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Yucca Mountain Site Characterization Project

Prediction of Pseudo Relative Velocity Response Spectra at Yucca Mountain for Underground Nuclear Explosions Conducted in the Pahute Mesa Testing Area at the Nevada Test Site

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PREDICTION OF PSEUDO RELATIVE VELOCITY RESPONSE SPECTRA AT YUCCA MOUNTAIN FOR UNDERGROUND NUCLEAR EXPLOSIONS CONDUCTED IN THE PAHUTE MESA TESTING AREA AT THE NEVADA TEST SITE

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ABSTRACT

Pseudo relative velocity response spectra (PSRV) have been calculated for a large body of surface ground motions generated by underground nuclear explosions. These spectra have been analyzed and fit using multiple linear regression techniques to develop a credible prediction technique for surface PSRVs. In addition, a technique for estimating downhole PSRVs at specific stations is included. A data summary, data analysis, prediction development, prediction evaluation, software summary and FORTRAN listing of the prediction technique are included in this report.

This work was performed under WBS 1.2.3.2.8.3.3.

Acknowledgements

J. G. Lee was responsible for data acquisition and J. D. Pearcey was responsible for data processing. J. W. Long reviewed the original manuscript and assisted in retrieval of older UNE test data, programming and data processing. K. A. Sabisch assisted in retrieval of the older UNE test data. M. C. Walck provided valuable advice on several technical areas of this work.

Foreword

The Yucca Mountain Site Characterization Project (YMP), managed by the Office of Geologic Disposal of the Office of Civilian Radioactive Waste Management of the U. S. Department of Energy, is examining the feasibility of siting a repository for commercial, high-level nuclear wastes at Yucca Mountain on and adjacent to the Nevada Test Site (NTS). This work, intended to extend our understanding of the ground motion at Yucca Mountain resulting from testing of nuclear weapons on the NTS, was funded by the Yucca Mountain project and the Military Applications Weapons Test Program. This report summarizes one aspect of the weapons test seismic investigations conducted in FY88.

Preface

The Weapons Test Seismic Investigations (WTSI) project has been working in support of the Yucca Mountain Site Characterization Project (YMP). If a waste storage facility is located near the Nevada Test Site (NTS) it will be subjected to ground shaking generated by underground nuclear weapons tests. A knowledge of expected ground motion levels from these tests will enable the designers to provide for the necessary structural support in the designs of the various components of the repository. The primary mission of the WTSI project involves recording and analyzing ground motion data from these underground nuclear explosions (UNEs) and developing a method to predict the amplitude of ground motions generated at the repository site from future weapons tests.

The WTSI project has deployed a total of 29 seismic stations specifically for the YMP. These seismic stations consist of triaxial accelerometers (i.e., accelerometers are mounted such that accelerations are measured in three mutually perpendicular directions), amplifiers, voltage controlled oscillators (VCO), multiplexers, and transmitters. All stations consist of surface accelerometers. Some of the stations also have companion instrumentation installed below the ground surface (generally at depths greater than 100 m). Initially, these stations were located at several points around the NTS. After the Yucca Mountain area became the focus of characterization activities in 1980, the first WTSI seismic station at Yucca Mountain was installed. Since that time, the WTSI project has had a total of 11 stations in the Yucca Mountain area. At the present time, five stations are active and four of these stations consist of surface and downhole instrumentation.

The data acquisition process consists of selecting UNEs of interest to the Project, turning the seismic stations on by radio and recording the ground motion on analog tape. The analog tape is sent to Sandia National Laboratories in Albuquerque, NM where it is digitized, processed, analyzed, and stored for future reference.

UNEs are selected primarily on the basis of explosive yields. Yields of interest to the Project are between 80 and 150 kt. The lower yield limit was selected because ground motions generated by these lower yields are of a very low amplitude and are of very little interest. The upper yield limit is mandated by the Threshold Test Ban Treaty of March 1976. The distance between the underground explosions of interest and Yucca Mountain varies from about 35 km to 50 km. Approximately five UNEs conducted annually that are of interest to the Project.

As stated above, the primary objective of this effort is to provide a method to predict ground motions at the repository site from future underground weapons tests. This requires not only the development of a prediction model, but a selection of the appropriate future UNE for use in design. A requirement of the design basis UNE is that it provide the largest ground motions at Yucca Mountain of any future UNE. The selection of the future UNE has been made on the basis of real estate availability studies and off-site damage criteria. This design basis event is defined as a 700 kt explosion in the Buckboard Area of NTS. The distance between this future UNE and Yucca Mountain is about 22.8 km (this is the distance from the closest point in the Buckboard Area suitable for testing to Yucca Mountain). The prediction model could be developed by either theoretical studies or empirical studies. Both approaches have limitations. Because of the complex nature of the geology, the three-dimensional nature of the problem, and limitations of current finite element or finite difference computer codes, quantitative results from theoretical studies would be subject to large uncertainties. The empirical approach uses past observations to predict future occurrences. The major limitation in this approach stems from the fact that the future event of interest to the Project falls outside of the realm of the existing data base. Even with this limitation, the empirical approach will have smaller uncertainties associated with the quantitative results than those from a theoretical study.

Because the UNE-generated ground motion data recorded at Yucca Mountain are from explosions of limited yield and distance variations, which do not encompass the design basis UNE, it is important to include ground motion data of larger yields and smaller distances in the analysis effort. Ground motion generated by UNEs has been of interest since the beginning of underground weapons testing. Ground motion data from UNEs, with yields up to 1400 kt, at both close-in locations (at distances within a few burial depths of the explosion) and at seismic distances (measured in terms of tens of burial depths from the explosion) have been recorded and studied. Many of these data were used to develop prediction models for the amplitude of ground motion and to study the transmission characteristics of the NTS area. These studies were conducted prior to the YMP and are not directly applicable to the project. However, the data from some of these older UNEs exist on tape and have been analyzed in the context of the YMP.

The resulting UNE ground motion data base assembled by the WTSI project for the YMP consists of ground motion data from a total of 61 UNEs. Of this number, 38 have been recorded at Yucca Mountain seismic stations. These 38 UNEs have explosive yields between 80 and 150 kt (the current treaty upper limit) and are located in the Yucca Flat and Pahute Mesa testing areas of the NTS. These areas are roughly 35 to 50 km away from Yucca Mountain. The remainder of the UNEs that make up the data base consists of earlier events with yields ranging up to 1400 kt and recording stations located at various points on the NTS at distances of 1 km and greater.

In addition to the primary objective discussed above, the WTSI project is analyzing the UNE ground motion data to understand another important issue. This is the relationship of the transmission of seismic waves and the geologic structure between the testing areas of NTS and Yucca Mountain.

Table P-1 lists the analysis reports that the WTSI project has prepared for the YMP. At this point in time, these reports may be categorized in three basic groups: (as shown in the table). 1) quality assurance related 2) prediction of surface ground motions and (3) prediction of downhole ground motions. (The subject of the transmission of seismic waves is discussed in both group 2 and 3 reports.) The work discussed in this report is covered by Problem Definition Memo 75-8 of the SNL-NWRT department. This report fits in categories 2 and 3. It addresses the subject of the prediction of surface ground motions as represented by the pseudo relative velocity (PSRV) response spectra. In addition it incorporates the work from SAND87-2381 to provide a prediction of downhole PSRV spectra. This report deals with component ground motions recorded at various stations on the NTS and in the Yucca Mountain area from UNEs in the Pahute Mesa Testing area of NTS. The prediction techniques developed in this effort provide acceptable results for UNE ground motions in the Yucca Mountain area as well as NTS in general.

Table P-1. Reports Generated by WTSI for the Yucca Mountain Site Characterization Project

SAND79-1002	Prediction of Ground Motion from Nuclear Weapons Tests at NTS, Vortman, L. J.(Group 2).
SAND80-1020/1	Prediction of Ground Motion from Underground Nuclear Weapons Tests as it Relates to Siting of a Nuclear Waste Storage Facility at NTS and Compatibility with the Weapons Test Program, Vortman, L. J.(Group 2).
SAND81-0784	A Field Comparison of the Kistler 303 and Q-FLEX 1100 and 1200 Accelerometers, Vortman, L. J.(Group 1).
SAND81-2214	Ground Motion from Earthquakes and Underground Nuclear Weapons Tests: A Comparison as it Relates to Siting a Nuclear Waste Storage Facility at NTS, Vortman, L. J.(Group 2).
SAND82-0174	Effects of Repository Depth on Ground Motion - The Pahute Mesa Data, Vortman, L. J. and Long, J. W.(Group 3).
SAND82-1647	Effect of Repository Depth on Ground Motion - The Yucca Flats Data, Vortman, L. J. and Long, J. W.(Group 3).
SAND82-2478	Prediction of Downhole Waveforms, Long, J. W., Sabisch, K. A., Stearns, S. D., and Vortman, L. J.(Group 3).
SAND83-1553	Stresses and Strains at Yucca Mountain from Underground Nuclear Explosions, Vortman, L. J.(Group 2).
SAND83-2625	Proceedings of the Conference on DOE Ground Motion and Seismic Programs On, Around and Beyond NTS, Vortman, L. J., Ed.(Groups 2 & 3).
SAND85-1605	Ground Motion at Yucca Mountain from Pahute Mesa Underground Nuclear Explosions, Vortman, L. J.(Group 2).
SAND86-0439	Component Ground Motion at the Nevada Test Site from Pahute Mesa Underground Nuclear Explosions, Long, J. W.(Group 2).

Table P-1. Reports Generated by WTSI for the Yucca Mountain Site Characterization Project (concluded)

SAND86-2201	Verification of Ground Motion Data Processing Codes, Phillips, J. S.(Group 1).
SAND87-1811	Evaluation of Equations for the Prediction of Peak Ground Motions at Yucca Mountain from Underground Nuclear Explosions in Pahute Mesa, Phillips, J. S. (Group 2).
SAND87-2381	Analysis of Component Surface/Downhole Ground Motions at Yucca Mountain from Underground Nuclear Explosions in Pahute Mesa, Phillips, J. S.(Group 3).

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1.0 INTRODUCTION

1.1 Background

One of the primary goals of the Yucca Mountain Site Characterization Project is the understanding and quantification of the seismic risk at the Yucca Mountain site. This seismic risk consists of both natural and man-made events. The major man-made events of interest to the Project are the underground nuclear explosions (UNEs) conducted at the Nevada Test Site (NTS). The quantification of seismic risk involves development of a credible prediction procedure for UNE-generated ground motions. Several ground motion quantities can be predicted (i.e. peak amplitudes, time histories or response spectra of either vector or component ground motions). Maximum amplitudes of ground motion are useful for some applications, such as gage ranging for upcoming UNEs, but are of limited value for structural analysis because they only provide one aspect of the ground motion environment. Time histories provide a complete picture of the ground motion environment, but they contain so much information it is difficult to determine which aspect of the environment is of most interest in the structural analysis. Response spectra condense the time history information into a form that is more useful than maximum amplitudes and less confusing than the full time histories. The subject of this report is the development of a prediction procedure for pseudo relative velocity (PSRV) response spectra. Only surface ground motions are analyzed in this report. A short discussion of the prediction of downhole motions based on earlier analyses is included in Chapter 3.0.

The PSRV spectrum is the response of a single degree-of-freedom (SDOF) system to a transient input, as a function of the system natural frequency. Many engineering systems may be represented as an SDOF system or a combination of SDOF systems such as that shown in Figure 1-1. This figure shows a schematic representation of an SDOF system subjected to a base motion. The parameters of this system are mass (m), spring stiffness (k), damping (c), base displacement (y), mass displacement (x), relative displacement (u), and time (t). A convenient representation of the response of such a system to the amplitude and frequency content of input ground motion is the response spectrum. The response spectrum may be expressed in terms of the relative displacement between the mass and the base, the relative velocity between the mass and the base, or the absolute acceleration of the mass. The following discussion will provide some background on the concept of the PSRV response spectrum.[1] Much of this information was condensed from Higgins et al., (1978), Newmark and Rosenbluth (1971), and Crawford et al., (1974).

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[1] *Note that the PSRV response spectrum will be referred to as the "PSRV" throughout this report.*

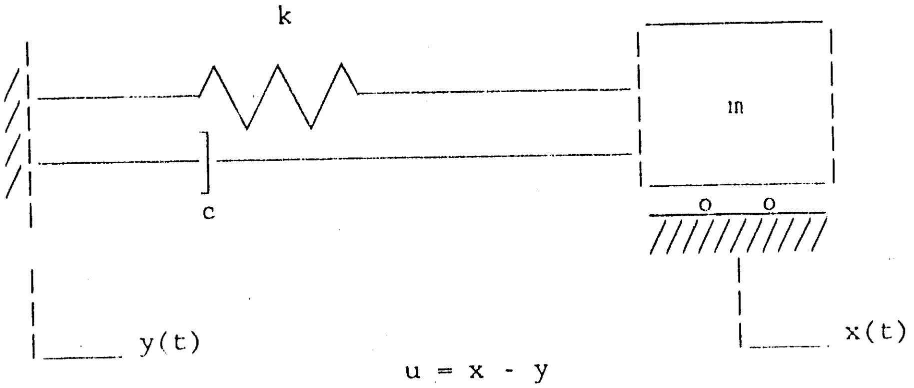

Figure 1-1. Single-Degree-of-Freedom-System Subjected to Base Motion.

The equation of motion for the mass in Figure 1-1 is

$$\ddot{u}(t) + 2\beta\omega_n \dot{u}(t) + \omega_n^2 u(t) = -\ddot{y}(t), \qquad (1\text{-}1)$$

where

x, y and u are as described above
the dot indicates differentiation with respect to time;
β is the damping ratio $(c/2\sqrt{km})$
ω is the undamped natural frequency $(\sqrt{k/m})$.

Assuming zero initial conditions, this equation can be solved to yield an expression for relative displacement (Higgins et al., 1978). This expression is

$$u = \frac{-1}{\omega_n\sqrt{1-\beta^2}} \int_0^t \ddot{y}(\tau)e^{-\beta\omega_n(t-\tau)} \sin\left[\omega_n \sqrt{1-\beta^2}\,(t-\tau)\right] d\tau . \qquad (1\text{-}2)$$

Expressions for relative velocity and absolute acceleration may be derived through manipulation (differentiation with respect to time, the use of the relationship between relative displacement and acceleration, and simplification. The maximum values from equation 1-2, and the derived expressions for absolute acceleration and relative velocity can be computed as a function of natural frequency and damping of the system for any base motion and plotted as a function of frequency. The resulting curves are the response spectra for the system. Each of these parameters is important in describing the response of the system. The maximum relative velocity spectrum is a direct measure of the maximum energy per unit mass in the system; the relative displacement spectrum is related to system strain; and absolute acceleration spectrum is related to the lateral force coefficient frequently used in building codes.

These spectra are usually simplified by making the assumption of small damping (i.e., $\beta < 0.2$, such that $\sqrt{1-\beta^2} \sim 1$). This simplifies Equation 1-2 to

$$u = \frac{-1}{\omega_n} \int_0^t \ddot{y}(\tau) e^{-\beta\omega_n(t-\tau)} \sin \omega_n' (t-\tau)\, d\tau . \qquad (1\text{-}3)$$

Performing the same manipulations discussed above and dropping the separate terms with β and β^2 yields expressions for absolute acceleration and relative velocity. The maximum values of pseudo absolute acceleration (or simply pseudo acceleration) and relative displacement are related in the following manner

$$A = \omega_n^2 D , \qquad (1\text{-}4)$$

where

A is the pseudo acceleration
D is the relative displacement.

