2.0 - 2.5 sec.	24
2.5 - 10.0 sec.	2

As only two accelerograms contain unfiltered data in the period range 2.5 - 10 seconds, the results for these periods are not statistically significant.

RESULTS AND DISCUSSION

The weighted statistical analyses of the site specific data set yields median and 84th percentile accelerations of 0.10g and 0.22g respectively. The equivalent mean m_{bLg} is 5.6 and the mean distance is 18 km. Figures 4 and 5 show the computed statistical spectra for 2% and 5% damping, respectively.

The standard error of the natural logarithm of peak acceleration obtained in the analysis is 0.8, considerably greater than the values of 0.4 to 0.6 associated with attenuation equations for moderate magnitude earthquakes. The reason for the large dispersion is that the inherent uncertainty in ground motions at a particular distance from a particular magnitude is increased due to the wide range of magnitudes and distances included in the data set.

A comparison analysis was performed with all data points given equal weight. The median and 84th percentile peak accelerations are 0.10g and 0.23g, respectively. The mean magnitude is 5.6, and the mean distance is 16 km. The unweighted statistical spectra are shown in Figures 6 and 7. There are only slight differences between the weighted and unweighted statistical accelerations and response spectra.

A comparison weighted statistical analysis was also performed using the all-soil-site data set listed in Table 1, with the data listed in Table 2 removed, to evaluate differences between the site specific data set (Table 2) and a data set of soil sites without a sharp velocity contrast at shallow depths. Statistical analysis of this data set results in median and 84th percentile peak accelerations of 0.09g and 0.21g, respectively, slightly lower than the values for the site-specific data set. The mean magnitude is 5.8 and the mean distance is 17 km.

REFERENCES

Basili, M. and Brady, G. (1978), "Low Frequency Filtering and the Selection of Limits for Accelerogram Corretions," Proceeding of the Sixth European Conference on Earthquake Engineering, Vol. 1, Dubrounik, Yugoslavia, September, 1978, pp. 251-258.

Basili, M., Polinari, S., Tinelli, G., Berardi, R., Berenzi, A. and Fonetti, L. (1976), "Strong Motion Records of Friuli Earthquake," Proceedings of Specialist Meeting on the 1976 Friuli Earthquake and the Antiseismic Design of the Nuclear Installations, Vol. II, Rome, Italy, October, 1977, pp. 375-386.

Campbell, K. W. (1981), "Near-Source Attenuation of Peak Acceleration," Bulletin of the Seismological Society of America, v. 71, no. 6, pp. 2039-2071, December.

Campbell, K. W., Chieruzzi, R., Duke, C.M. and Lew, M. (1979), "Correlations of Seismic Velocity with Depth in Southern California," UCLA-BNG-7965, University of California, School of Engineering and Applied Sciences, Los Angeles, California, October.

Donovan, N. C. (1973), "A Statistical Evaluation of Strong Motion Data, Including the February 9, 1971 San Fernando Earthquake," Proceedings of the Fifth World Conference on Earthquake Engineering, Rome, 25-29 June 1973, v. 1, p. 1252-1261.

Fumal, T. E. (1978), "Correlations Between Seismic Wave Velocities and Physical Properties of Near Surface Geologic Materials in the San Francisco Bay Region, California," USGS Open File Report 78-1067.

Herrmann, R. B. and Nuttli, O. W. (1982), "Magnitude: The Relations of M_L to m_{bLg}," Bulletin of the Seismological Society of America, Vol. 72, No. 2, pp. 389-398, April.

Huey, A. S. (1948), "Geology of the Telsa Quadrangle, California," California Division of Mines and Geology Bulletin 140, July.

McGuire, R. K. (1974), "Seismic Structural Response Risk Analysis, Incorporating Peak Response Regressions on Earthquake Magnitude and Distance," Massachusetts Institute of Technology Department of Civil Engineering, Research Report R74-51, August.

Muzzi, F. and Pugliese, A. (1977), "Analysis of the Dynamic Response of Soil Deposit in Locality Ca'Dant (Cornini-Forgaria)," Proceedings of Specialist Meeting on the 1976 Earthquake and the Antiseismic Design of Nuclear Installations, Vol. II, Rome, Italy, October 11-13, pp. 541-566.

Muzzi, F. and Vallini, S. (1977), "The Friuli 1976 Earthquake Considered as a 'Near Source Earthquake' Presentation and Discussion of the Surface Recordings," Proceedings of Specialist Meeting on the 1976 Friuli Earthquake and the Antiseismic Design of Nuclear Installations, Vol. II, Rome, Italy, October 11-13, pp. 460-526.

Nuttli, O. W. and Herrmann, R. B. (1982), "Earthquake Magnitude Scales," ASCE, Journal of Geotechnical Engineering Division, Vol. 108, No. GT5, pp. 783-786, May.

Shannon & Wilson, Inc. and Agbabian Associates (SW-AA) (1977), "Verification of Subsurface Conditions at Selected 'Rock' Accelerograph Stations in California, Vol. 2," Report to the U.S. Nuclear Regulatory Commission, NUREG/CR-0055, September, 1980.

Trifunic, M. D. (1970), "Low Frequency Digitization Errors and a New Method for Zero Base-Line Correction of Strong-Motion Accelerograms," Earthquake Engineering Reserach Laboratory, EERL 70-07, California Institute of Technology, Pasadena, California.

Trifunic, M. D. and Lee, V. W. (1973), "Routine Computer Processing of Strong Motion Accelerograms," Earthquake Engineering Research Laboratory, EERL 73-03, California Institute of Technology, Pasadena, California.

U.S. Geological Survey (1981), "Strong-Motion Accelerograph Station List - 1980; Open File Report 81-664.

Table 1

Available Recordings for Soil Sites from Magnitude M_L 5.8 ±0.5 Earthquakes

EARTHQUAKE	DATE Y M D	TIME H M S	MAGNITUDE MB	ML	MS	DEPTH (KM)	RECORDING STATION	USGS STAT NO	SITE CLAS	DISTANCE TO: HYPOC (KM)	EPIC (KM)	RUPT (KM)	RECORD	COMP	PEAK ACCEL VOL 1 (G)	VOL 2 CM/S/S
PARKFIELD, CALIF.	66 627	202614	5.8	5.6	6.4	8.0	CHOLAME-SHANDON ARRAY #2 CA	1013	ABC	30.0	28.9	.1	B033 B033	N65E N25W	.509	479.6
PARKFIELD, CALIF.	66 627	202614	5.8	5.6	6.4	8.0	CHOLAME-SHANDON ARRAY #5 CA	1014	ABB	31.2	30.2	5.3	B034 B034	N05W N85E	.403 .467	347.8 425.7
							CHOLAME-SHANDON ARRAY #8 CA	1015	ABB	32.4	31.4	9.2	B035 B035	N50E N40W	.279 .276	232.6 269.6
							CHOLAME-SHANDON ARRAY #12 CA	1016	ABB	34.6	33.7	14.7	B036 B036	N50E N40W	.066 .072	52.1 63.2
LYTLE CREEK, CALIF.	70 912	63053	5.2	5.4		8.0	6074 PARK DRIVE WRIGHTWOOD, CA	290	BAB	15.4	13.2		W334 W334	S65E S25W	.146 .205	139.0 194.4
							CEDAR SPRINGS DAM: PUMPHOUSE, CDWR	112	AAB	23.7	22.3		W336 W336	S54E S36W	.062 .073	56.0 69.4
MANAGUA NICARAGUA (MAIN SHOCK)	721223	029 0	5.6	6.1	6.2	5.0	ESSO REFINERY MANAGUA NICARGUA	3501	ABB	7.5	7.0	5.0	MN05 MN05	SOUT EAST	.330 .390	318.0 351.3
POINT MUGU	73 0 0	0 0 0		6.0	.5	.2	NAVAL RESRCH & EVAL LAB PORT HUEN	272	BBD	25.0	18.0		PM01 PM01	LONG TRAN	.130 .080	
FRIULI SEQUENCE	76 5 6	20 015	6.0	6.2	6.5	26.0	CODROIPO, ITALY	8004	ADD	34.6	22.8		F032 F032	NORT EAST	.065 .087	60.9 85.5
FRIULI SEQUENCE	76 5 9	05348	5.1	5.5		1.0	FORGARIA-CORN., ITALY	8014	ABB	25.2	25.2		F051 F051	NORT EAST	.043 .037	42.2 34.7
							MAIANO (CNEN), ITALY	8015	ACB	24.8	24.8		F052 F052	NORT EAST	.084 .048	80.1 44.9
							TOLMEZZO, ITALY - ENEL FIXED	8012	ABB	22.0	22.0		F054 F054	NORT EAST	.041 .035	36.2 31.3
FRIULI SEQUENCE	76 511	2244 2	5.2	5.3		19.0	FORGARIA-CORN., ITALY	8014	ABB	21.3	9.7		F059 F059	NORT EAST	.190 .308	182.7 299.4
							MAIANO (CNEN), ITALY	8015	ACB	22.4	11.8		F060 F060	NORT EAST	.075 .082	68.6 67.5
							TARCENTO, ITALY	8011	ABB	22.3	11.7		F061 F061	NORT EAST	.036 .077	35.0 69.6

Table 1 (Cont'd)