Pseudo acceleration amplitudes are generally close to the absolute acceleration (Newmark and Rosenbluth, 1971). The derived expression for the pseudo relative velocity differs from the other two parameters by a factor of the natural frequency and the fact that it contains a cosine function rather than a sine function. If the cosine is replaced by the sine in the expression for the relative velocity, the three parameters are related in the following manner

$$\frac{1}{\omega_n} A = V = \omega_n D \qquad (1\text{-}5)$$

where

V is the pseudo relative velocity.

Relative velocity and pseudo velocity will be significantly different when the system period is much longer than the duration of the input ground motion (Higgins et al., 1978). For many instances, however, the pseudo velocity and relative velocity will be roughly equal.

The A, V and D parameters are generally plotted in log space on tripartite graph paper. An example is shown in Figure 1-2. The horizontal axis is frequency and the vertical axis is pseudo relative velocity. Any point on this plot for a given frequency describes the system strain, energy absorbed by the system, and the maximum force in the system.

The ground motion quantities that are actually measured are ground velocity and ground acceleration versus time. These time histories are recorded in analog, digitized, processed, and filtered. In general, the frequencies most often filtered from the "raw" data are those less than 0.3 Hz and greater than 30 Hz. These filtered waveforms are used as input to the computer code used to calculate PSRVs (see Appendix A). The PSRVs are run at a damping factor of 5%. Although the PSRV is not technically observed ground motion, it will be referred to as "observed data" in the text of this report. In some instances, plots of PSRVs will be presented in this report that show data extending from 0.1 to 100 Hz. This is done merely as a plotting convenience. The analyses and discussions that follow apply only to 5% damped PSRVs at frequencies between 0.3 and 30 Hz.

The quantities discussed in this report are measured in the following units:

Pseudo Accelerations are in gs;
Pseudo Relative Velocities are in cm/s;
Relative Displacements are in cm;
Source-to-station distance is in km;
Weapon yield is in kt.

These are the units used in the regression analyses and are the units used for input into the prediction procedure. Source-to-station distance, as defined in this report, is the slant range from the shot point to the measurement location.

1.2 Objectives

The primary objective of this report is to document the development of a credible prediction technique for PSRVs of UNE-generated ground motions at Yucca Mountain. This effort will focus on the prediction of surface ground motions but incorporate past work on downhole motions as well (Phillips, 1987). In addition, some effort is made to identify and quantify station effects at the Yucca Mountain stations.

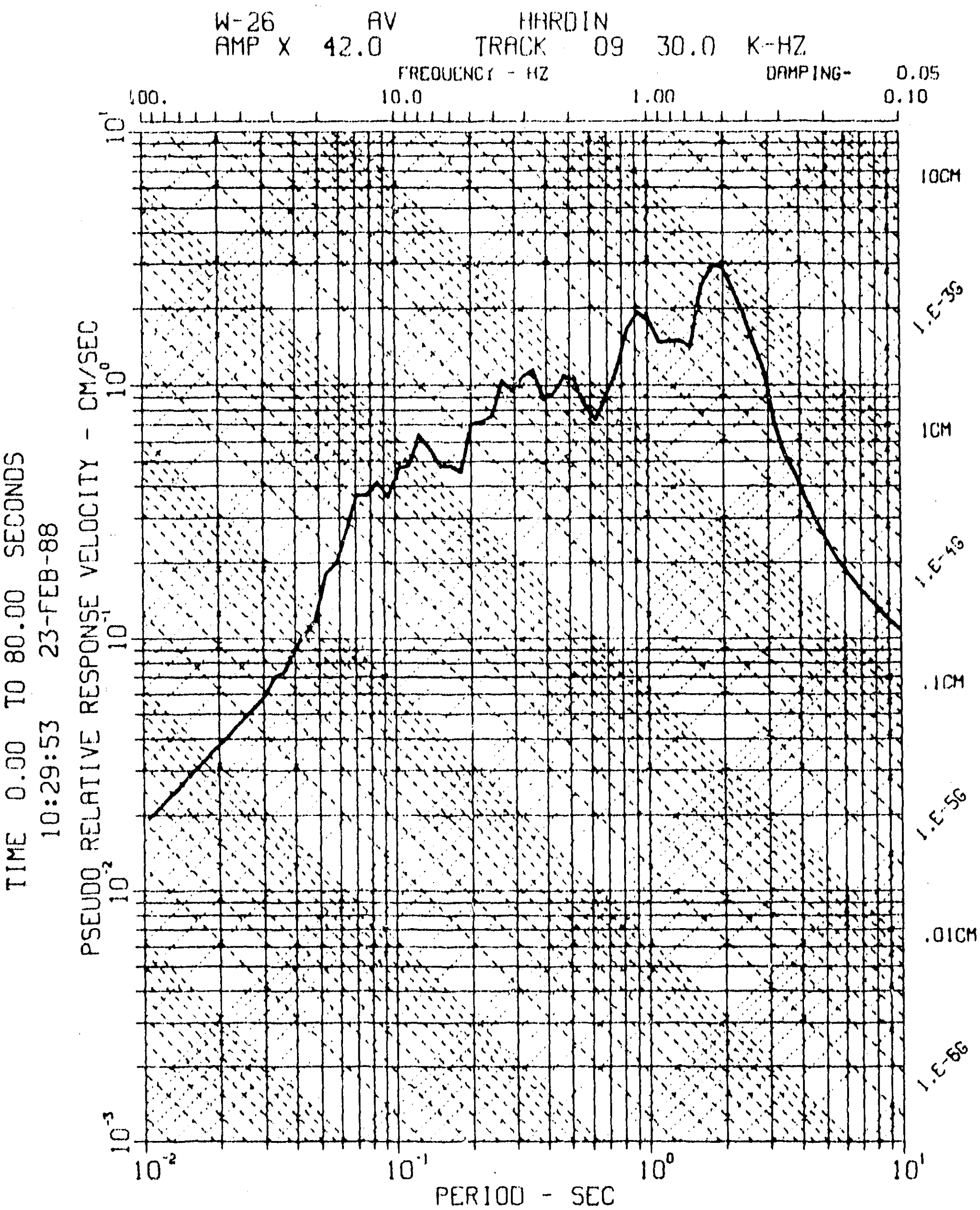

Figure 1-2. Example of a PSRV Plotted on Tripartite Paper (Event Hardin, Station W26)

1.3 Organization

This report contains a large amount of information. In addition, some aspects of this effort are classified. In an effort to present the information in a logical manner and protect the classified material, this report is organized as follows. Chapter 2 contains an unclassified summary of the data base used in the analyses presented in this report. A summary of the data analyses is contained in Chapter 3. The recommended prediction equations and an evaluation of these equations are presented in Chapter 4. Conclusions are given in Chapter 5. A total of three appendices are included in this report.

Appendix A contains the verification and description of the computer codes used in the analyses. Appendix B contains a FORTRAN listing of the prediction procedure developed in this study. A classified summary of the data base used for this effort will be published as a separate report.

2.0 DATA SUMMARY

A map of NTS is shown in Figure 2-1. This map shows the relative locations of the major weapons testing areas (of interest to the project) and Yucca Mountain. The UNEs discussed in this report have been conducted in Areas 19 and 20 of NTS (Pahute Mesa). Included on this figure are the approximate locations of the design basis UNE and the various stations that have been fielded in support of the Yucca Mountain Site Characterization Project. Table 2-1 lists the locations and dates of operation of the WTSI stations that have been used in the support of the Yucca Mountain Site Characterization Project. Figure 2-2 shows an enlargement of the Yucca Mountain area. A total of eleven stations (five of which had downhole instrumentation) have been fielded in the Yucca mountain area. Currently, there are five active stations four of which have companion downhole instrumentation.

The core of the ground motion data used in this effort was originally selected for the analyses presented in Vortman (1986). (This study was similar in objectives to the current effort, however, only peak amplitudes were analyzed.) This initial selection, described by Vortman, was made on the basis of judgement and experience. The study reported herein expanded and edited the original data base.

Table 2-2 summarizes the event names, dates, general locations and a description of the type of ground-motion monitoring for older UNEs used in this study. Ground motions were generally monitored for two reasons in this group of events. The first reason was to understand close-in ground motion. These stations were at distances generally less than 10 km from the UNE. These are noted as "scientific" stations in Table 2-2. The second reason for monitoring ground motions was to assess off-site safety. These stations were both on-site and off-site. These stations are listed as "USGS" in Table 2-2. In addition, a number of UNEs included in this set were monitored after the initiation of the Nevada Nuclear Waste Site Investigations (predecessor to the Yucca Mountain Site Characterization Project), but prior to the narrowing of those investigations to the Yucca Mountain area. These events have stations categorized as "NNWSI" in Table 2-2. In this effort, the ground motion data from these UNEs were examined for suitability and quality. The last column in Table 2-2 indicates the number of ground motion records used in this study. The off-site stations were not used because the facilities of concern to this project are primarily on-site. Ground motions from close-in stations which exhibited the characteristics of spall were also eliminated from the data set.[2] Pahute Mesa UNEs that have been monitored through FY88

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[2] *Spall results when a compressive wave impinges on a free surface. The compressive wave is reflected back into the material as a tensile wave. Geologic materials are very weak in tension and the material fractures. When failure occurs "layers" of material are thrown into the air. At some point the upward velocity of the layers is*

at the Yucca Mountain stations are shown in Table 2-3. In general, the data from this group of events are internally consistent and of good quality. Very few data records were eliminated from this set because of problems. Ground motion at Yucca Mountain was first recorded in 1980. The reader should be aware that between 1980 and 1986 this effort was designated at the lowest quality assurance (Q/A) level. During FY86 the Q/A level was upgraded to the highest level. Events in Table 2-3 designated as QI were recorded in compliance with the requirements of this higher Q/A level.

The final data base used for this study consists of recorded ground motions from 49 UNEs. Ground motions were recorded at Yucca Mountain for 28 of these events. The remaining 21 UNEs predate the installation of recording instruments at Yucca Mountain. The source-to-station distance variation in this data base is from approximately 1 to 60 km. The yield variation is from 80 to 1400 kt. The distribution of yields in the data base is as follows: 9 events had yields greater than 500 kt; 7 events had yields between 150 and 500 kt; and the remainder of the events had yields between 80 and 150 kt (all UNEs recorded at Yucca Mountain are included in this last group). The final data set included a total of 585 vertical, 585 radial and 587 transverse component records. This data base was selected to provide as broad a spectrum in source-to-station distances and yields as possible. This is necessary to minimize the bias to a specific range of yields and source-to-station distances in the data base and to encompass the distance and yield parameters of the design basis UNE.

In addition to the 49 UNEs used to derive the prediction equations, 4 UNEs which were not included in the data set were used to evaluate the prediction equations. These events consist of one large yield event (>500) and three recent UNEs recorded at Yucca Mountain (yield between 80 and 150 kt). These events were selected to try to gage the accuracy of the procedure in a "true" predictive situation.

The analysis of this data set is discussed in the subsequent chapters of this report.

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cancelled by the gravitational forces and the layers fall back to the surface. This phenomenon is observed at close-in stations but is not representative of the ground motions that will be observed in the Yucca Mountain area from current or future UNEs.

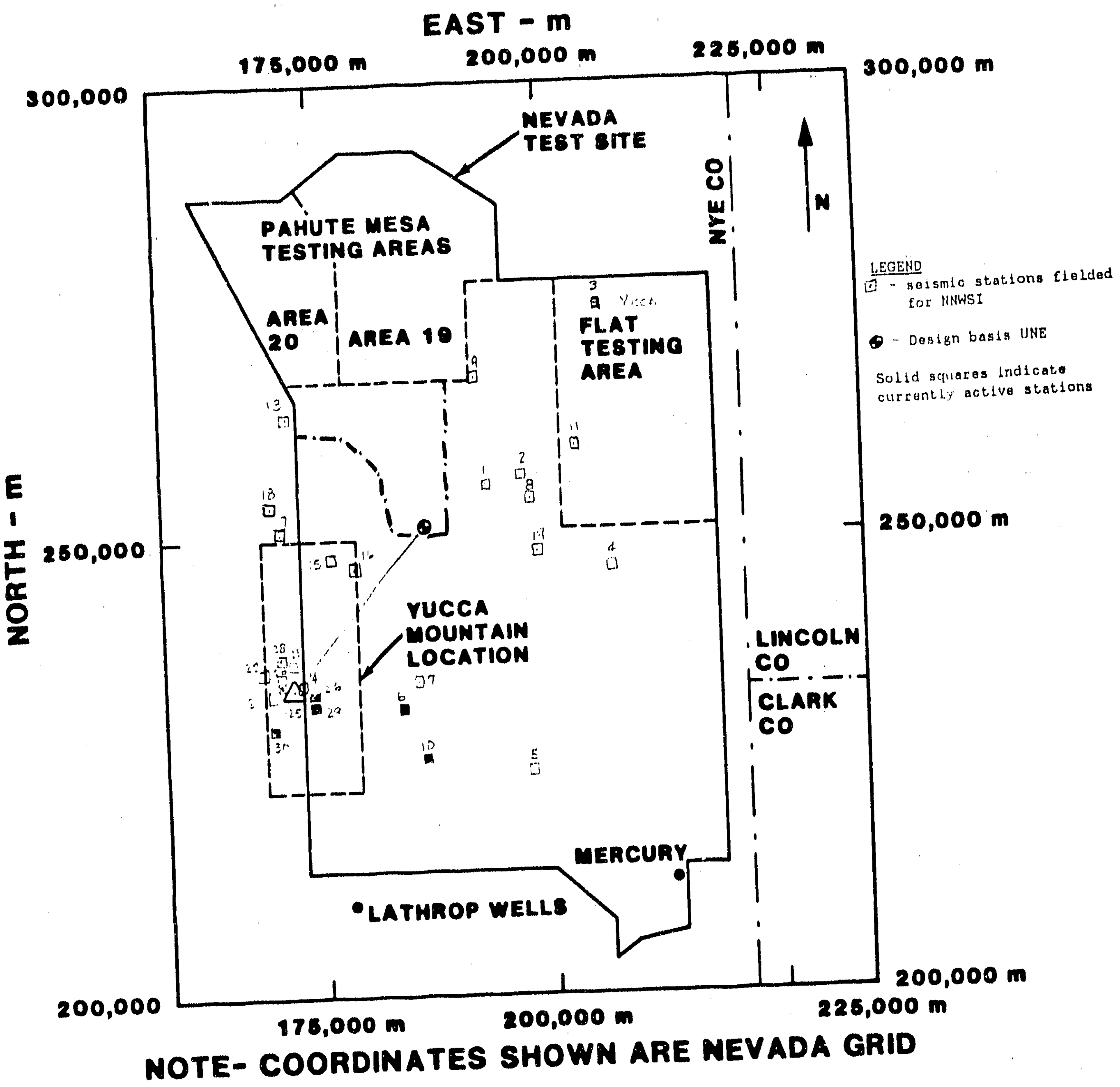


Figure 2-1. Location of Current Testing Areas, Past and Present WTSI Seismic Stations, the Design Basis UNE, and Yucca Mountain on NTS

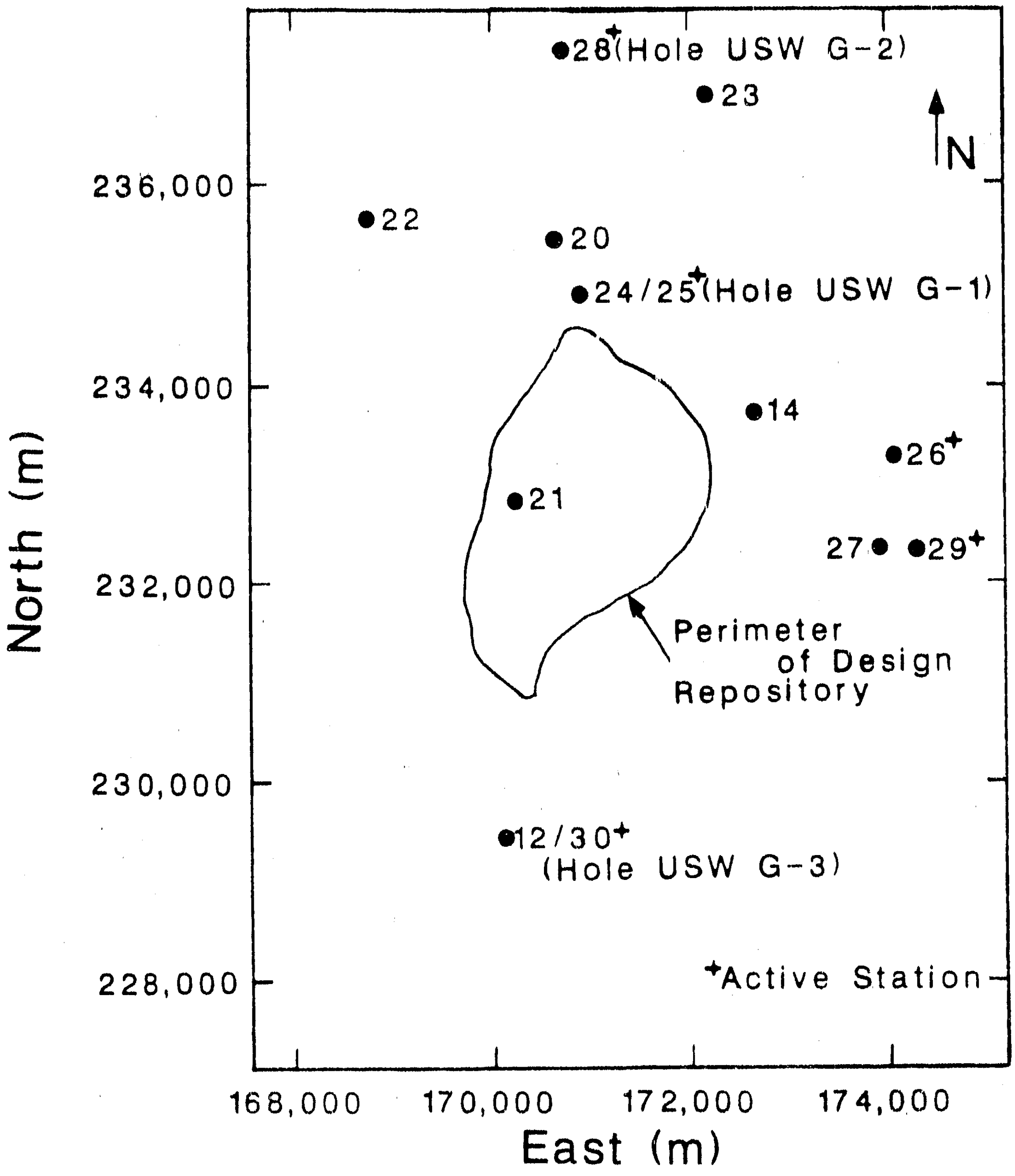


Figure 2-2. Location of the Yucca Mountain Stations

TABLE 2-1 WEAPONS TEST SEISMIC INVESTIGATION STATION LOCATIONS.

Station	Location	Hole No.	Depth (m)	Medium	Date Installed
W-1	Area 16	None	Surface Only	Eleana Shale	8/77 (Removed 11/77)
W-2	Syncline Ridge	None	Surface Only	Limestone over Eleana Shale	8/77 (Removed 6/78)
W-3	Piledriver	Ue-15.01	Surface 417	Granite	9/77 (Removed 5/83)
W-4	Area 6	Ue-6b	Surface 130	Alluvium	4/77 (Removed 5/78)
W-5	Skull Mountain	None	Surface Only	Tuff	10/77 (Moved 5/81) (Removed 10/83)
W-6	ETS-2	None	Surface Only	Alluvium	10/77
W-7	Calico Hills	None	Surface Only	Eleana Shale	10/77
W-8	Yacht Hole	Ue-1L	Surface 679	Alluvium over Eleana Shale	3/78 (Removed 8/78) 570a
W-9	Rainier Mesa	U-12g.08 CH No. 1	Surface 432	Tuff	12/77 (Removed 4/84)
W-10	Well J-11	J-11	Surface 356b 343	Alluvium over Tuff	3/78 4/78
W-10'	200	J-11'	Surface 61	Alluvium	3/78 (Removed 7/81)
W-11	Area 4	Ue-4aa	Surface 346	Alluvium over Limestone	3/78 (Removed 4/84)
W-12 (W-30)	Yucca Mountain	USW-GU3	Surface 352	Tuff	3/83 (W-30 on 1/85)

TABLE 2-1 WEAPONS TEST SEISMIC INVESTIGATION STATION LOCATIONS. (continued)

Station	Location	Hole No.	Depth (m)	Medium	Date Installed
W-13	Area 18	Ue-18r	Surface 762	Tuff over Welded Tuff	6/78 8/78 (Removed 4/84)
W-14	Yucca Mountain	None	Surface Only	Tuff	6/80 (Removed 7/85)
W-15	Dome Mountain	None	Surface Only	Lava	10/78 (Removed 6/82)
Station	Location	Hole No.	Depth (m)	Medium	Date Installed
W-16	40 Mile Canyon	None	Surface Only	Rhyolite	10/78 (Removed 8/82)
W-17	N. Timber Mtn	None	Surface Only	Tuff	7/78 (Removed 8/82)
W-18	S. Timber Mtn	None	Surface Only	Tuff	7/78 (Removed 8/82)
W-19	Mine Mountain	None	Surface Only	Limestone	2/79 (Removed 9/80)
W-20	Yucca Mountain	None	Surface Only	Tuff	7/80 (Moved to USW-G1 4/82)
W-21	Yucca Mtn, SW	None	Surface Only	Tuff	7/80 (Removed 8/85)
W-22	Yucca Mtn, NW	None	Surface Only	Tuff	7/80 (Removed 8/85)
W-23	Yucca Mtn, NE	None	Surface Only	Tuff	7/80 (Removed 8/85)
W-24	Yucca Mountain	USW-G1	Surface 564	Tuff	3/82 (Removed 7/83)

TABLE 2-1 WEAPONS TEST SEISMIC INVESTIGATION STATION LOCATIONS. (concluded)

Station	Location	Hole No.	Depth	Medium	Date Installed
W-25	Yucca Mountain	USW-G1	Surface 358 305c	Tuff	8/83
W-26	Yucca Mountain	None	Surface Only	Alluvium	4/84
W-27	Yucca Mountain	None	Surface 35	Alluvium	6/84 (Removed 8/84)
W-28	Yucca Mountain	USW-G2	Surface 375 358c	Tuff	6/84
W-29	Yucca Mountain	UE25 RF-4	Surface 82	Alluvium	2/85
A	Jackass Flats	None	Surface Only	Alluvium	8/78
B	Jackass Flats	None	Surface Only	Alluvium	8/78 (Removed 8/84)
C	Jackass Flats	None	Surface Only	Alluvium	8/78 (Removed 8/84)
D	Jackass Flats	None	Surface Only	Alluvium	8/78 (Removed 8/84)

a. after 4/78
b. before 12/78
c. after 4/87

TABLE 2-2 SUMMARY OF OLDER PAHUTE MESA EVENTS USED IN THIS STUDY

Event	Area	Date	Station Type and Number				Number of Stations Used in this Study
			Scientific	USGS	YMP	Total	
Halfbeak	19	06/30/66	6	4	-	10	2
Scotch	19	05/23/67	3	1	-	4	2
Boxcar	20	04/26/68	8	6	-	14	6
Jorum	20	09/16/69	6	7	-	13	1
Handley	20	03/26/70	7	2	-	9	1
Almendro	19	06/06/73	5	17	-	22	4
Tybo	20	05/14/75	10	-	-	10	1
Mast	19	06/19/75	7	1	-	8	3
Camenbert	19	06/26/75	6	1	-	7	2
Kasseri	20	10/28/75	7	1	-	8	0
Inlet	19	11/20/75	7	1	-	8	3
Muenster	19	01/03/76	6	1	-	7	2
Fontina	20	02/12/76	7	1	-	8	3
Chesire	20	02/14/76	8	1	-	9	2
Estuary	19	03/09/76	4	1	-	5	4
Colby	20	03/14/76	9	-	-	9	6
Pool	19	03/17/76	10	3	-	13	5
Fondutta	19	04/11/78	5	-	8	13	13
Backbeach	19	04/11/78	2	-	8	10	9
Panir	19	08/31/78	5	-	9	14	14
Farm	20	12/16/78	4	-	16	20	15
Sheepshead	19	09/26/79	2	-	17	19	17
Pepato	20	11/06/79	4	-	16	20	16
Colwick	20	04/26/80	-	-	18	18	16

TABLE 2-3 SUMMARY OF PAHUTE MESA EVENTS RECORDED AT YUCCA MOUNTAIN.

Station	12/30	14	20	21	22	23	24	25	26	27	28	29
Location - N E	229421 170231	233834 172241	235386 170860	232863 170350	235645 168888	236852 172250	234848 170993	234848 170993	233233 174163	232316 174007	237386 170841	232288 174365
Elevation	1480 1128	1255	1462	1482	1580	1447	1325 762	1325 967 1021 (>4/87)	1111	1124 1089	1554 1179 1196 (>4/87)	1109 1026
Type	Surface 352	Surface Only	Surface Only	Surface Only	Surface Only	Surface Only	Surface 564	Surface 358 305 (>4/87)	Surface Only	Surface 35	Surface 375 358 (>4/87)	Surface 82
Dates of Operation	3/83 to present	6/80 to 7/85	7/80 to 4/82	7/80 to 8/85	7/80 to 8/85	7/80 to 8/85	3/82 to 7/83	8/83 to present	4/84 to present	6/84 to 8/84	6/84 to present	2/85 to present
Event (Area & Date)												
Kash 20 6/12/80		X										
Tafi 20 7/25/80		X	X	X		X						
Serpa 19 12/17/80		X	X	X	d	c						
Harzer 19 6/6/81		X	X	X	X	X						
Molbo 20 2/12/82		X	X	X	X	X						
Hosta 19 2/12/82		X		X	X	X						
Gibne 20 4/25/82		X		X	X	X	X/X					
Nebbiolo 19 6/24/82		X		X	X		b/X					
Cabra 20 3/26/83	X/X	c,d		X		X	X/X					
Chancellor 19 9/1/83	X/X	X		X		X		X/X				
Kappeli 20 7/27/84	X/X	X		X		e		X/X	X	X/X	d/X	
Egmont 20 12/9/84	c,e/a	X		X	X	X		X/X	X		c/X	

TABLE 2-3 SUMMARY OF PAHUTE MESA EVENTS RECORDED AT YUCCA MOUNTAIN (continued).

Station	12/30	14	20	21	22	23	24	25	26	27	28	29
Location - N E	229421 170231	233834 172241	235386 170860	232863 170350	235645 168888	236852 172250	234848 170993	234848 170993	233233 174163	232316 174007	237386 170841	232288 174365
Elevation	1480 1128	1255	1462	1482	1580	1447	1325 762	1325 967 1021 (>4/87)	1111	1124 1089	1554 1179 1196 (>4/87)	1109 1026
Type	Surface 352	Surface Only	Surface Only	Surface Only	Surface Only	Surface Only	Surface 564	Surface 358 305 (>4/87)	Surface Only	Surface 35	Surface 375 358 (>4/87)	Surface 82
Dates of Operation	3/83 to present	6/80 to 7/85	7/80 to 4/82	7/80 to 8/85	7/80 to 8/85	7/80 to 8/85	3/82 to 7/83	8/83 to present	4/84 to present	6/84 to 8/84	6/84 to present	2/85 to present
Event (Area & Date)												
Tierra 19 12/15/84	x/a	X		X	X			b/X	X		X/X	
Towanda 19 5/2/85	X/X	X		X	X	X		X/X	X		X/a	X/X
Salut 20 6/12/85	X/X	X		X	X	X		X/X	X		X/X	X/X
Serena 20 7/25/85	X/X	X		X	X	X		X/X	X		X/X	X/X
Goldstone 20 12/28/85	X/X							X/X	X		X/X	X/X
Jefferson 20 4/22/86	X/X							X/X	X		X/X	X/X
Darwin 20 6/25/86	X/X							X/X	X		X/X	X/X
Labquark 19 9/30/86	X/X							X/X	X		X/X	X/X
Belmont 20 11/16/86	X/X							X/X	X		X/X	X/X
Bodie 20 12/13/86	X/X							k	X		X/X	X/X
Delamar 20 4/18/87	X/X							k	X (QI)		j	X/X

TABLE 2-3 SUMMARY OF PAHUTE MESA EVENTS RECORDED AT YUCCA MOUNTAIN (concluded).

Station	12/30	14	20	21	22	23	24	25	26	27	28	29
Location - N E	229421 170231	233834 172241	235386 170860	232863 170350	235545 168888	236852 172250	234848 170993	234848 170993	233233 174163	232316 174007	237386 170841	232288 174365
Elevation	1480 1128	1255	1462	1482	1580	1447	1325 762	1325 967 1021 (>4/87)	1111	1124 1089	1554 1179 1196 (>4/87)	1109 1026
Type	Surface 352	Surface Only	Surface Only	Surface Only	Surface Only	Surface Only	Surface 564	Surface 358 305 (>4/87)	Surface Only	Surface 35	Surface 375 358 (>4/87)	Surface 82
Dates of Operation	3/83 to present	6/80 to 7/85	7/80 to 4/82	7/80 to 8/85	7/80 to 8/85	7/80 to 8/85	3/82 to 7/83	3/83 to present	4/84 to present	6/84 to 8/84	6/84 to present	2/85 to present
Event (Area & Date)												
Hardin 20 4/30/87	X/X							X/X (QI)	X (QI)		X/X (QI)	X/X
Lockney 19 9/24/87	X/a (QI)							X/X (QI)	X (QI)		X/X (QI)	X/X (QI)
Kernville 20 2/15/88	X/a (QI)							X/X (QI)	X (QI)		X/X (QI)	X/X (QI)
Comstock 20 6/2/88	X/a (QI)							X/X (QI)	X (QI)		X/X (QI)	X/X (QI)
Alamo 19 7/7/88	X/a (QI)							X/X (QI)	X (QI)		X/X (QI)	X/X (QI)
Kearsarge 19 8/17/88	X/a (QI)							X/X (QI)	X (QI)		X/X (QI)	X/X (QI)

Notes:

a. Surface only
b. Downhole only
c. No AV at surface
d. No AR at surface
e. No AT at surface
f. No AV downhole
g. No AR downhole
h. No AT downhole
i. Quality of records not yet determined
j. Not installed for shot
k. No data obtained

(QI) Indicates under QI

Station 25/28 at different depths after 4/87

All distances shown in meters

3.0 DATA ANALYSIS

3.1 Introduction and Method

Observed ground motion is a function of the source (energy and coupling), source-to-station distance and the geology. This geology is made up of the source geology, receiver (or station) geology and the travel path geology. A prediction procedure for any aspect of ground motion should take these parameters into consideration. In this study, as in others done for this project, all sources are assumed to be the same (i.e., a radially expanding compressional shock front at the shot point). Source energy is described in terms of the explosive yield of the UNE. Differences in source geology are assumed to be small because all UNEs in this study were conducted in Pahute Mesa. In addition, differences in coupling are considered to be of only minor importance (as shown in the analyses of Vortman, 1986) in this data set largely because of the similarity in source geologies. Differences in travel path geology are largely ignored in this approach. (Travel path is implicitly considered in the Yucca Mountain data set because the source and receiver areas are the same; i.e., essentially only one path. This approach is not without precedent or success; e.g., Environmental Research Corporation, 1984. Station geology is broadly classified as either alluvium or rock to account for differences in receiver structure.