Available Recordings for Soil Sites from Magnitude M_L 5.8 ±0.5 Earthquakes

EARTHQUAKE	DATE Y M D	TIME H M S	MAGNITUDE MB	ML	MS	DEPTH (KM)	RECORDING STATION	USGS STAT NO	SITE CLAS	DISTANCE TO: HYPOC (KM)	EPIC (KM)	RUPT (KM)	RECORD	COMP	PEAK ACCEL VOL 1 (G)	VOL 2 CM/S/S
FRIULI SEQUENCE	76 511	2244 2	5.2	5.3		19.0	TOLMEZZO, ITALY - ENEL FIXED	8012	ABB	23.2	13.4		F063	NORT	.030	27.8
													F063	EAST	.032	26.9
FRIULI SEQUENCE	76 911	163112	5.2	5.5	5.5	9.0	FORGARIA-CORN., ITALY	8014	ABB	18.2	15.8		F131	NORT	.095	92.1
													F131	EAST	.115	105.6
							TARCENTO, ITALY	8011	ABB	11.7	7.5		F133	NORT	.204	201.6
													F133	EAST	.105	93.9
							BUIA, ITALY	8023	ABC	13.6	10.2		F135	NORT	.049	
													F135	EAST	.040	
FRIULI SEQUENCE	76 911	1635 0	5.3	5.9	5.4	6.0	FORGARIA-CORN., ITALY	8014	ABB	15.7	14.5		F138	NORT	.131	119.7
													F138	EAST	.233	223.7
							BUIA, ITALY	8023	ABC	15.2	14.0		F143	NORT	.233	226.1
													F143	EAST	.108	99.9
FRIULI SEQUENCE	76 915	31519	5.7	6.1	6.0	9.0	BUIA, ITALY	8023	ABC	10.8	6.0		F156	NORT	.110	107.3
													F156	EAST	.096	91.9
							FORGARIA-CORN., ITALY	8014	ABB	13.5	10.0		F152	NORT	.263	255.0
													F152	EAST	.218	208.0
FRIULI SEQUENCE	76 915	92118	5.4	6.0	5.9	12.0	TARCENTO, ITALY	8011	ABB	22.5	19.0		F172	NORT	.139	135.1
													F172	EAST	.110	108.3
							FORGARIA-CORN., ITALY	8014	ABB	23.3	20.0		F168	NORT	.353	337.5
													F168	EAST	.335	323.8
							BUIA, ITALY	8023	ABC	22.5	19.0		F177	NORT	.085	81.1
													F177	EAST	.095	85.9
COYOTE LAKE, CA	79 8 6	10 522	5.3	5.7	5.6	9.6	GILROY ARRAY STA #2	1409	ABD	17.0	14.0	7.5	CL03	N40W	.260	248.9
													CL03	S50W	.200	186.5
							GILROY ARRAY STA #3	1410	ABD	16.7	13.6	6.0	CL04	N40W	.270	245.6
													CL04	S50W	.260	252.4
							GILROY ARRAY STA #4	1411	ABD	15.5	12.2	4.5	CL05	S00E	.260	246.2
													CL05	S90E	.240	228.1
							SAN JUAN BAUTISTA: 101/156 OVERPASS	1492	DAC	29.4	27.8	17.2	CL08	S67E	.120	110.9
													CL08	S23W	.110	84.8

Table 1 (Cont'd)

Available Recordings for Soil Sites from Magnitude M_L 5.8 ±0.5 Earthquakes

EARTHQUAKE	DATE Y M D	TIME H M S	MAGNITUDE MB	ML	MS	DEPTH (KM)	RECORDING STATION	USGS STAT NO	SITE CLAS	DISTANCE TO: HYPOC (KM)	EPIC (KM)	RUPT (KM)	RECORD	COMP	PEAK ACCEL VOL 1 (G)	VOL 2 CM/S/S
COYOTE LAKE, CA	79 8 6	10 522	5.3	5.7	5.6	9.6	SAN JUAN BAUTISTA (C126)	1377	ABB	29.4	27.8	15.6	CL10	S57E	.090	103.6
													CL10	N33E	.110	110.0
IMPERIAL AFTERSHOCK A31	791015	235843	5.2	5.5	5.7	9.1	CALIPATRIA FIRE STA (CT40)	5061	BDD	16.1	13.3		A31B	N45W	.124	
													A31B	S45W	.168	
							EL CENTRO ARRAY # 1: BORCHARD RANCHE	5056	ADD	24.6	22.9		A31C	S50W	.114	
													A31C	S40E	.093	
							EL CENTRO ARRAY # 2: KEYSTONE ROAD	5115	ADD	22.6	20.7		A31D	S50W	.113	
													A31D	S40W	.091	
							EL CENTRO ARRAY # 4: 2905 ANDERSON R	955	ADD	22.2	20.2		A31E	S50W	.063	
													A31E	S40E	.032	
							EL CENTRO ARRAY # 5: 2801 JAMES ROAD	952	ADD	21.5	19.5		A31F	S50W	.161	
													A31F	S40E	.118	
							EL CENTRO ARRAY # 8: 95 EAST CRUICKS	958	ADD	24.3	22.6		A31G	S50W	.052	
													A31G	S40E	.067	
							SALTON SEA: WILDLIFE REFUGE	5062	ADD	21.4	19.4		A31J	N45W	.082	
													A31J	S45W	.071	
LIVERMORE SEQUENCE : SHOCK A	80 124	11 0 9	5.3	5.9	5.9	5.9	SAN RAMON: EASTMAN KODAK BLDG	1418	ABB	17.7	16.7	17.6	LA01	S00E	.148	
													LA01	S90W	.063	
							SAN RAMON FIRE STATION	1383	ABB	18.2	17.2	21.7	LA02	N70E	.042	
													LA02	N20W	.053	
							ANTIOCH	1308	ACD	20.3	19.5	28.5	LA03	N00E	.010	
													LA03	N90W	.040	
							PLEASANT HILL: CITIZENS SAVINGS	9906	DBD	26.4	25.7	35.0	LA05	N90E	.028	
													LA05	N00E	.028	
							DEL VALLE DAM	1265	ABB	25.9	25.2	12.9	LA23	S66W	.240	249.9
													LA23	S24E	.140	126.7
MAMMOTH LAKES SHOCK A	80 525	93345	6.1	6.1	6.1	8.9	CONVICT CREEK	1324	ACD	9.0	1.5		ML01	S00E	.464	381.1
													ML01	N90E	.428	396.6
							MAMMOTH LAKES HIGH SCHOOL GYM	1490	BAD	14.0	10.8		ML02	S74W	.327	
													ML02	N16W	.262	
MAMMOTH LAKES SHOCK B	80 525	94927	5.5	6.0		13.8	CONVICT CREEK	1324	ACD	16.3	8.6		ML11	S00E	.200	168.3
													ML11	N90E	.170	148.7
							MAMMOTH LAKES HIGH SCHOOL GYM	1490	BAD	14.2	3.5		ML12	S74W	.370	
													ML12	N16W	.430	
MAMMOTH LAKES SHOCK C	80 525	124451	5.5	6.1	5.8	16.4	CONVICT CREEK	1324	ACD	17.0	6.1		ML21	S00E	.193	181.8
													ML21	N90E	.239	213.0
MAMMOTH LAKES SHOCK D	80 527	75057	5.7	6.2	6.0	14.2	CONVICT CREEK	1324	ACD	18.6	12.0		ML31	S00E	.331	297.2
													ML31	N90E	.267	230.5

Table 2

Selected Recordings for Site Specific M_L 5.8 ±0.5 Data Set

EARTHQUAKE	DATE Y M D	TIME H M S	MAGNITUDE MB	ML	MS	DEPTH (KM)	RECORDING STATION	USGS STAT NO	SITE CLAS	DISTANCE TO: HYPOC (KM)	EPIC (KM)	RUPT (KM)	RECORD	COMP	PEAK ACCEL VOL 1 (G)	VOL 2 CM/S/S
LYTLE CREEK, CALIF.	70 912	63053	5.2	5.4		8.0	6074 PARK DRIVE WRIGHTWOOD, CA	290	BAB	15.4	13.2		W334	S65E	.146	139.0
													W334	S25W	.205	194.4
FRIULI SEQUENCE	76 5 9	05348	5.1	5.5		1.0	FORGARIA-CORN., ITALY	8014	ABB	25.2	25.2		F051	NORT	.043	42.2
													F051	EAST	.037	34.7
							MAIANO (CNEN), ITALY	8015	ACB	24.8	24.8		F052	NORT	.084	80.1
													F052	EAST	.048	44.9
							TOLMEZZO, ITALY - ENEL FIXED	8012	ABB	22.0	22.0		F054	NORT	.041	36.2
													F054	EAST	.035	31.3
FRIULI SEQUENCE	76 511	2244 2	5.2	5.3		19.0	FORGARIA-CORN., ITALY	8014	ABB	21.3	9.7		F059	NORT	.190	182.7
													F059	EAST	.308	299.4
							MAIANO (CNEN), ITALY	8015	ACB	22.4	11.8		F060	NORT	.075	68.6
													F060	EAST	.082	67.5
							TARCENTO, ITALY	8011	ABB	22.3	11.7		F061	NORT	.036	35.0
													F061	EAST	.077	69.6
							TOLMEZZO, ITALY - ENEL FIXED	8012	ABB	23.2	13.4		F063	NORT	.030	27.8
													F063	EAST	.032	26.9
FRIULI SEQUENCE	76 911	163112	5.2	5.5	5.5	9.0	FORGARIA-CORN., ITALY	8014	ABB	18.2	15.8		F131	NORT	.095	92.1
													F131	EAST	.115	105.6
							TARCENTO, ITALY	8011	ABB	11.7	7.5		F133	NORT	.204	201.6
													F133	EAST	.105	93.9
FRIULI SEQUENCE	76 911	1635 0	5.3	5.9	5.4	6.0	FORGARIA-CORN., ITALY	8014	ABB	15.7	14.5		F138	NORT	.131	119.7
													F138	EAST	.233	223.7
FRIULI SEQUENCE	76 915	31519	5.7	6.1	6.0	9.0	FORGARIA-CORN., ITALY	8014	ABB	13.5	10.0		F152	NORT	.263	255.0
													F152	EAST	.218	208.0
FRIULI SEQUENCE	76 915	92118	5.4	6.0	5.9	12.0	TARCENTO, ITALY	8011	ABB	22.5	19.0		F172	NORT	.139	135.1
													F172	EAST	.110	108.3
							FORGARIA-CORN., ITALY	8014	ABB	23.3	20.0		F168	NORT	.353	337.5
													F168	EAST	.335	323.8
LIVERMORE SEQUENCE : SHOCK A	80 124	11 0 9	5.3	5.9	5.9	5.9	DEL VALLE DAM	1265	ABB	25.9	25.2	12.9	LA23	S66W	.240	249.9
													LA23	S24E	.140	126.7