Using the principles discussed above, empirical prediction models for UNE ground motions (and PSRVs) generally assume that observed ground motions are primarily a function of yield and distance. In addition, the assumption is made that the data are lognormally distributed and distance attenuation behavior is adequately described as linear in log-log space (a power curve). The equation of the power curve has the form:

$$P = K W^a R^b \qquad (3\text{-}1)$$

where P is the parameter of interest;
W is the yield;
R is the source-to-station distance;
K is a fitting coefficient (intercept at x=1);
a is the fitting coefficient on W;
b is the fitting coefficient on R. For the data in this study, b is always negative.

Fundamental least square linear regression techniques are used to determine the K, a, and b coefficients for this equation. These best fit equations are an average of all data included in the regressions and can be used to predict best estimate UNE ground motions. The associated statistics generated in the regression can be used to provide uncertainty information on this best estimate. For this work, the complete prediction of the PSRV will consist of the best estimate <u>and</u> the uncertainty bounds. The uncertainty bounds discussed in this study are the 95% confidence intervals (i.e., 95% of the data will be included in the upper and lower bounds). This corresponds to the 97.5% nonexceedance probability level.

The linear regression routines provide the upper and lower bounds on all three coefficients of Equation 3-1. Initially, the upper and lower bounds were determined from the variation of all three coefficients. Determining the upper and lower bounds in this manner produced an uncertainty spread of almost two orders of magnitude (top to bottom). After review, it was apparent that the data, the best estimate, and the bounds should be compared on the same basis. This is not the case when all three coefficients vary independently. Using the fact that b is negative, equation 3-1 can be expressed as follows:

$$P = K\left(\frac{R}{W^{a/b}}\right)^{-b} \qquad (3\text{-}2)$$

where

$\frac{R}{W^{a/b}}$ is the scaled range.

The equations for the bounds were "converted" such that the yield coefficient (a/b in Equation 3-2) was the same as the best estimate. An example of the data and the bounds scaled to the same basis as the best estimate is shown in Figure 3-1. (This figure shows the vertical acceleration data--a total of 537 points.) Note, the spread of the upper and lower bounds vary from about 3 to about 8 (top to bottom.) Using the regression coefficients in this way allows the intercept and the attenuation (range) coefficient to vary but holds the yield coefficient constant for a data group (i.e., one frequency). The data fit in this manner provide a reasonable description of the best estimate and the uncertainty associated the prediction using these correlations.

As discussed earlier, the PSRV consists of response parameters calculated at discrete frequencies. In this study the response parameter analyzed is the pseudo velocity. The computer code used in this effort calculates pseudo velocity from the ground motion time history at 48 different frequencies between 0.3 and 30 Hz. The empirical prediction of the PSRV will involve the use of 48 individual equations of the form of Equation 3-1.

Basically two analyses were performed on these data. These analyses are listed below and will be discussed in detail in the remaining sections of this chapter.

- **Single Event Analysis** - A total of 15 of the events included in this study had a sufficient number of stations and a large enough variation in source-to-station distance that a single event analysis could be performed. This "single event analysis" involved a linear regression analysis of the calculated PSRVs. The linear regression was determined with all available data for an event, then some data were eliminated and the regression repeated. Comparison of the various regressions with the "observed" PSRVs allowed an assessment of receiver effects both at Yucca Mountain stations and other NTS stations identified as anomalous.

- **Multiple Event Analysis** - Data from all events were grouped in the same fashion as discussed in Vortman (1986). A multiple linear regression was computed for each group and subgroup for each component (vertical, radial or transverse) and the results compared. The rationale behind this approach is to determine which group provides the most accurate prediction for the problem of interest.

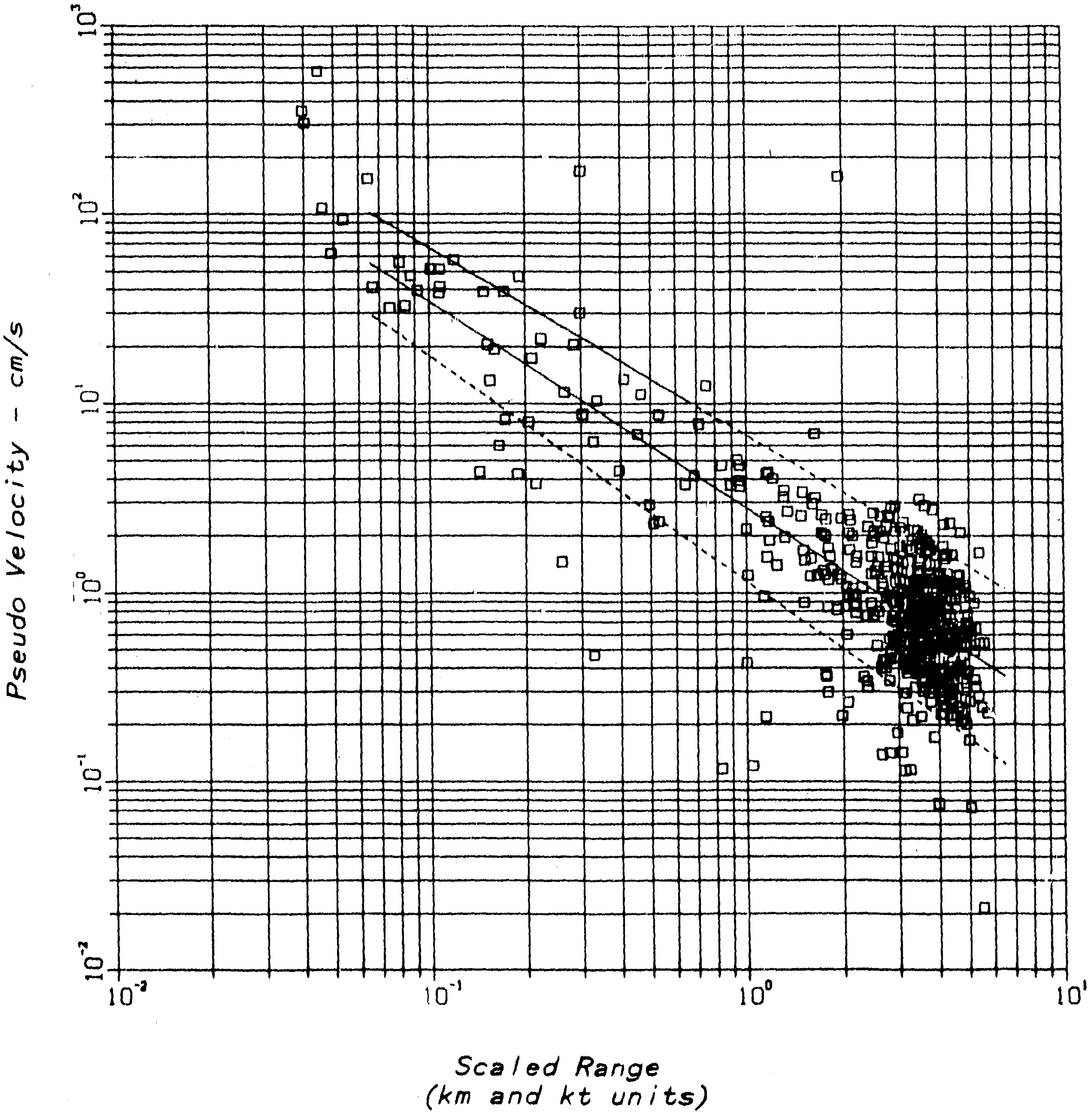


Figure 3-1 Pseudo Velocity versus Scaled Range for a Frequency of 0.35 Hz Vertical Acceleration Data

3.2 Single Event Analysis

As mentioned above, 15 events were instrumented well enough to do an individual analysis. The purpose of these analyses was to identify anomalous behavior at particular stations. Anomalous behavior in this instance is defined as a substantial deviation from the overall event average. The objective of the total effort is to develop a prediction procedure that is generally applicable to NTS and Yucca Mountain. The empirical approach used here determines the average value (via linear regression) of pseudo velocity from a number of observations. In general, observations that deviate substantially and consistently from the average should not be included in the average, _if_ a plausible explanation of the deviation can be determined _and_ it is shown not to be a contributing factor to observed ground motions at Yucca Mountain. By analyzing a relatively complete ground motion data set from a single event, source characteristics, source coupling, and source geology are eliminated as possible variables in the problem. Because many of the same stations are used on these events, the assimilation of the results of these analyses will provide an indication of the nature and amplitude of the anomalous behavior as well as station effects observed at Yucca Mountain.

In general, the procedure used in these analyses was to perform the regression on all data available for the event. Because source characteristics (yield) are eliminated from the analysis the linear regression equation is of the form:

$$P = K R^b \qquad (3\text{-}3)$$

where
P is the parameter of interest
K is a fitting coefficient (intercept at $x=1$)
R is the source-to-station distance
b is the fitting coefficient on distance.

These regression equations were then used to "predict" the PSRV for each station which was compared to the observed PSRVs. Yucca Mountain stations were eliminated from the event data set (if available) and an additional set of regression equations were determined. These regression equations were also used to "predict" PSRVs. These "predictions" were compared to the observed PSRVs at Yucca Mountain.

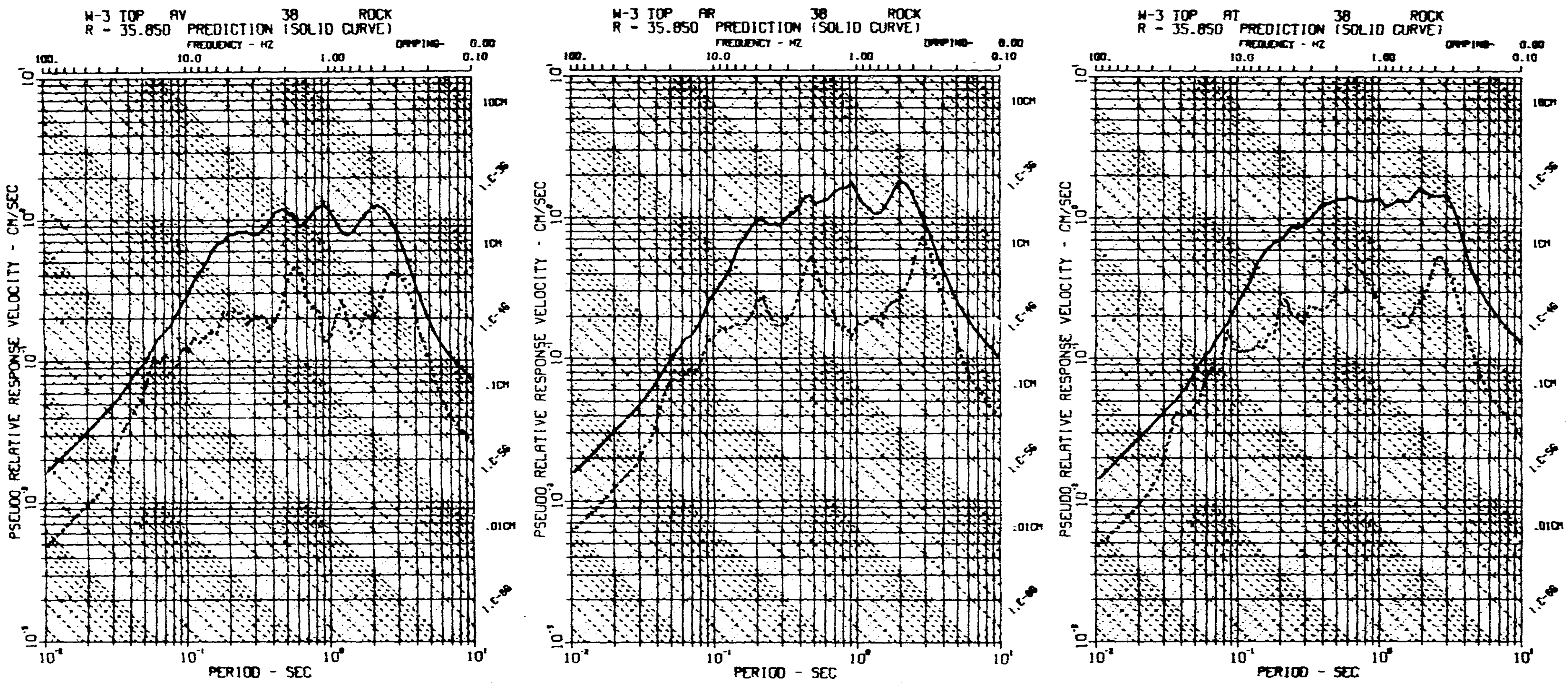
3.2.1 Anomalous Stations

In earlier work (Vortman, 1986), stations W-3, W-6, W-9, W-15, A, B, C, and D were determined to be anomalous. The nature of the anomalous behavior was determined from observations of maximum vector amplitude. These anomalies were attributed to station geology. Station W-3 was installed on Climax granite and produced maximum velocity and displacements that were low relative to the overall average. Stations W-6 and A through D were installed on alluvium and are located in the NRDS area of the NTS. Observed ground accelerations from these stations are high relative to the overall average (by as much as a factor of 10 at W-6, with smaller differences at A-D). Stations W-9 (installed on tuff at Rainier Mesa) and W-15 (installed on lava at Dome Mountain) had larger observed displacements than the overall average. These differences were identified as topographic effects.

In this current effort, the PSRVs for these eight stations were compared to the individual event average. Examples of these comparisons for the vertical, radial, and transverse components from a typical UNE are shown in Figures 3-2 through 3-9. The observed PSRVs (indicated as dashed lines on Figure 3-2 at station W-3 are well below the event average at all frequencies for all three components. This comparison is typical of station W-3 for all events studied. Comparisons of observed and average PSRVs for station W-6 are shown in Figure 3-3. At frequencies above 2 Hz, observed PSRVs are well above the event average for this station. At frequencies less than 2 Hz, the average and observed PSRVs are about the same. This is typical of most UNEs recorded at this station. The observed PSRVs at station W-9 (Figure 3-4) are average at frequencies above 1 Hz but become greater than the average at lower frequencies. The comparisons for the various events recorded at station W-9 do not indicate a strong trend to be either above or below the event average. Figure 3-5 shows the comparison of observed PSRVs and the event average for station W-15. The event average compares favorably on the radial and transverse components in frequency content as well as amplitude with the observed value. The vertical component is generally less than the event average for this station. For most of the 15 events, all components compare favorably with event averages at this station. Stations A through D (Figures 3-6 and 3-7) exhibit much the same behavior as observed for station W-15 (i.e., neither consistently high nor low).

In summary, only stations W-3 and W-6 appeared to be anomalous (on a consistent basis) with respect to the event average. The other stations appear to have equal likelihood of being either high or low.

The contributing factor to the anomalous behavior at station W-3 is the station geology. This is the only station in the group founded on granite. The properties of this material are substantially different from the other "rock" included in the data set and not typical of the material present at Yucca Mountain.

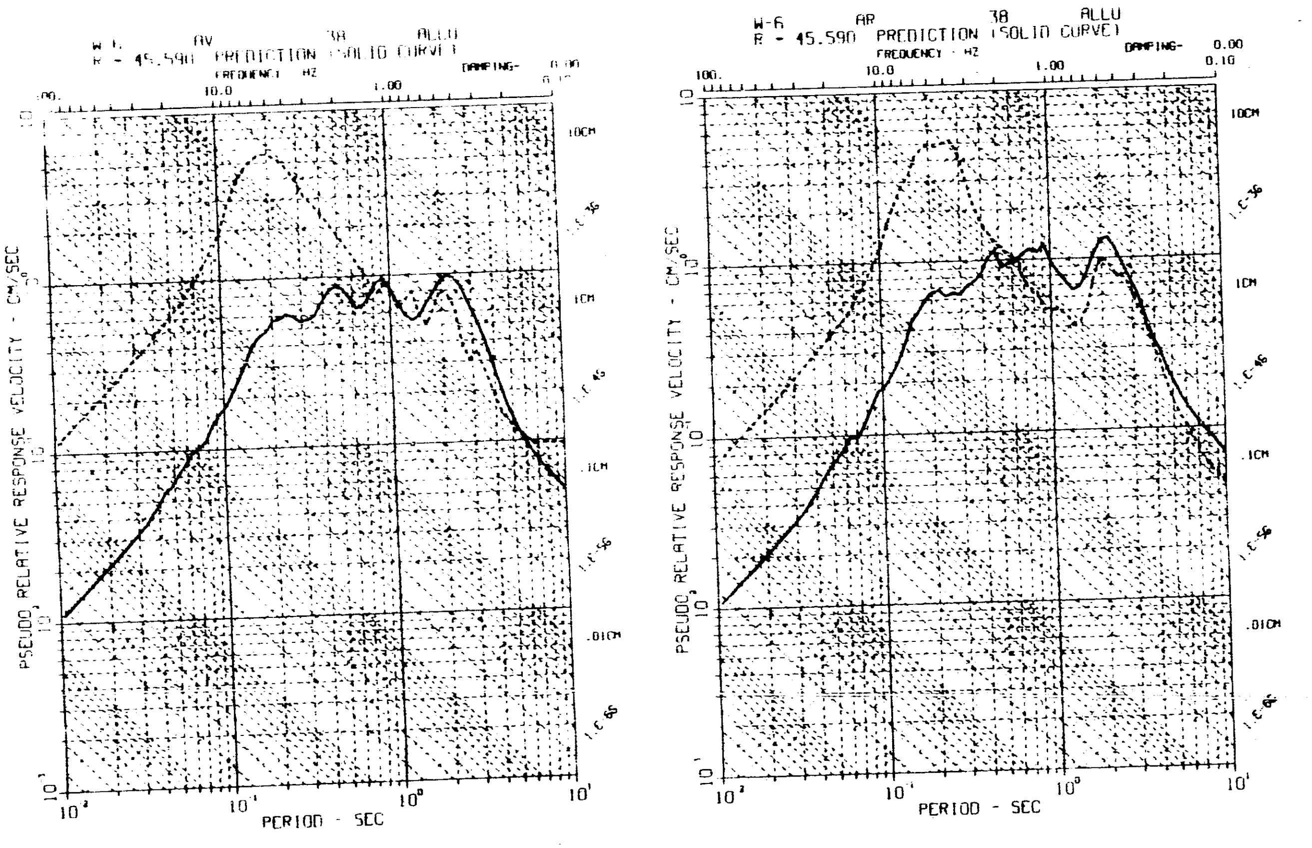


Vertical

Radial

Transverse

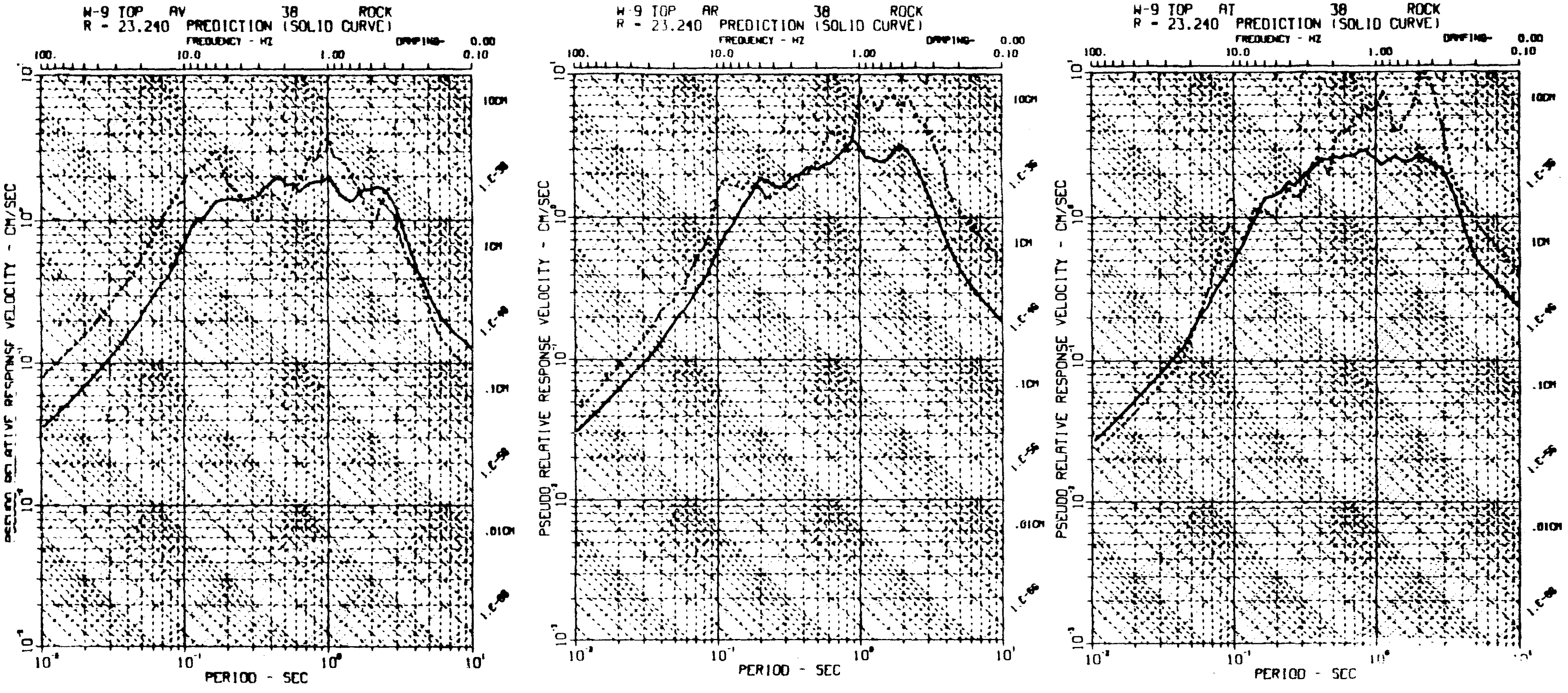
Figure 3-2. Comparison of the Average PSRV (solid line) and Actual PSRV (dashed line) for Station W-3, Event 38



Vertical

Radial

Figure 3.3. Comparison of the Average PSRV (solid line) and Actual PSRV (dashed line) for Station W-6, Event 38

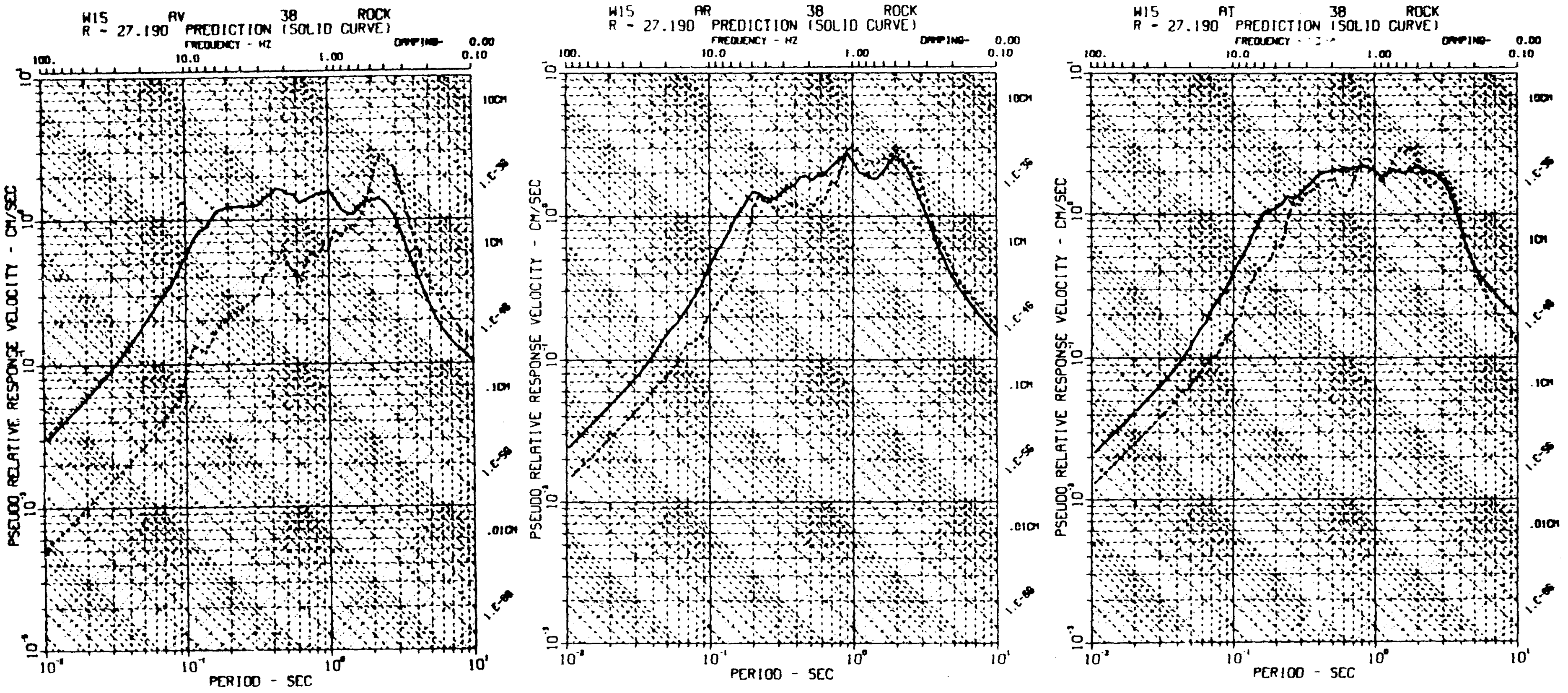


Vertical

Radial

Transverse

Figure 3-4. Comparison of the Average PSRV (solid line) and Actual PSRV (dashed line) for Station W-9, Event 38

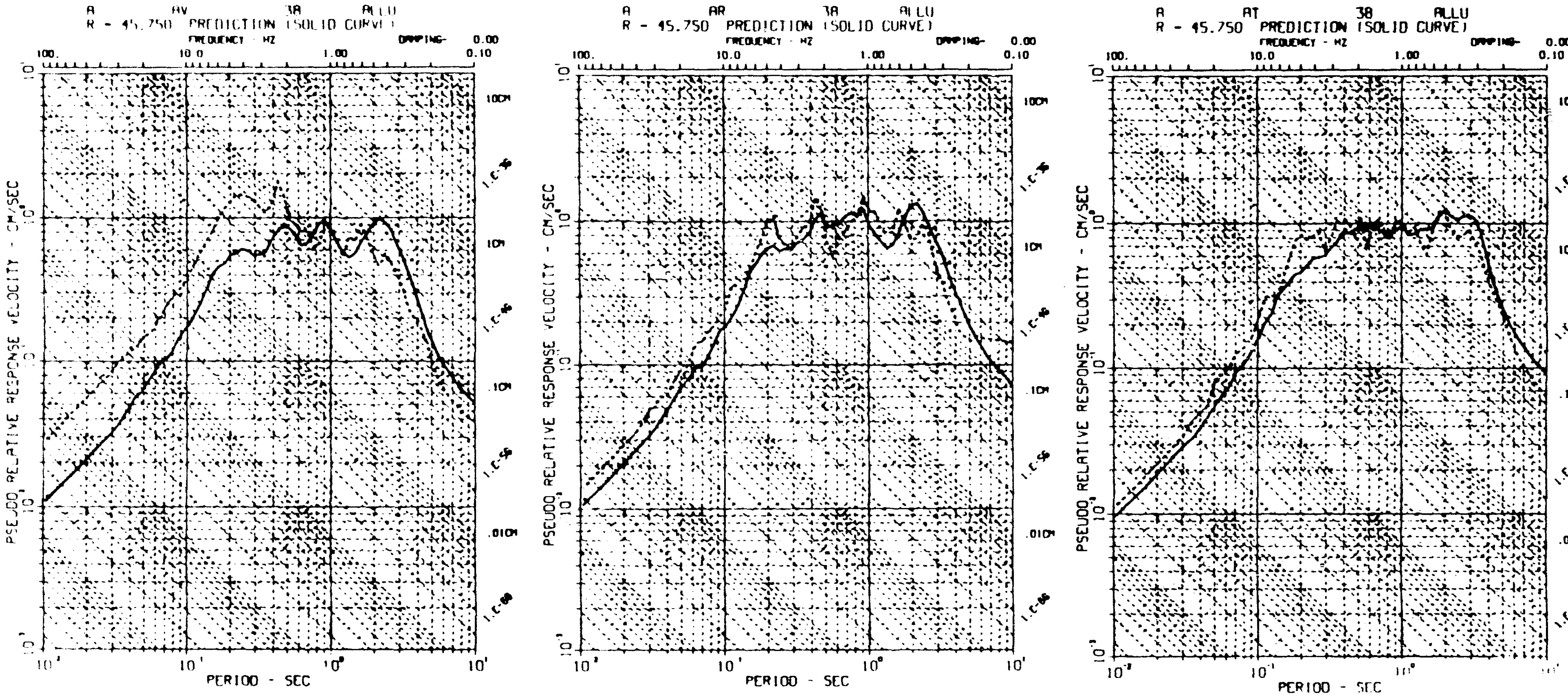


Vertical

Radial

Transverse

Figure 3-5. Comparison of the Average PSRV (solid line) and Actual PSRV (dashed line) for Station W-15, Event 38