THREE-LETTER CLASSIFICATION CODE FOR TABLES 1 AND 2

FIRST LETTER: Structure Type and Instrument Location

Designation	Description
A	Free-field instrument or one-story structure; the instrument is located at the lowest level of the structure and within ± several feet of the ground surface.
B	Two to four-story structure of light construction; the instrument is located at the lowest level of the structure and within ± several feet of the ground surface.
C	Two to four-story structure of light construction; the instrument is located below the ground surface at the lowest level of the structure.
D	Structure of heavy construction; the instrument is located at the lowest level of the structure and within ± several feet of the ground surface.
E	Structure of heavy construction; the instrument is located below the ground surface at the lowest level of the structure.
F	Structure housing instrument is buried below the ground suface.
G	Structure of light or heavy construction; the instrument is located at the ground surface or below, but is not at the lowest level of the structure.

SECOND LETTER: Deep Local Geology

Designation	Description
A	Hard Rock; competent, typically with V_s > 4000 fps; generally includes metamorphic and intrusive igneous rocks.
B	Soft Rock; less competent, typically with 2000 $\leq V_s \leq$ 4000 fps; generally includes sedimentary and extrusive igneous rocks.
C	Old Alluvium; unconsolidated sediments of Miocene age or older; typically may have some "soft rock" characteristics, i.e. $V_s \geq$ 2000 fps.
D	Recent Alluvium; unconsolidated sediments of Pliocene age or younger.

THREE LETTER: Near-Surface Geology

Designation	Description
A	Rock; the instrument is founded on rock material or a very thin (less than 10 to 15 feet) of soil over rock; typically is on a ridge or hillside.
B	Shallow Soil; the instrument is founded in or on soil up to 150 to 200 feet thick over rock material; typically is in a narrow canyon, near the edge of a valley or on a hillside.
C	Deep Narrow Soil; the instrument is founded in or on soil at least 200 to 300 feet thick over rock material in a narrow canyon or valley not more than several kilometers wide.
D	Deep Broad Soil; the instrument is founded in or on soil at least 200 to 300 feet thick over rock material in a broad canyon or valley.

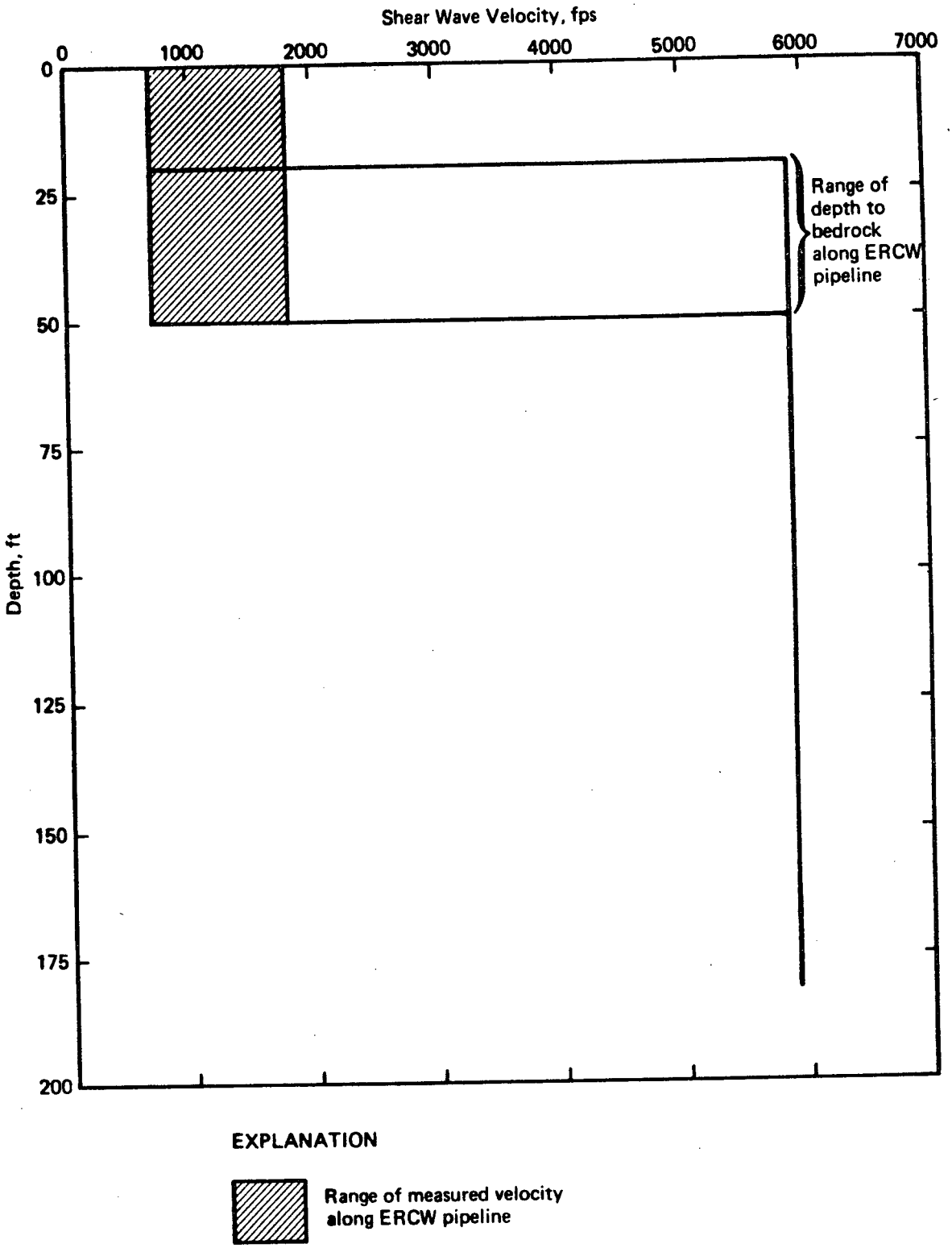


Figure 1 — Shear Wave Velocity Profile Along ERCW Pipeline

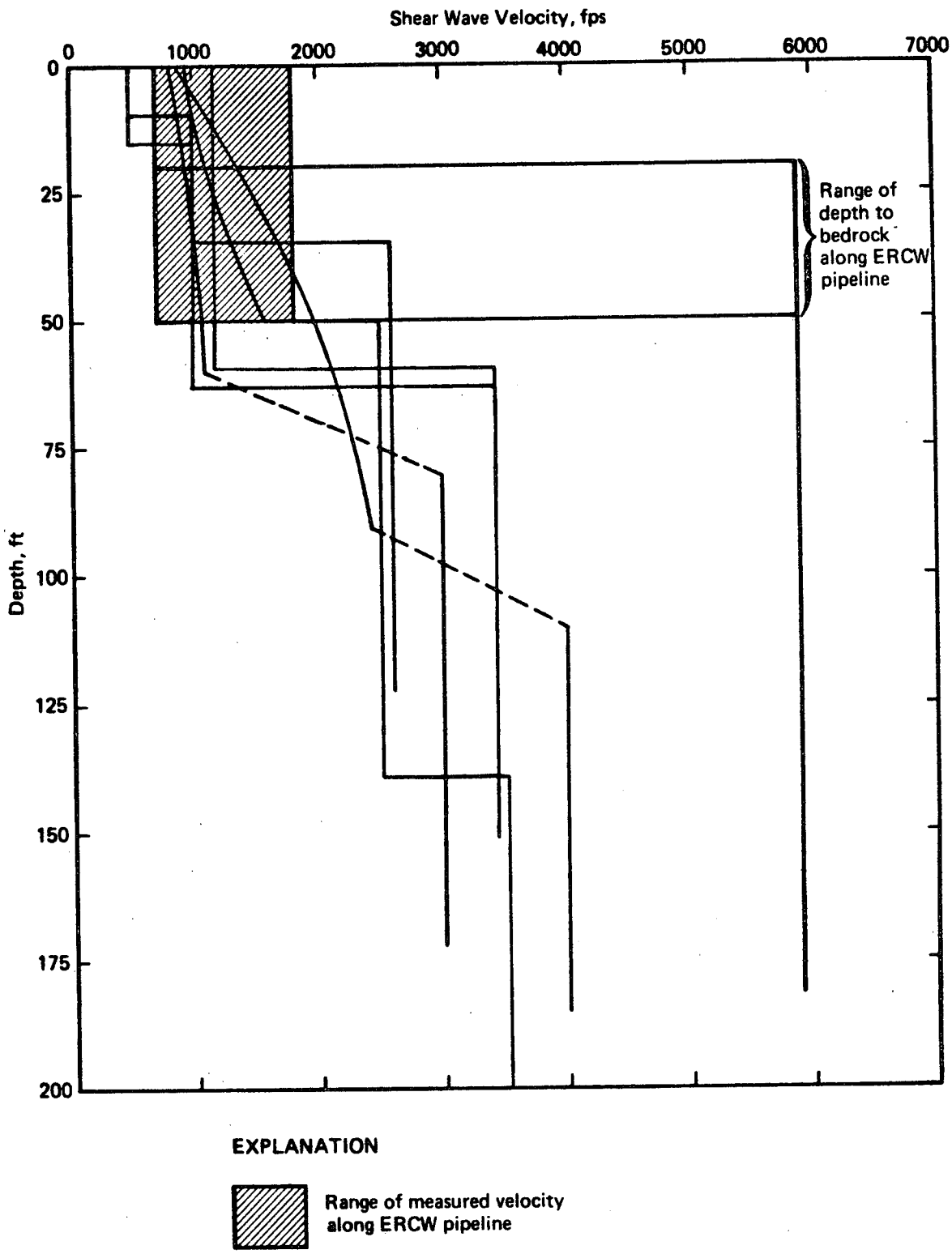
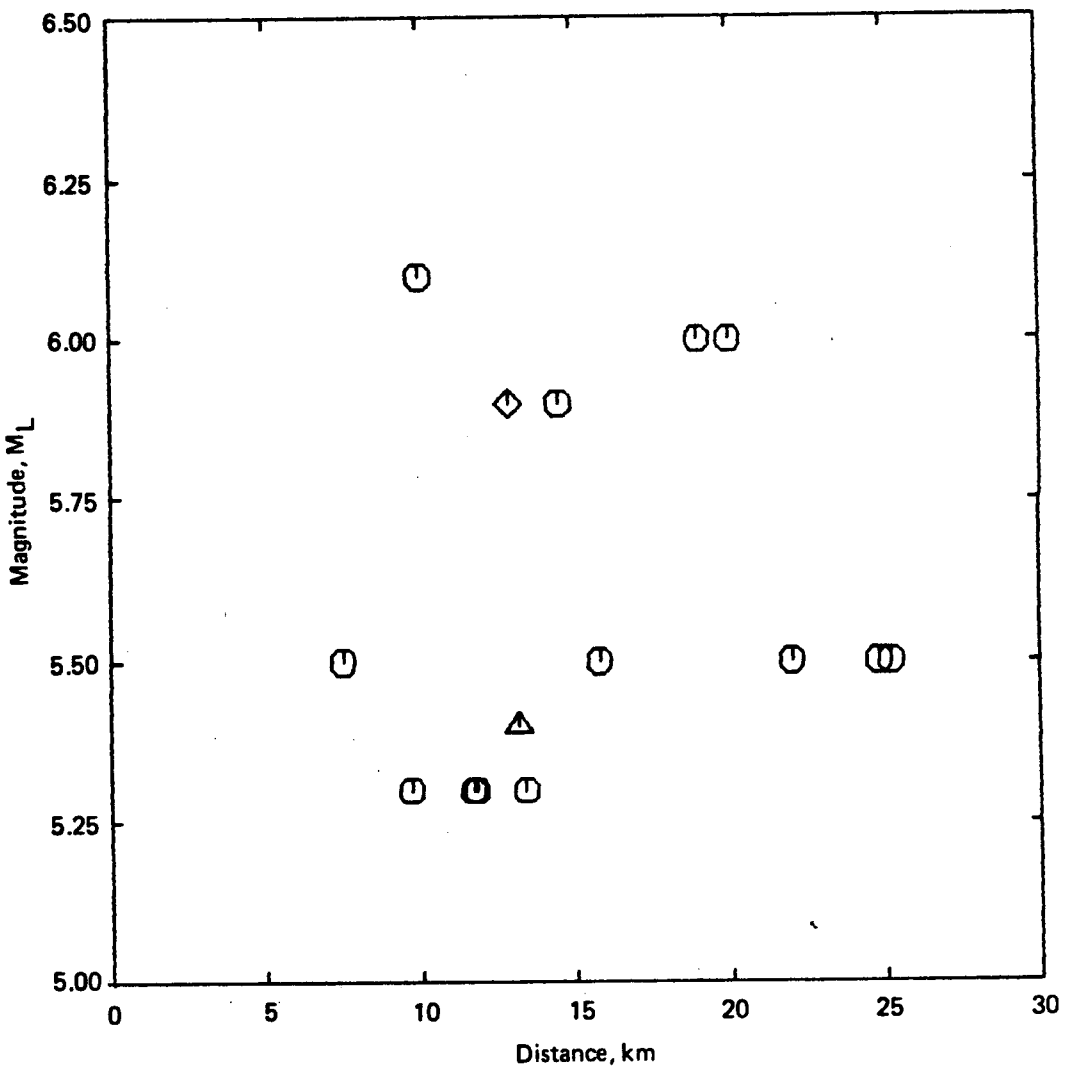


Figure 2 – Overplot of Shear Wave Velocity Profiles for Selected Recording Stations



EXPLANATION

1980 Livermore Earthquake

1976 Friuli, Italy Earthquakes

1970 Lytle Earthquake

Figure 3 – Scattergram of Magnitude and Distance for Site Specific Data Set

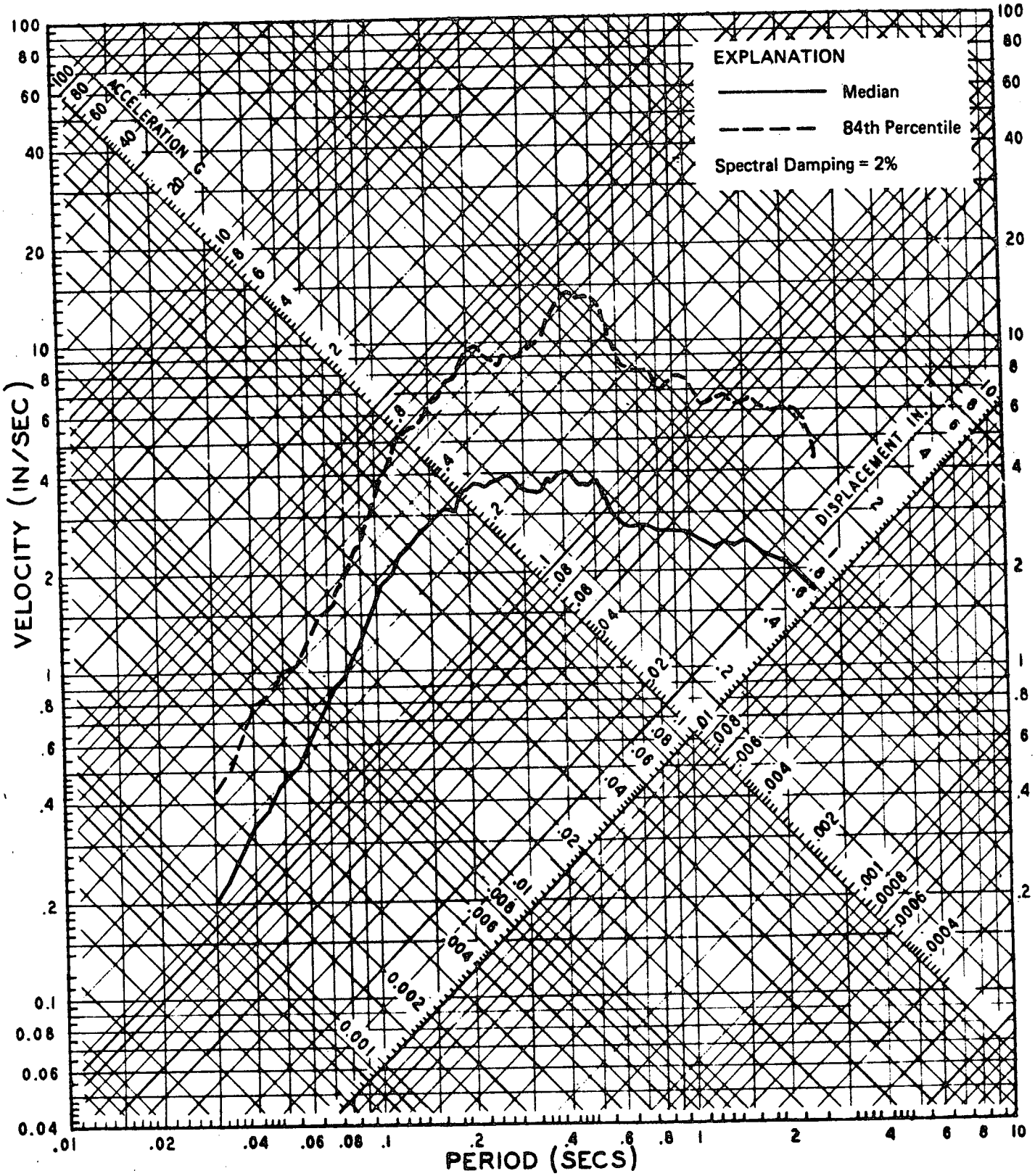


Figure 4 — Statistical Response Spectra for Site Specific Data Set (Weighted): 2% Spectral Damping