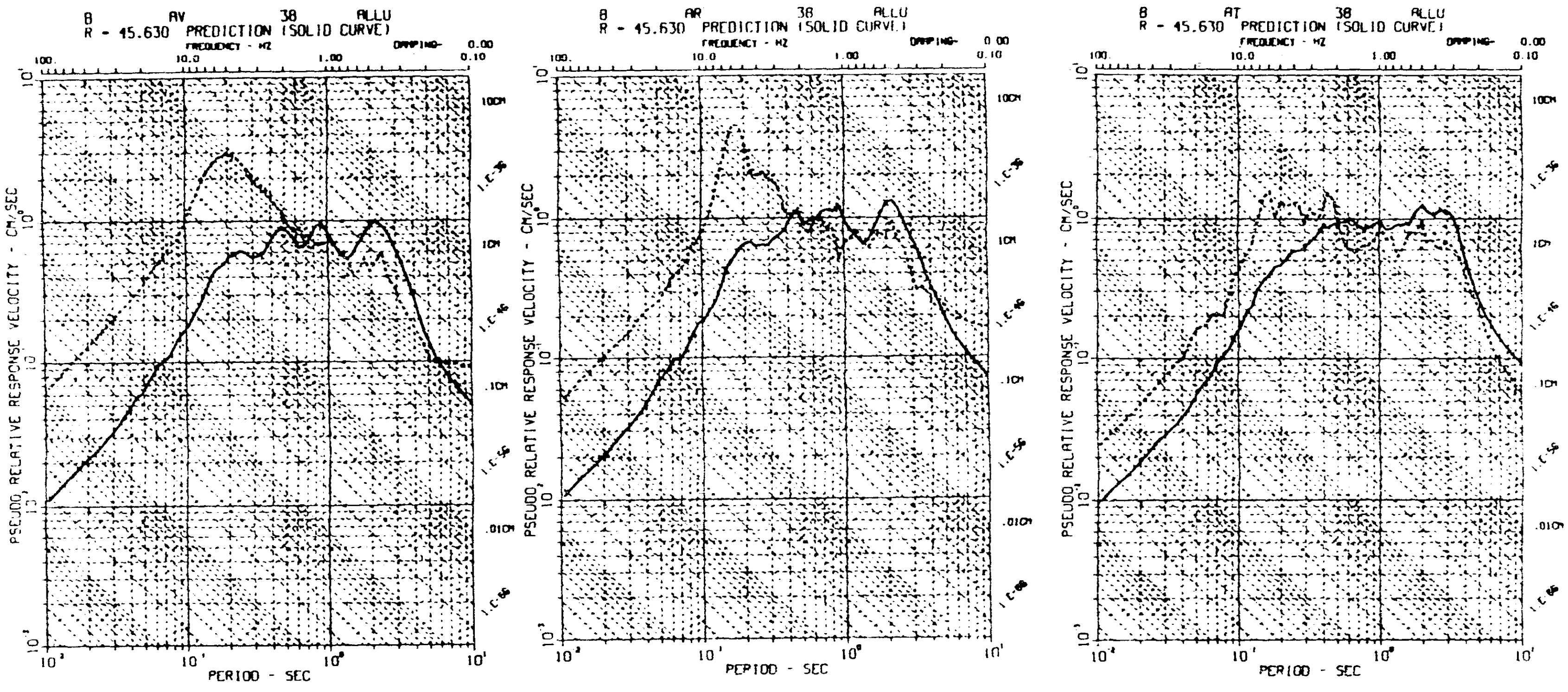


Vertical

Radial

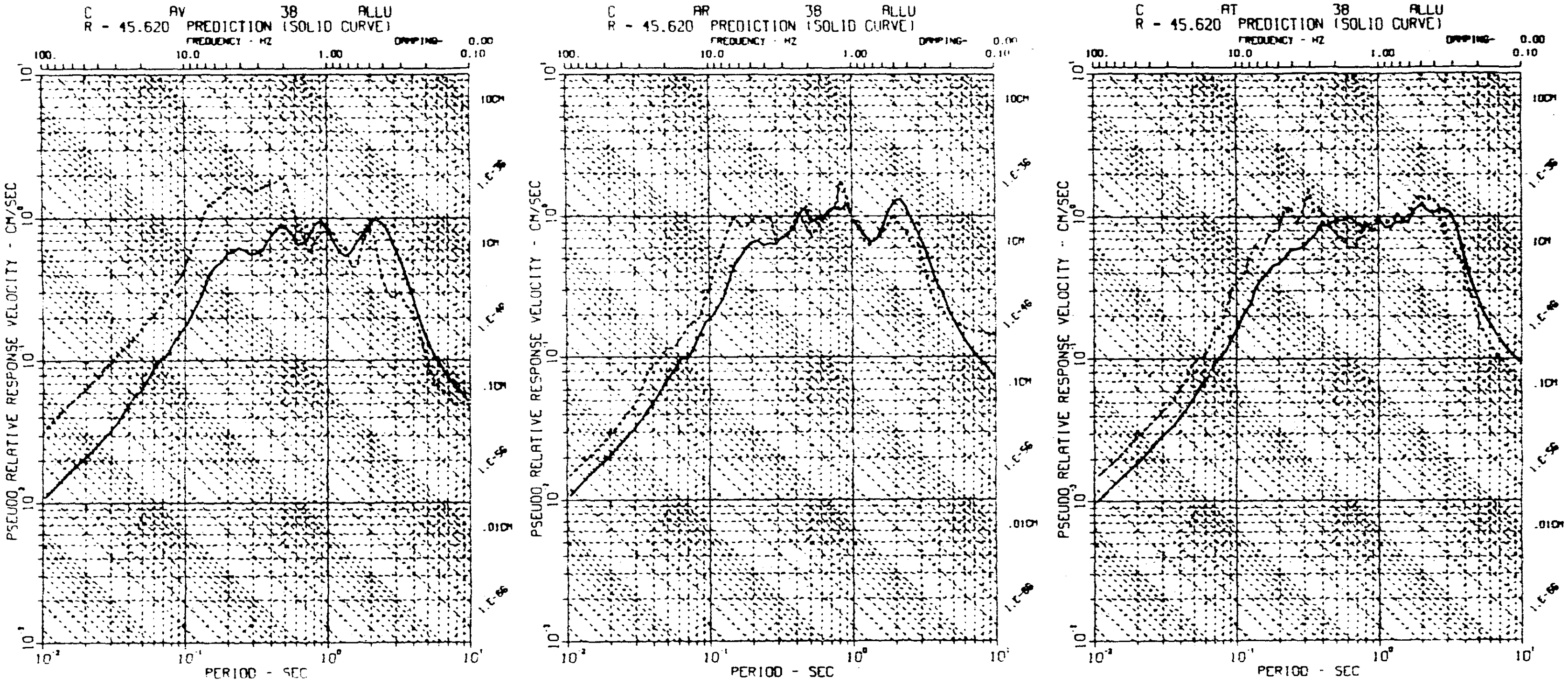
Transverse

Figure 3-6. Comparison of the Average PSRV (solid line) and Actual PSRV (dashed line) for Station A, Event 38



Vertical *Radial* *Transverse*

Figure 3-7. Comparison of the Average PSRV (solid line) and Actual PSRV (dashed line) for Station B, Event 38

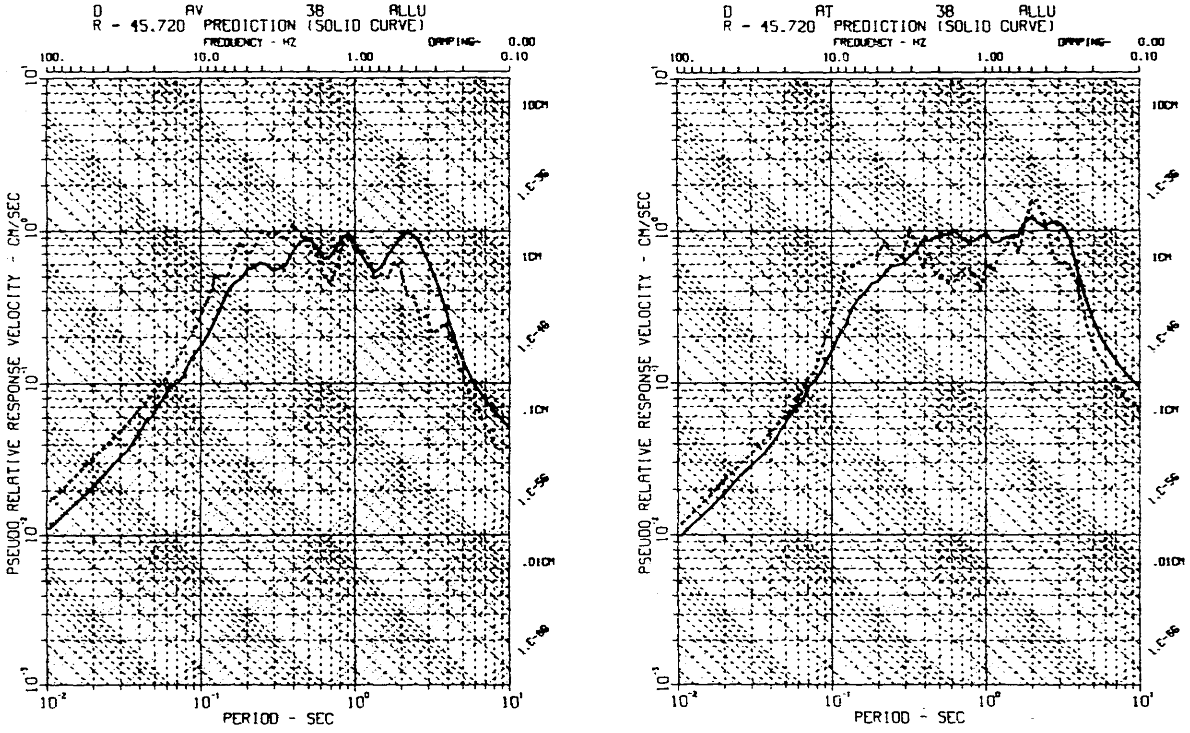


Vertical

Radial

Transverse

Figure 3-8. Comparison of the Average PSRV (solid line) and Actual PSRV (dashed line) for Station C, Event 38



Vertical

Transverse

Figure 3-9. Comparison of the Average PSRV (solid line) and Actual PSRV (dashed line) for Station D, Event 38

The anomalous ground motions observed at station W-6 are attributed to the travel path geology between Pahute Mesa and Jackass Flats on the NTS. Walck (1988) presents evidence that this anomaly is a function of the structure under the Timber Mountain Caldera. This structure has the effect of focusing seismic energy at this station over a narrow band of azimuths. Even though the travel path between Yucca Mountain and Pahute Mesa runs through the Timber Mountain Caldera, the study in (in preparation, b) found very little, if any, effect of this geologic structure on observed motions at Yucca Mountain. The studies support the elimination of data recorded at this station as anomalous and not a part of the expected ground motion environment at Yucca Mountain.

3.2.2 Yucca Mountain Stations

Of the 15 events analyzed on an individualized basis, 8 were recorded at Yucca Mountain. The Yucca Mountain stations that were most active in this time frame, (i. e., recorded a majority of these UNEs) were W-14, W-21, W-22 and W-23. Ratios of observed pseudo velocities to average (determined from linear regression) pseudo velocities were calculated for each of these four Yucca Mountain stations. These ratios were plotted versus frequency and all events recorded at a station were overlaid. These plots are shown in Figures 3-10 through 3-13. A value of 1 on these figures indicates that observed and average values are equal. Values greater than 1 indicate that the observed values are greater than the average.

Most of the pseudo velocities observed at the Yucca Mountain stations were greater than the event average and the amplitude of the ratio varies as a function of frequency. In addition, the amplitude of the ratio varies substantially from one event to another at the same station. In most instances, however, there appears to be a characteristic shape of the ratio versus frequency curve for a component at a station. The ratio versus frequency curve for stations W-14 (Figure 3-10) and W-23 (Figure 3-11) are generally similar in shape. The largest differences between the observed and average pseudo velocities for these stations are generally in the low frequencies (< 4 Hz). The amplitudes of the difference ratios generally vary between 2 and 4 for station W-14 and 2 and 8 for station W-23. The largest differences in the amplitude ratios occurred at frequencies greater than 3 Hz for station W-22 (Figure 3-12). The amplitude of the difference ratio observed at this station varies between 3 and 7. The differences between the observed and average pseudo velocities at station W-21 (Figure 3-13) occur over most frequencies. The amplitude of the difference ratio varies between 1 and 4.

Figure 3-14 shows the topography in the vicinity of these stations. All four of these stations were installed on ridges. In general, the other stations used in the linear regression were located in relatively flat terrain. It is likely that the increase in PSRV amplitude at these stations is due to topographic effects. Topographic effects have been observed on earthquakes and UNEs. A review of theoretical and experimental studies (Geli et al., 1988) indicated that on the mountain tops, there is generally a broadband amplification for wavelengths comparable to the mountain width. This is coupled with an alternation of amplification and deamplification at the base of the mountain, beginning with a deamplification at low frequencies (wavelengths greater than mountain width). For the stations of interest here, the "mountain widths" vary from approximately 750 m near station W-22 to 2100 m near station W-21. The determination of these widths is somewhat ambiguous given the topography and the travel path direction (e.g., at station W-22, the

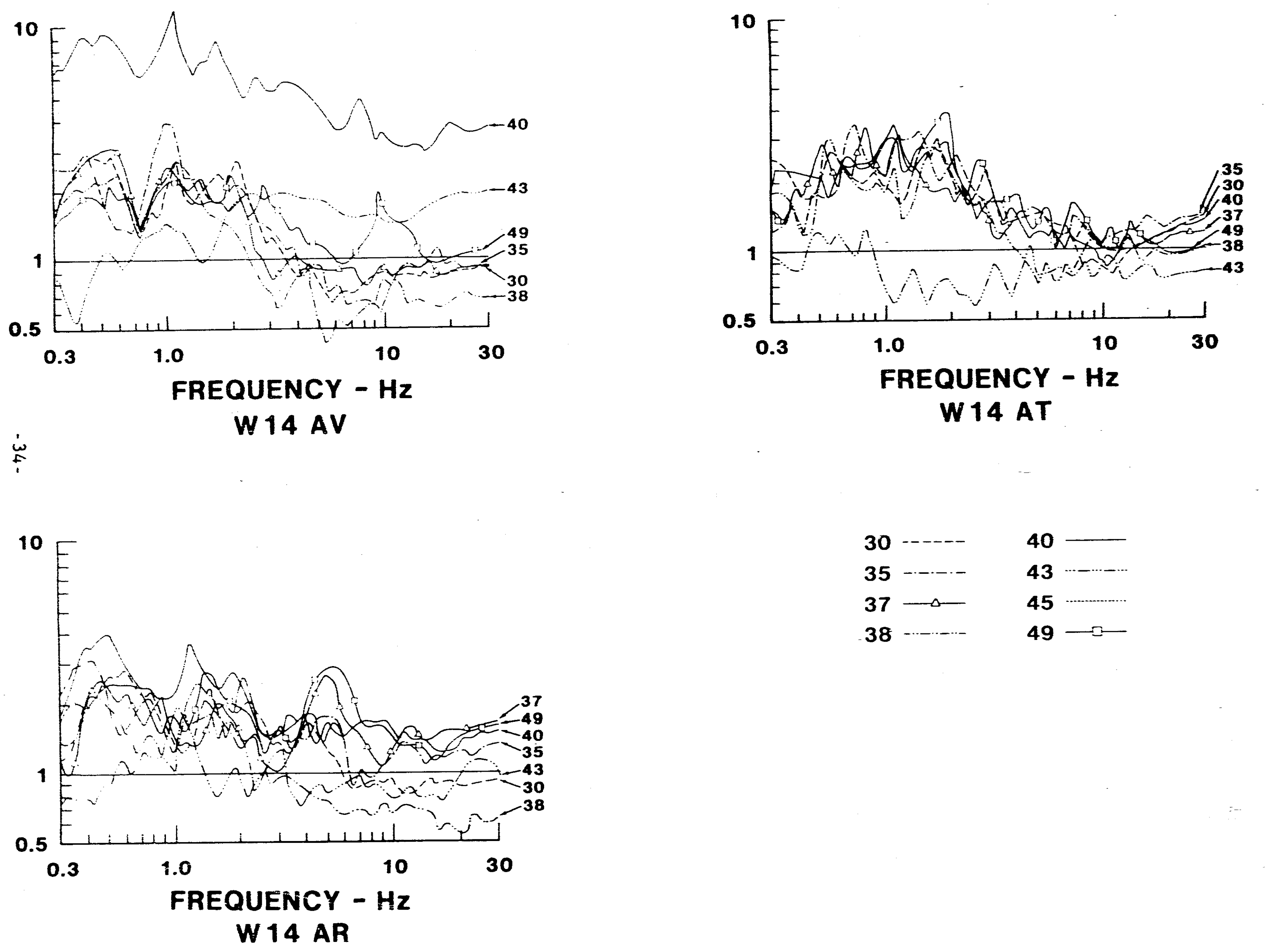


Figure 3-10. Ratios of measured/average pseudo velocities for events recorded at Station W-14