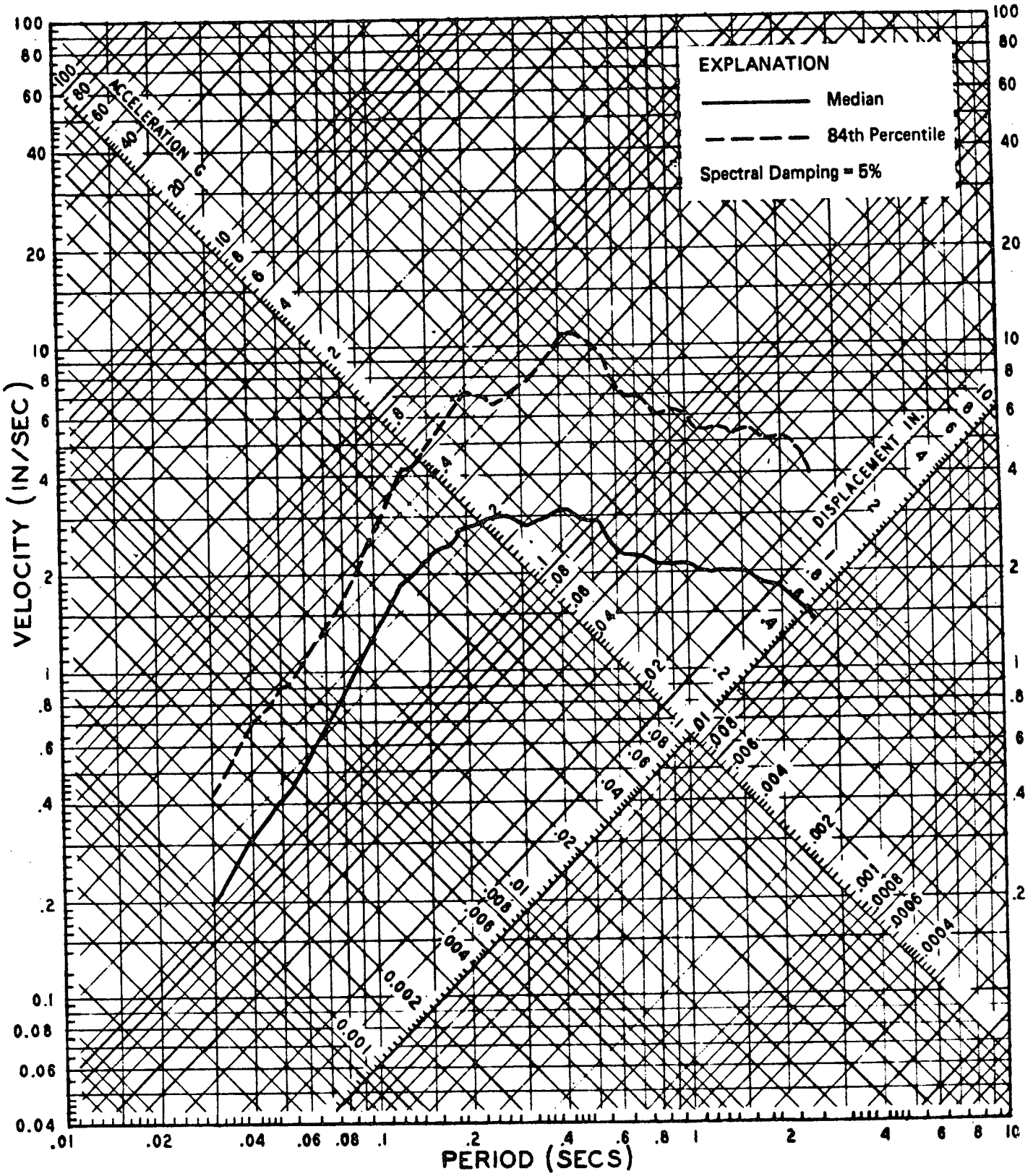


Figure 5 — Statistical Response Spectra for Site Specific Data Set (Weighted): 5% Spectral Damping

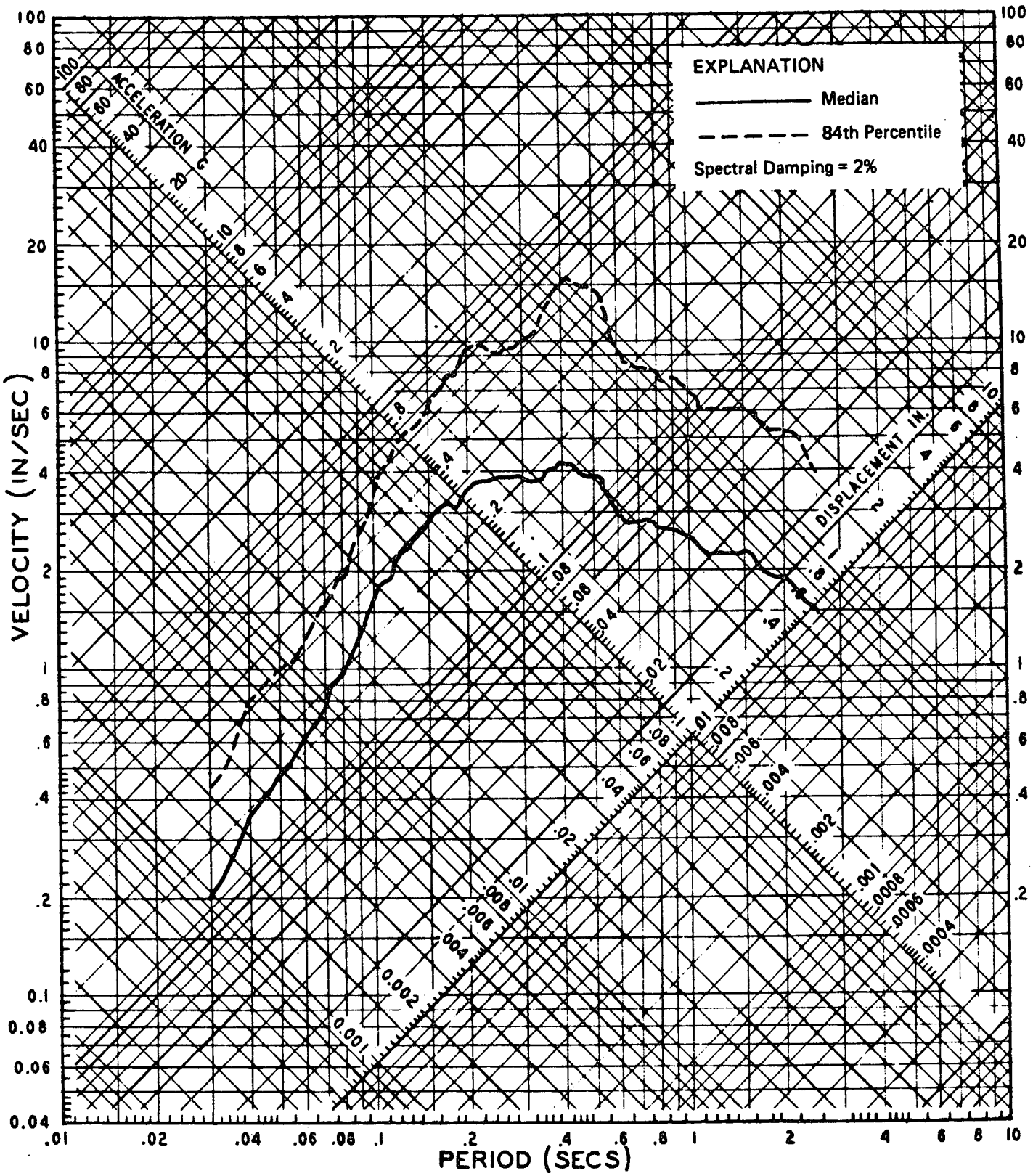


Figure 6 – Statistical Response Spectra for Site Specific Data Set (Unweighted) : 2% Spectral Damping

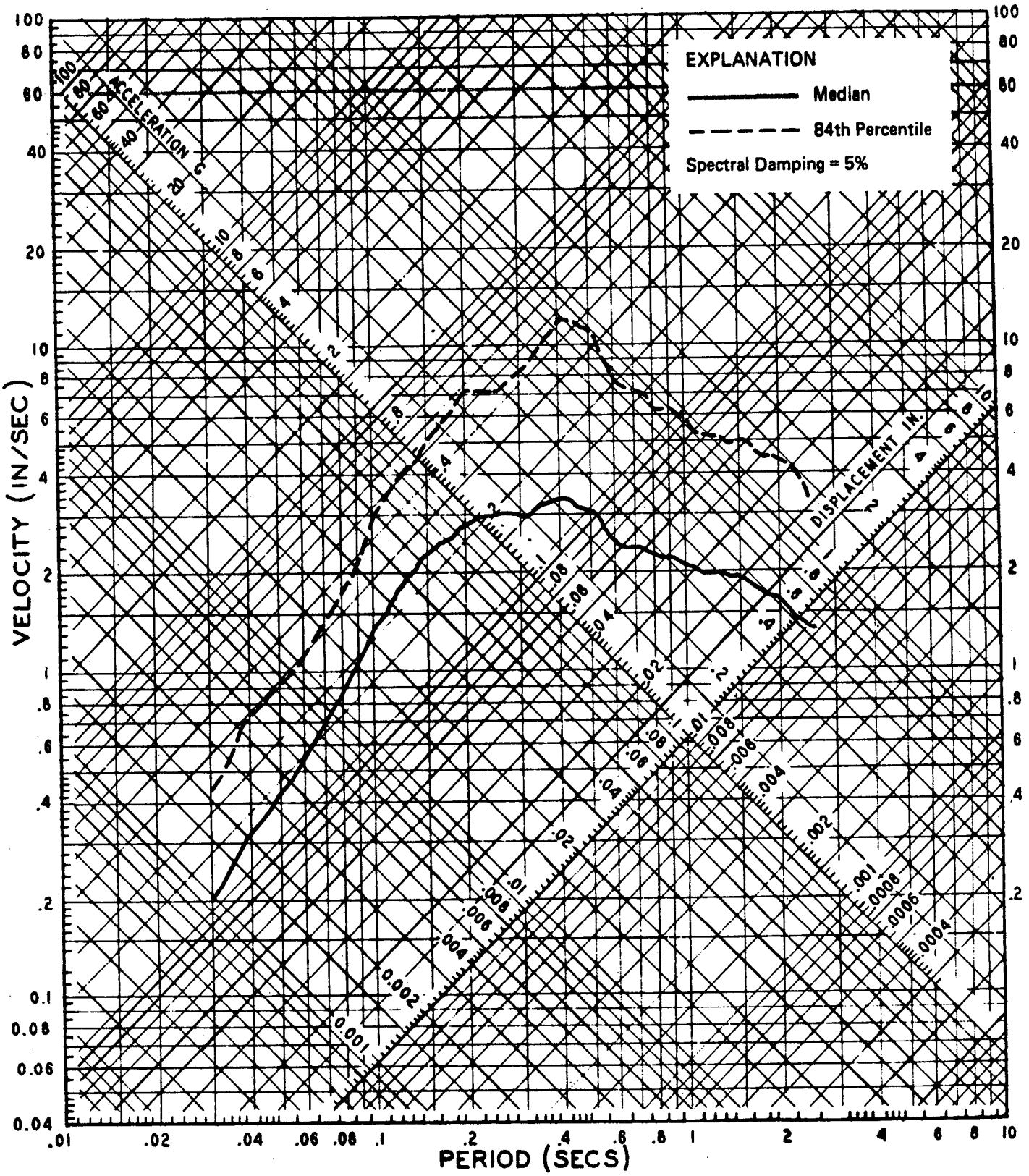


Figure 7 — Statistical Response Spectra for Site Specific Data Set (Unweighted) : 5% Spectral Damping

APPENDIX A

The site descriptions and shear wave velocity profiles presented in this appendix are compiled from data published in the literature. Where specific information was not available about the site geology, the site conditions were estimated from geologic maps and the shear wave velocities were estimated from published data for similar geologic units.

A-1 6074 Park Drive, Wrightwood

The former recording station at 6074 Park Drive, Wrightwood, California is designated USGS Station No. 290. The instrument was located on a concrete slab on grade within two feet of the ground surface in a partial basement of a one story building. The site is underlain by at least 90 feet of dense granular alluvium overlying crystalline basement rock (Shannon and Wilson, 1977). The estimated depth to rock is less than 150 feet as rock outcrops within 120 feet of the site. The shear wave velocity profile shown in Figure A-1 was estimated from published data for similar materials (Campbell et. al., 1979).

A-2 Del Valle Dam

The recording station at Del Valle Dam is designated USGS Station No. 1265. The instrument is located in an instrument shelter at the downstream toe of an earth dam in a narrow canyon. The site is underlain by shallow alluvium of unknown depth overlying Cretaceous sandstones and shales (USGS, 1981, Huey, 1948). The depth to rock is estimated to be less than 100 feet. The velocity profile shown in Figure A-2 is estimated from measured velocities in similar materials (Fumel, 1978).

A-3 Forgaria - Cornino, Italy

The site of the temporary recording station at Forgaria-Cornino is underlain by approximately 50 feet of alluvial deposits. The alluvial material is underlain by a sloping bedrock consisting of marly sandstone and sandstone (Muzzi and Vallini, 1977). Figure A-3 shows the shear wave velocity profile for the site estimated from measured velocities in similar materials (Muzzi and Pugilese, 1977).

A-4 Tolmezzo, Italy

The instrument at the Tolmezzo recording station is located in an instrument shelter. The site is underlain by approximately 66 feet of weathered and fractured limestone over competent limestone. The shear wave velocity profile shown in Figure A-4 was estimated from the measured compression wave velocities reported by Muzzi and Vallini (1977)

A-5 Maiano, Italy

The free field instrument at Maiano, Italy is located in an instrument shelter. The site is underlain by approximately 60 ft of gravel over stiff clays and gravels. The shear wave velocity profile shown in Figure A-5 was estimated from the measured compression wave velocities reported by Muzzi and Vallini (1977).

A-6 Tarcento, Italy

The temporary recording station at Tarcento, Italy, was located on approximately 60 feet of alluvial soils overlying marl and sandstone (Basili et. al., 1978). The shear wave profile shown in Figure A-6 is estimated from velocities measured in similar materials (Muzzi and Pugilese, 1977).

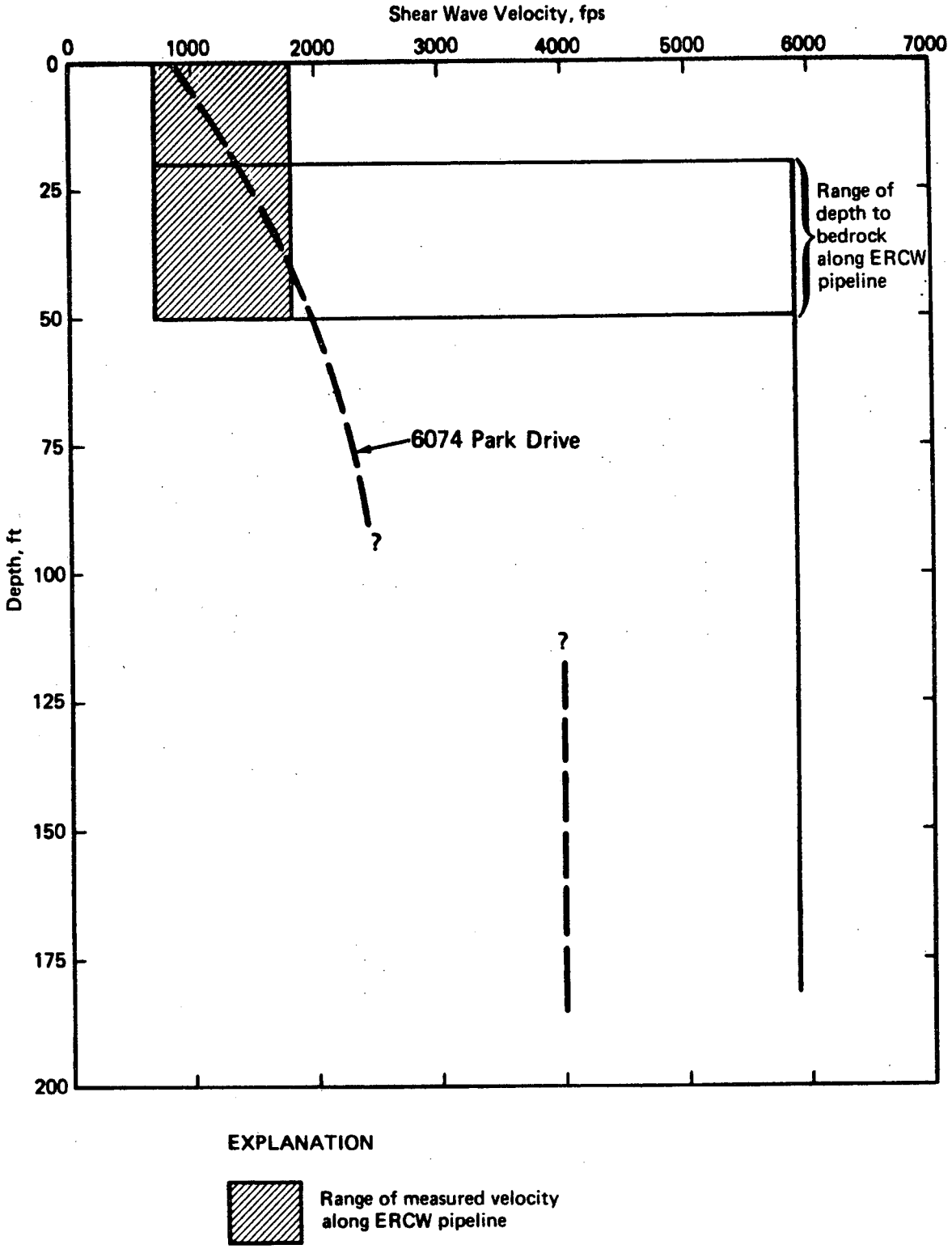


Figure A-1 — Comparison of Shear Wave Velocity Profiles: 6074 Park Drive, Wrightwood versus ERCW Pipeline