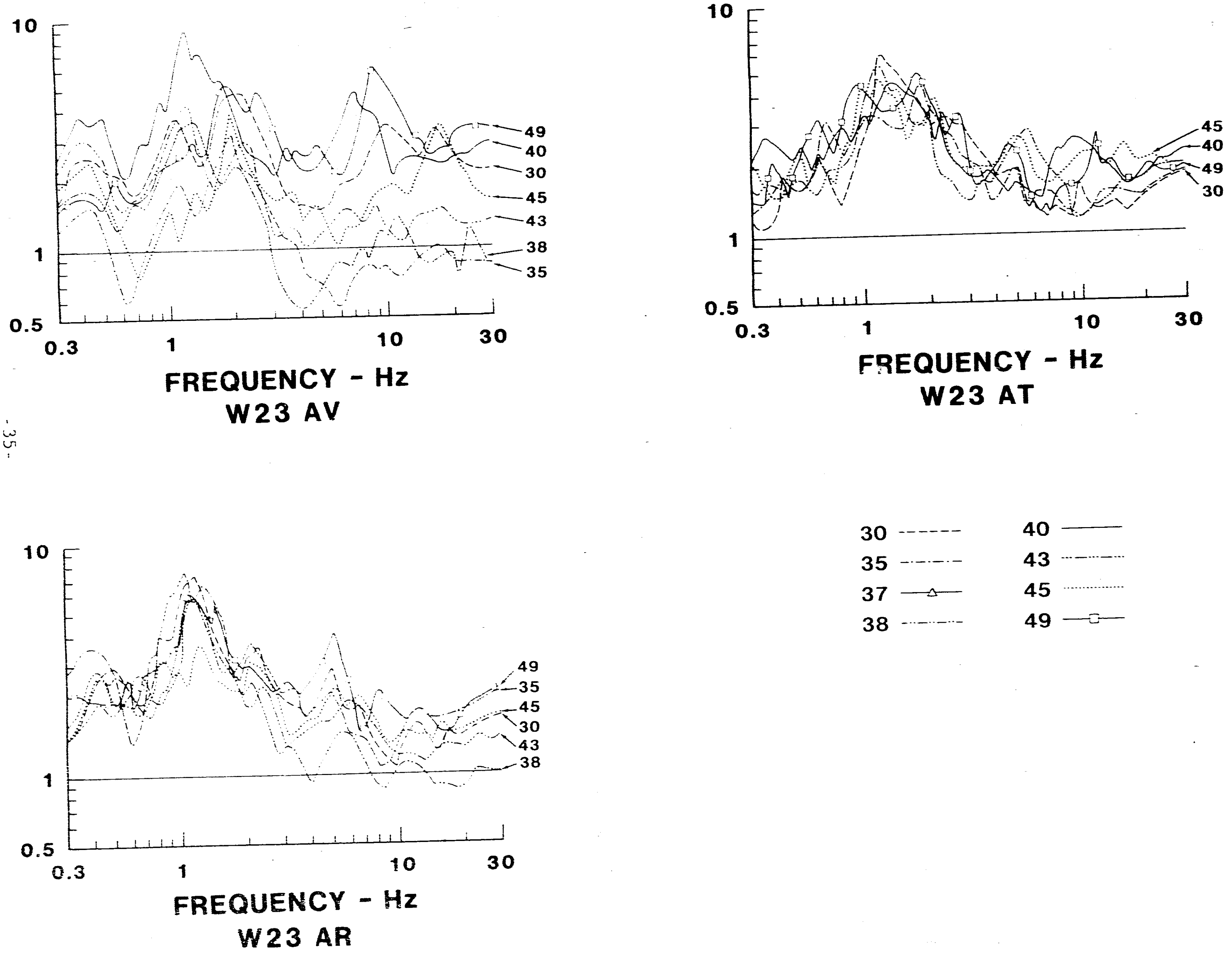


Figure 3-11. Ratios of measured/average pseudo velocities for events recorded at Station W-23

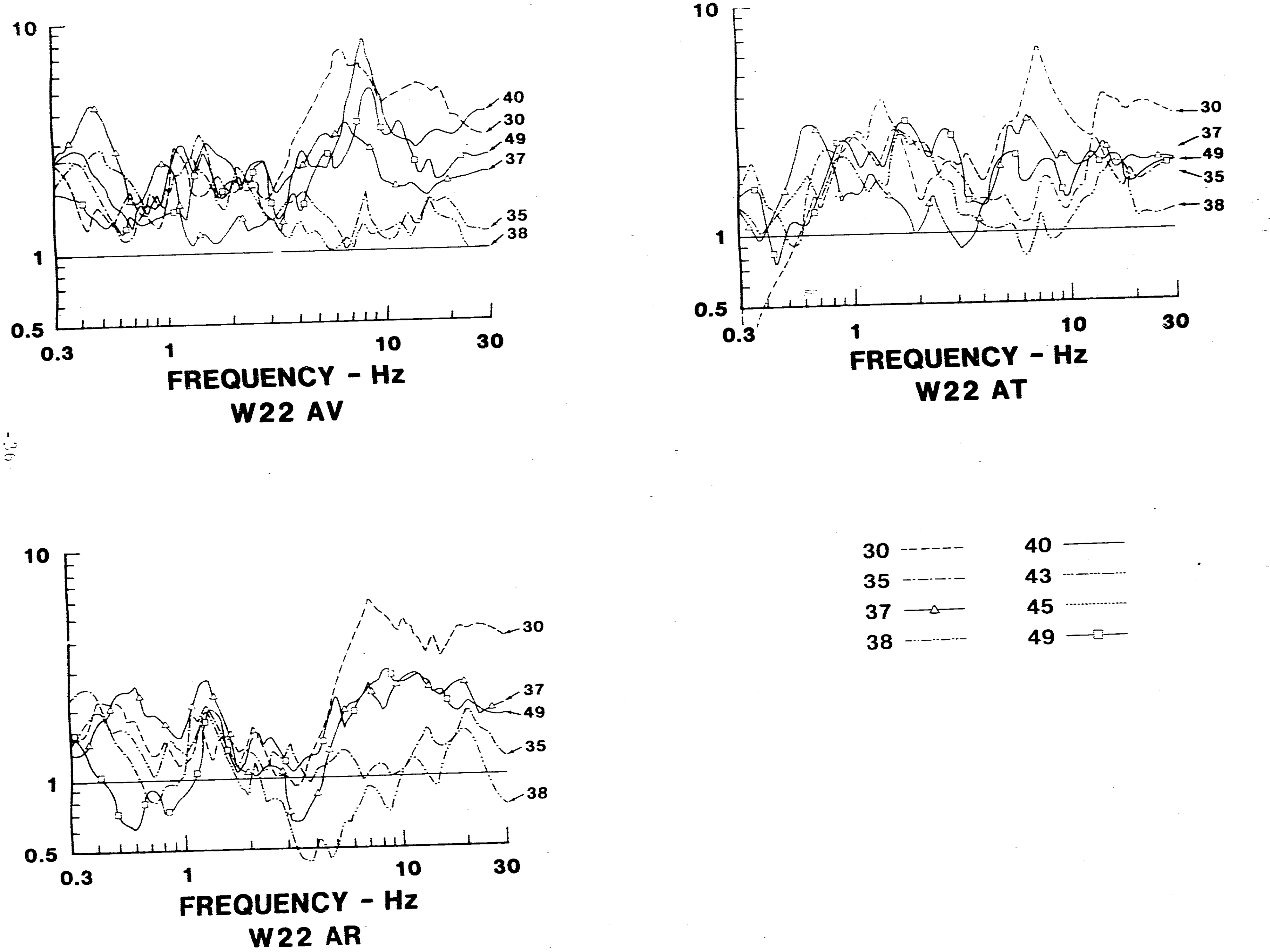


Figure 3-12. Ratios of measured/average pseudo velocities for events recorded at Station W-22

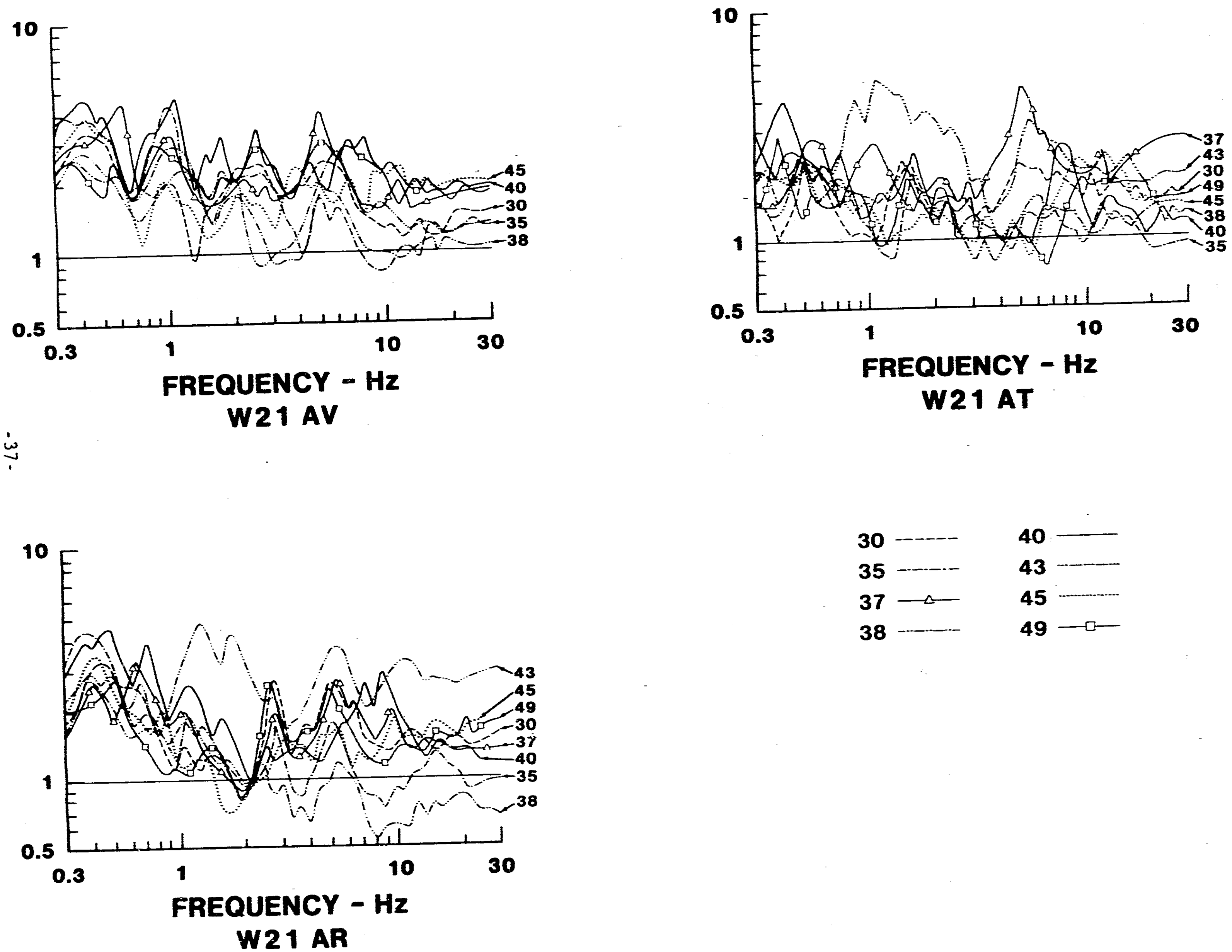
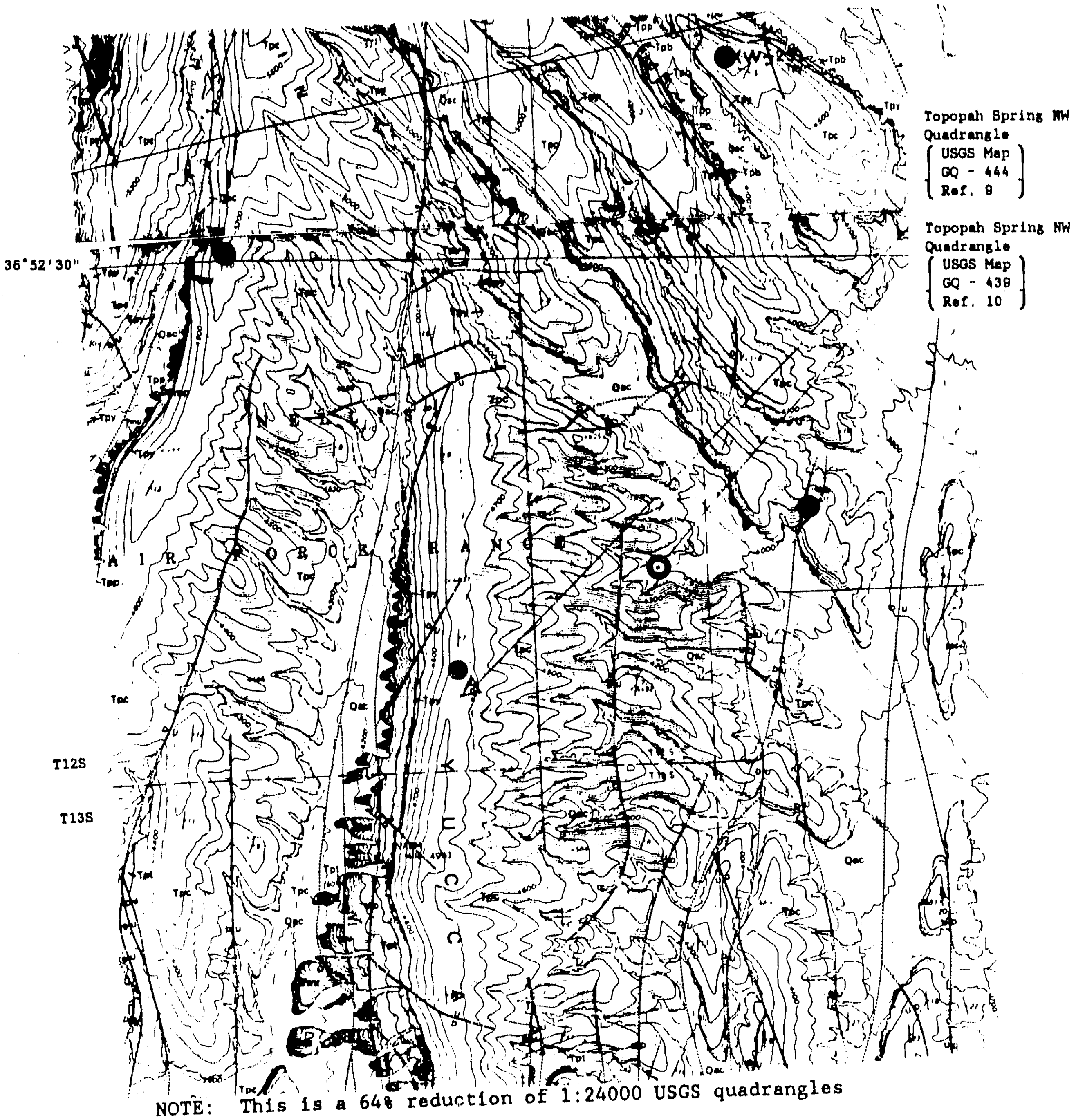