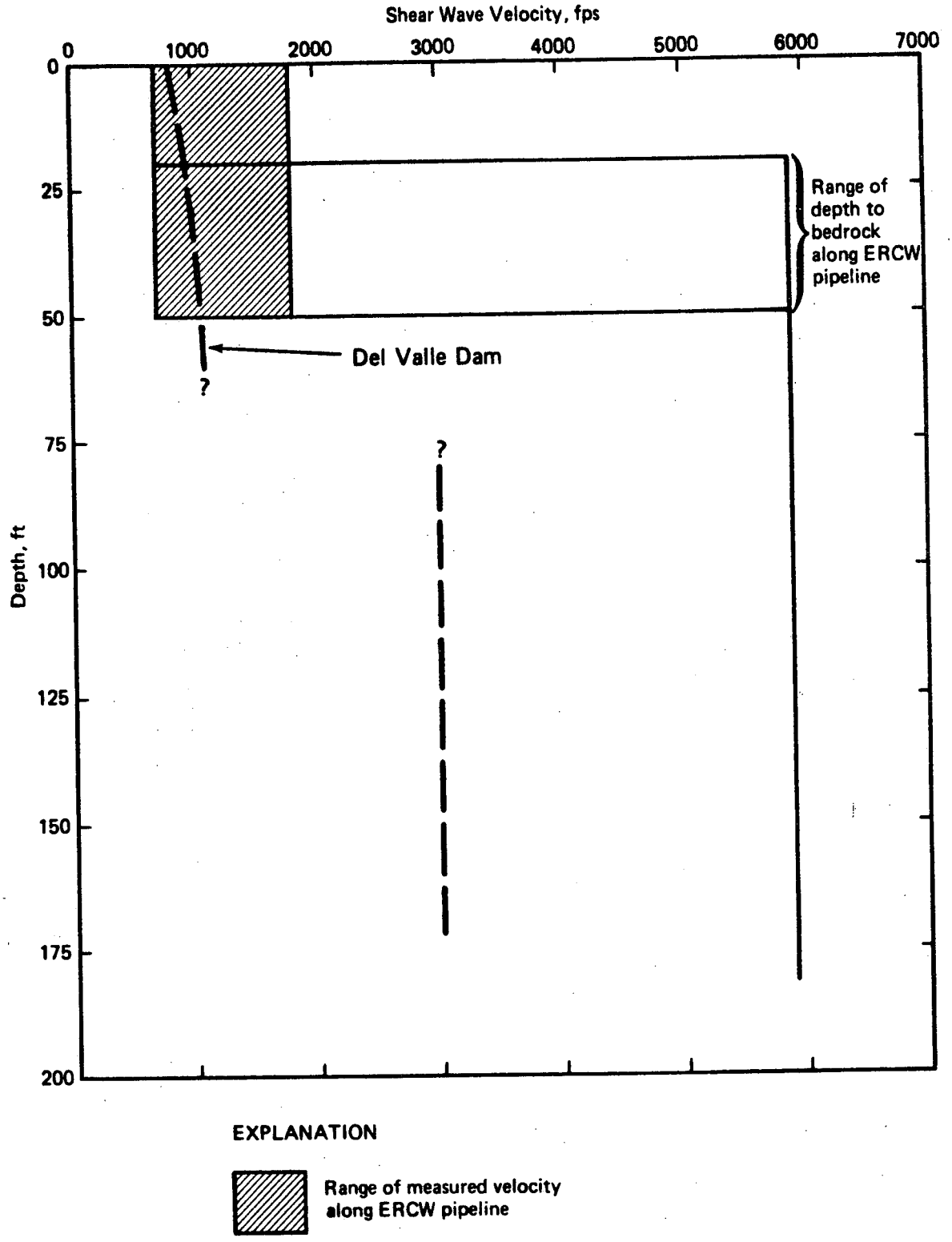


Figure A-2 – Comparison of Shear Wave Velocity Profiles: Del Valle Dam versus ERCW Pipeline

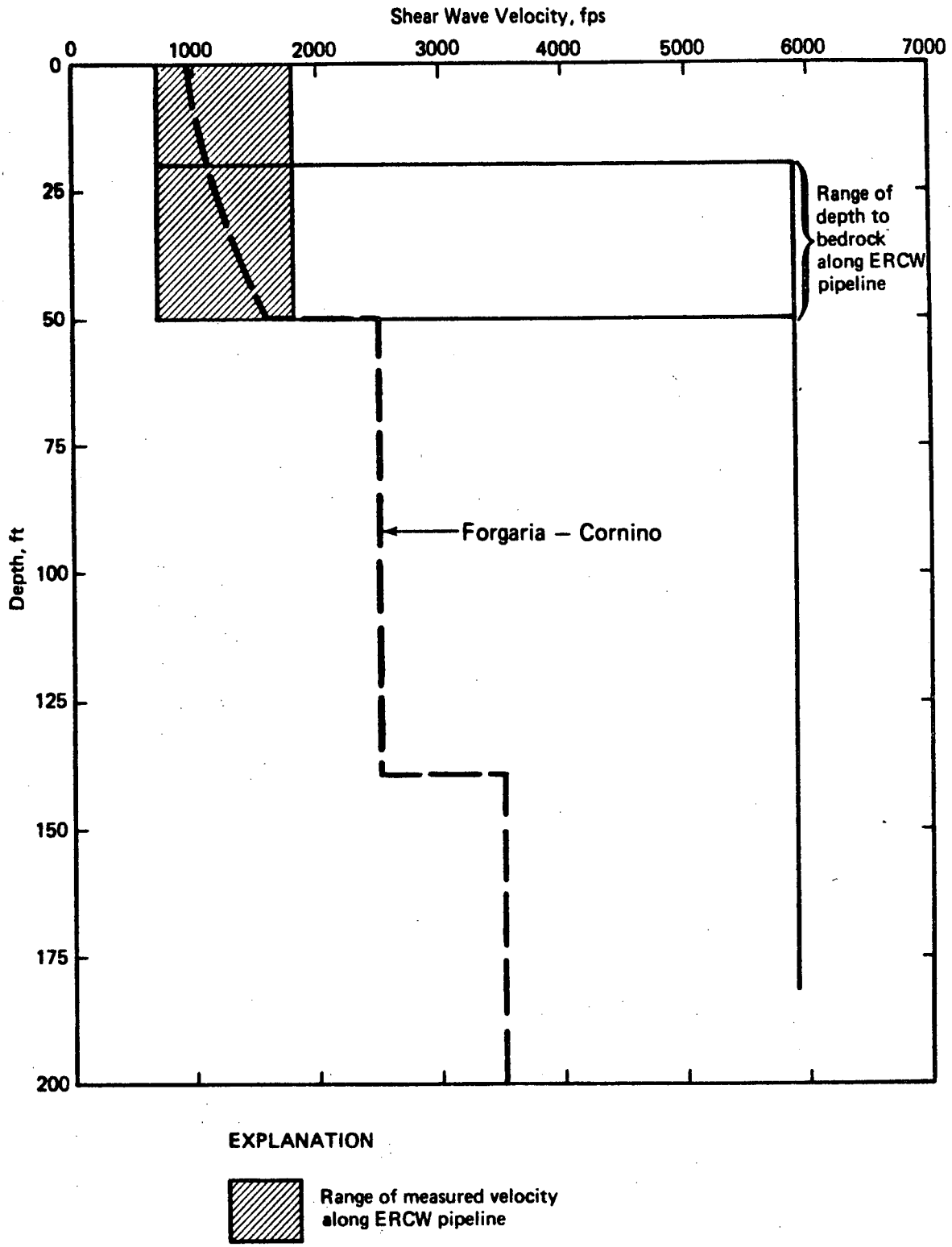


Figure A-3 – Comparison of Shear Wave Velocity Profiles: Forgaria–Cornino versus ERCW Pipeline

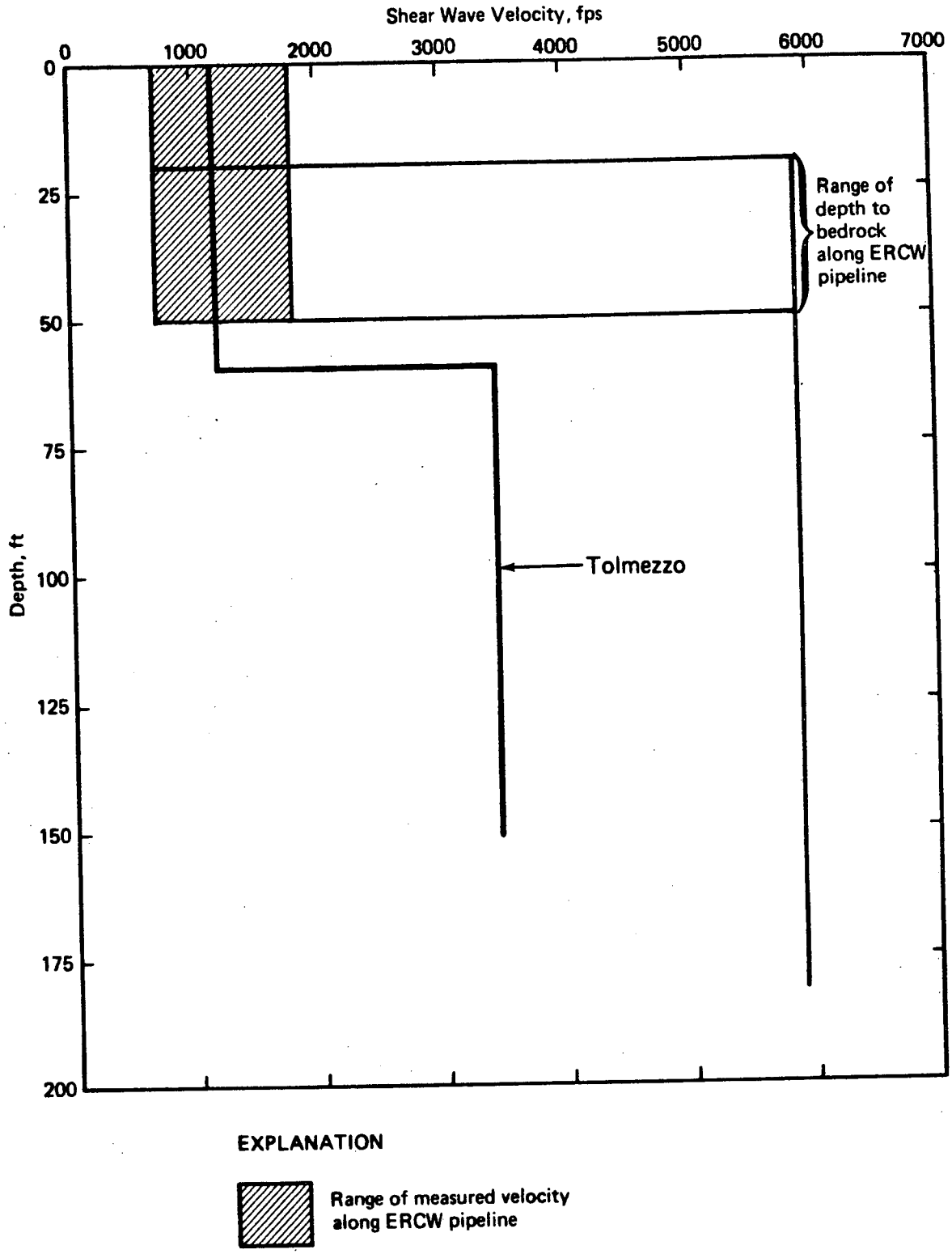


Figure A-4 – Comparison of Shear Wave Velocity Profiles: Tolmezzo versus ERCW Pipeline

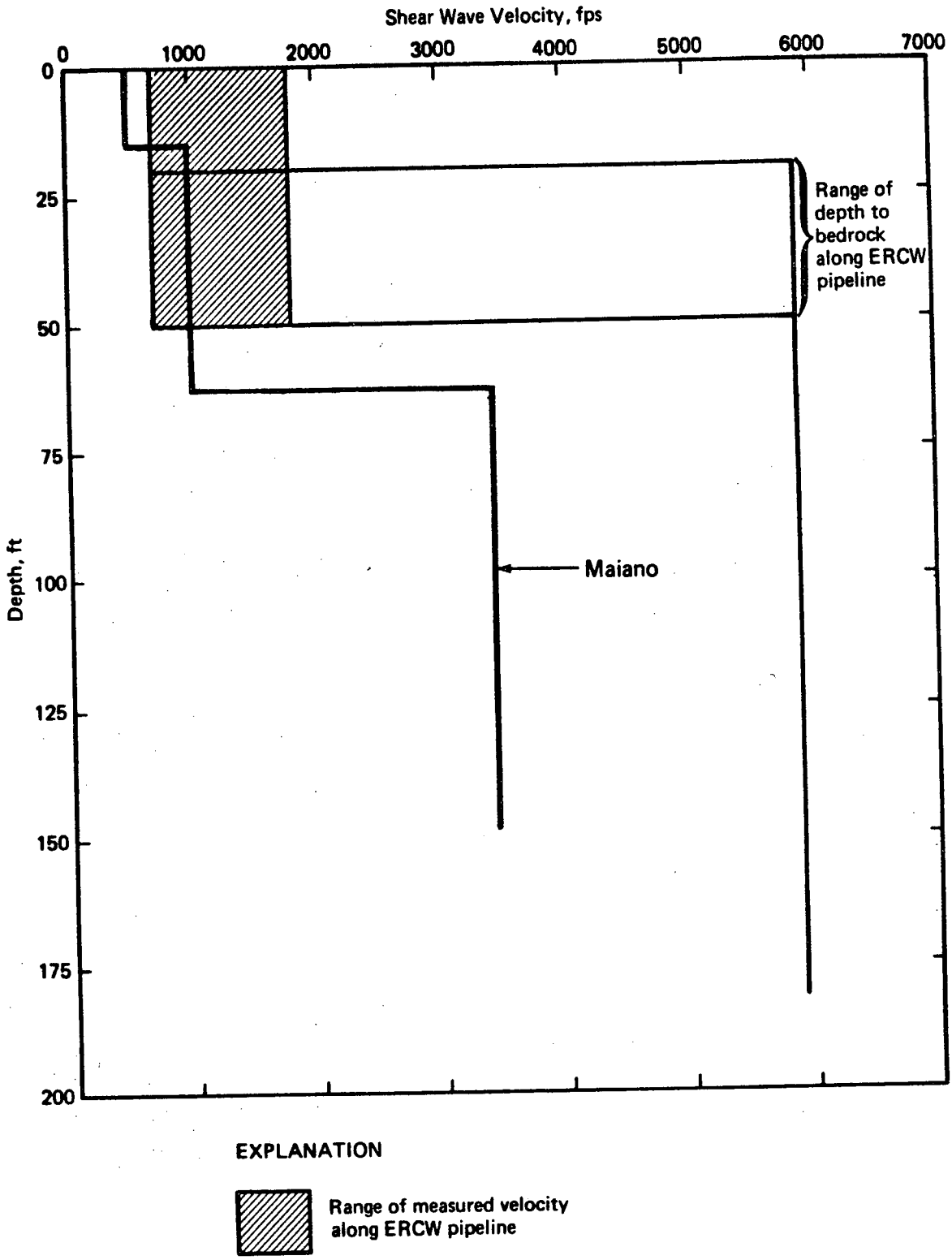


Figure A-5 — Comparison of Shear Wave Velocity Profiles: Maiano versus ERCW Pipeline

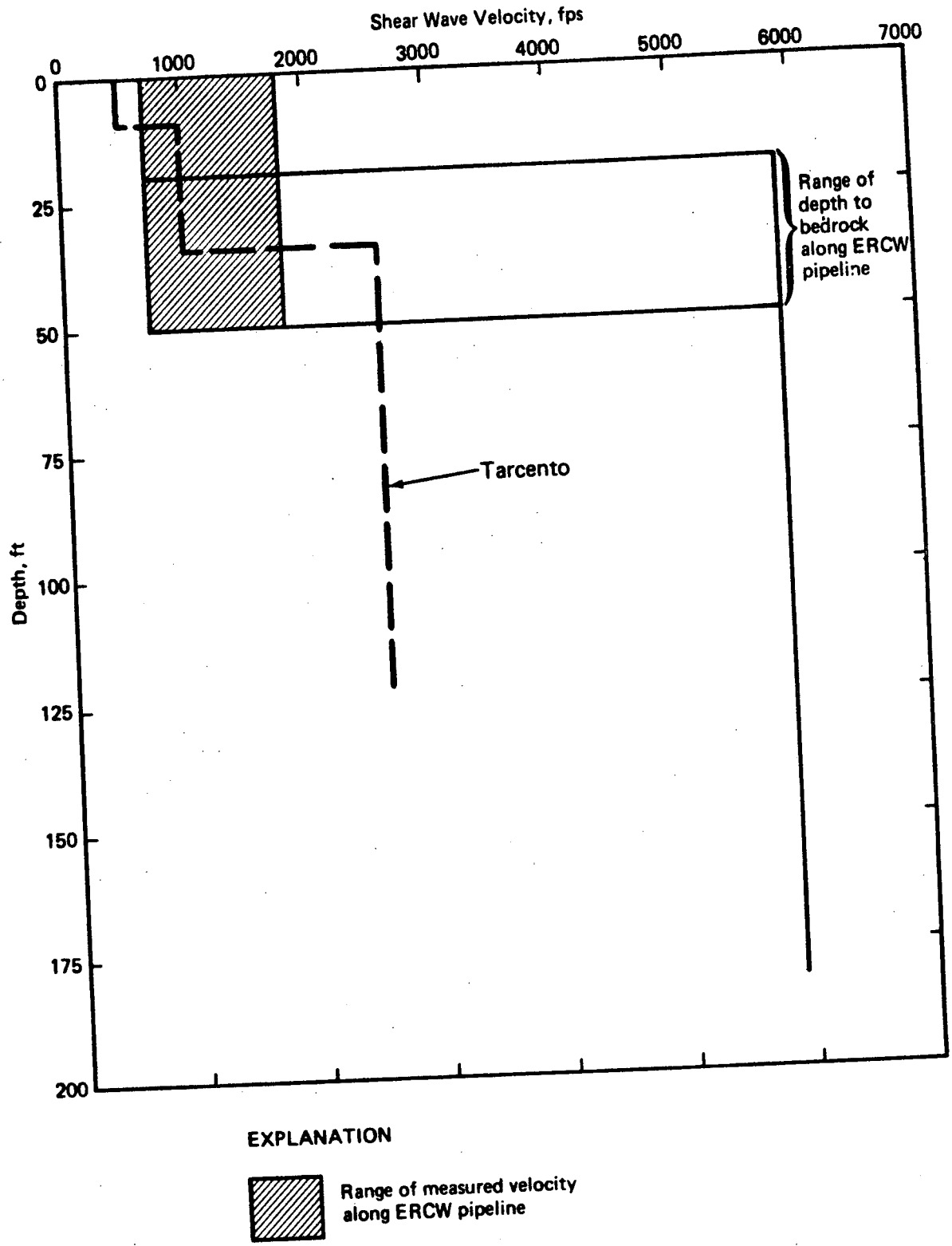


Figure A-6 – Comparison of Shear Wave Velocity Profiles: Tarcento versus ERCW Pipeline