Figure 3-13. Ratios of measured/average pseudo velocities for events recorded at Station W-21



NOTE: This is a 64% reduction of 1:24000 USGS quadrangles

Figure 3-14. Topographic map showing the location of Stations W-14, W-21, W-22, and W-23.

width could be taken as 750 m or 3000 m). If a wave speed of 5100 m/s is assumed (this is the apparent wave speed determined from arrival time and source-to-station distance), the approximate frequency of amplification should range between 6.8 and 2.4 Hz. These values of frequency are not inconsistent with the observations noted earlier on Figures 3.2.2-1 through 3.2.2-4. Theoretical and experimental studies do not agree on the amount of amplification that will occur at a particular station. As reported by Geli et al., (1988), observations of ground motion amplification have ranged from factors of 30 (seismic motions generated by cavity collapse observed at Butler Mountain, NV) to 1.25 (UNE generated motions observed at NASA Mountain, NV). The degree of amplification observed at the Yucca Mountain stations discussed here falls within these bounds.

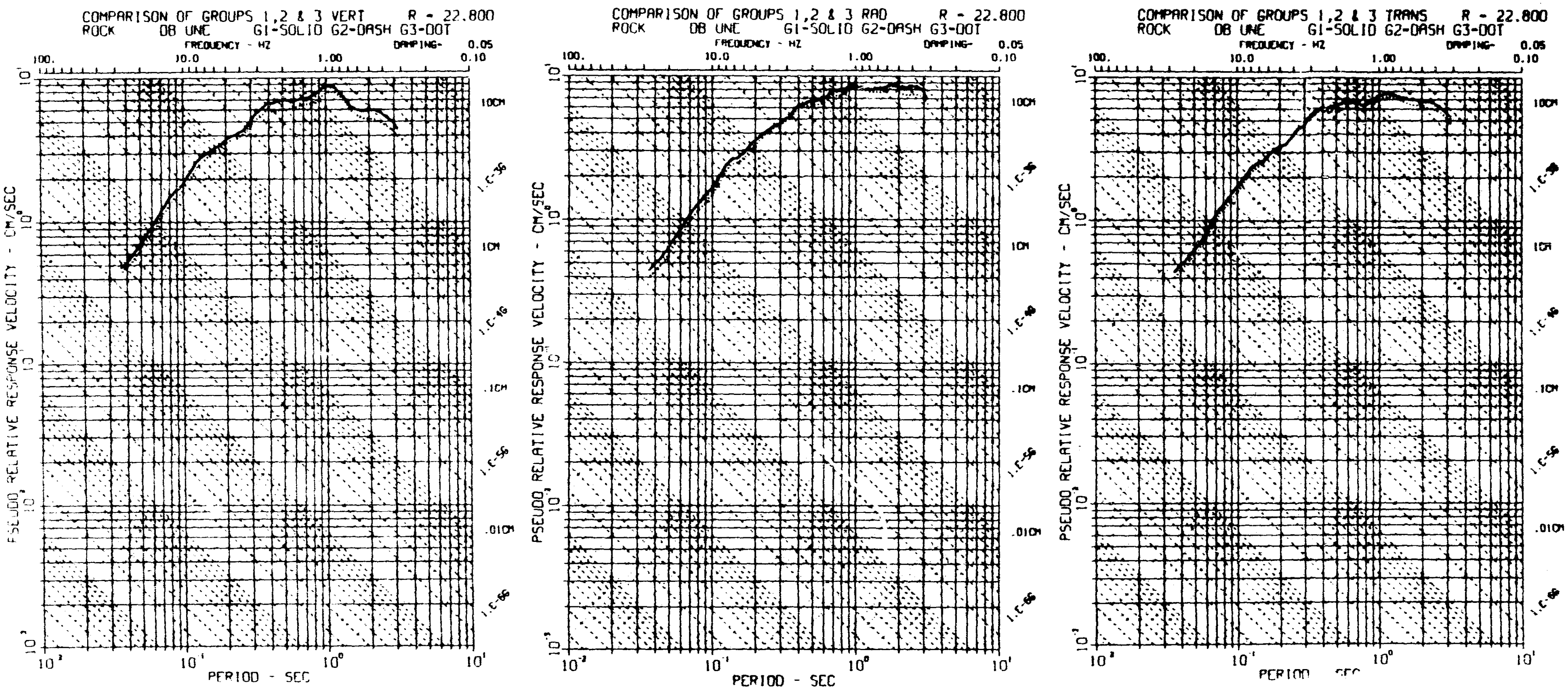
3.3 Multiple Event Analysis

The data from all events were grouped in several ways. Group I included all data. Group II consisted of Group I data minus data from the anomalous stations (W-3 and W-6 as identified earlier). Group III consisted of Group II data minus all Yucca Mountain stations. In addition, each major group described above was further subdivided into groups based on receiver geology. These subgroups were only stations on rock only stations on alluvium and all stations regardless of geology. A total of 27 regressions is dictated by this grouping scheme. In the course of the analysis it was determined that the alluvium-only data set did not have enough variation in source-to-station distance to do satisfactory regressions. Therefore, the total number of regressions performed was reduced to 18.

To evaluate the adequacy of the regressions of the various groups two basic comparisons were made. These consisted of comparing "predictions," using the derived equations, of two primary events. The first was a 700-kt UNE at 22.8 km away (the design basis UNE). This would help determine the differences in the various groups at the predictive end of the spectrum. The second was a 150 kt UNE at 45 km away. This second event is "typical" of the majority of the data in the data base and would help gage the bias factor associated with each group.

Comparison plots of the predicted PSRVs for the design basis UNE are shown in Figures 3-15 and 3-16. It is clear from these figures that the differences between the various data groups are small. It was noted earlier that the Yucca Mountain stations are to the high side of the average. The effect of the elimination of these stations (Group III) can be seen in these figures. As might be expected, the Group III (dotted) curve is slightly less than the other two groups. The Group II curve is indistinguishable on these plots because relatively few data points were removed (Group I vs. Group II). For the case where the rock and alluvium data were grouped together, the anomalous stations tend to cancel each other out (i.e., one high and one low).

Similar conclusions may be drawn from the comparisons made for the typical UNE (Figures 3-17 and 3-18). For the data recorded at stations on a rock geology (Figure 3-17), the three groups show more separation than the comparisons made for the design basis UNE. This stems from the fact that there are more data at these typical ranges and yields and, therefore, more scatter. In addition, the Yucca Mountain stations are more significant at this range. The Group II fit is higher because the anomalous station in this group was low relative to the average. The Group III fit is lower because the Yucca Mountain stations tend to be higher than the average station.

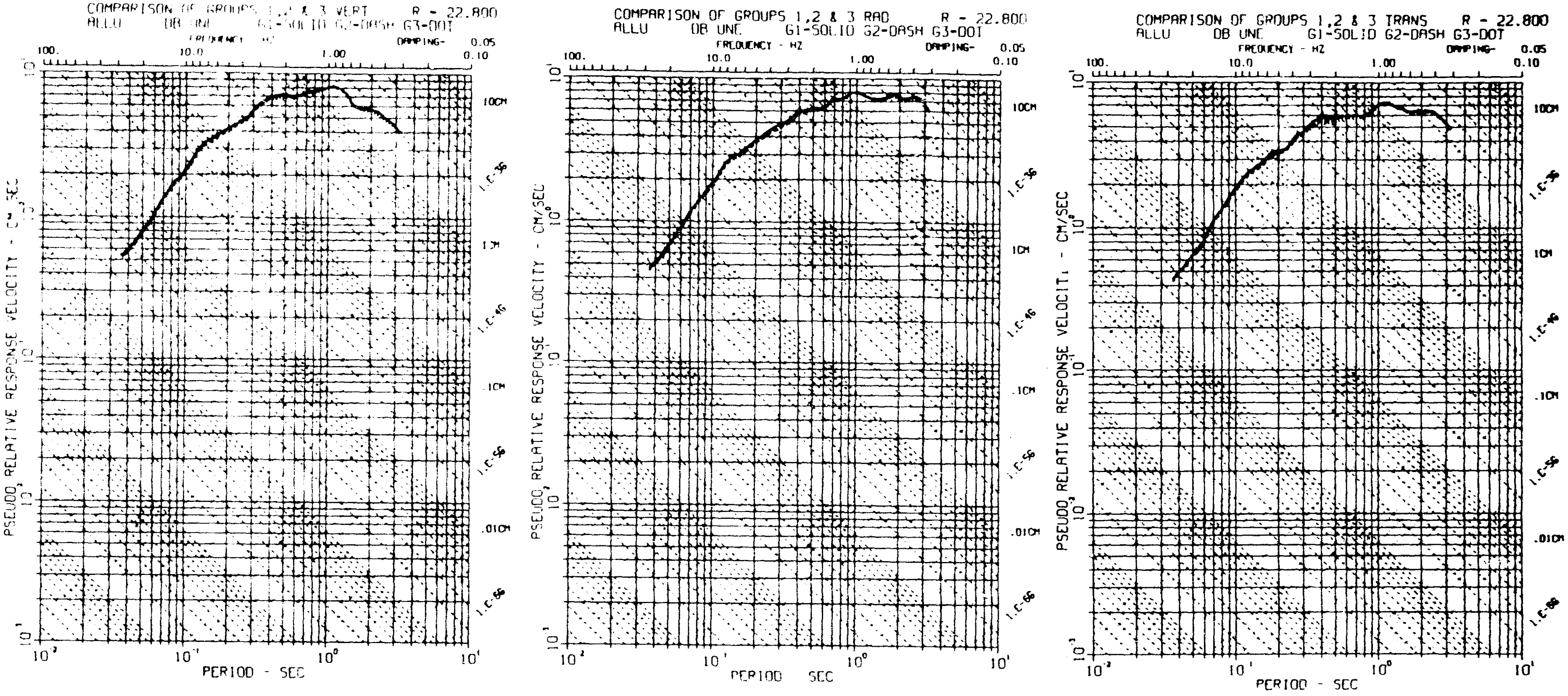


Vertical

Radial

Transverse

Figure 3-15. **Comparison of Groups I, II, and III - Rock Geology for the design basis UNE**

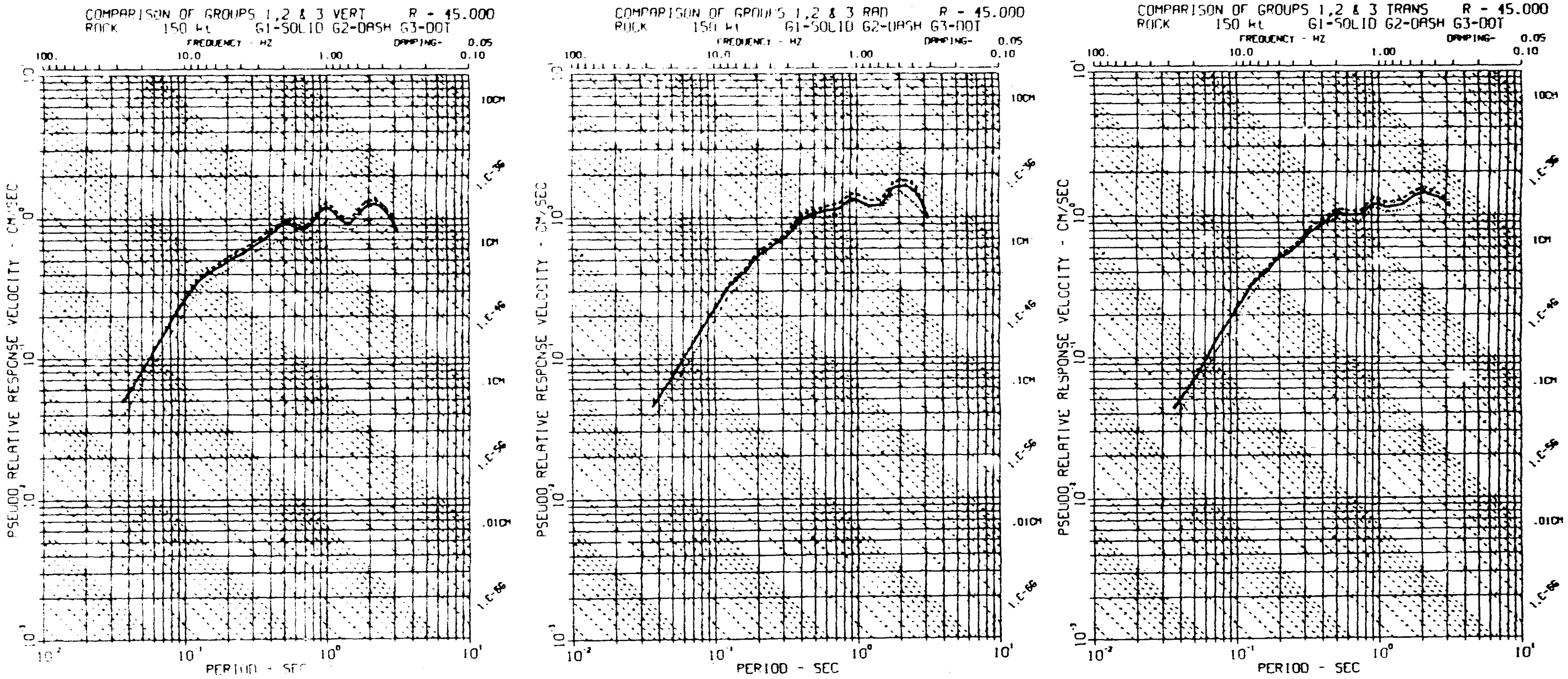


Vertical

Radial

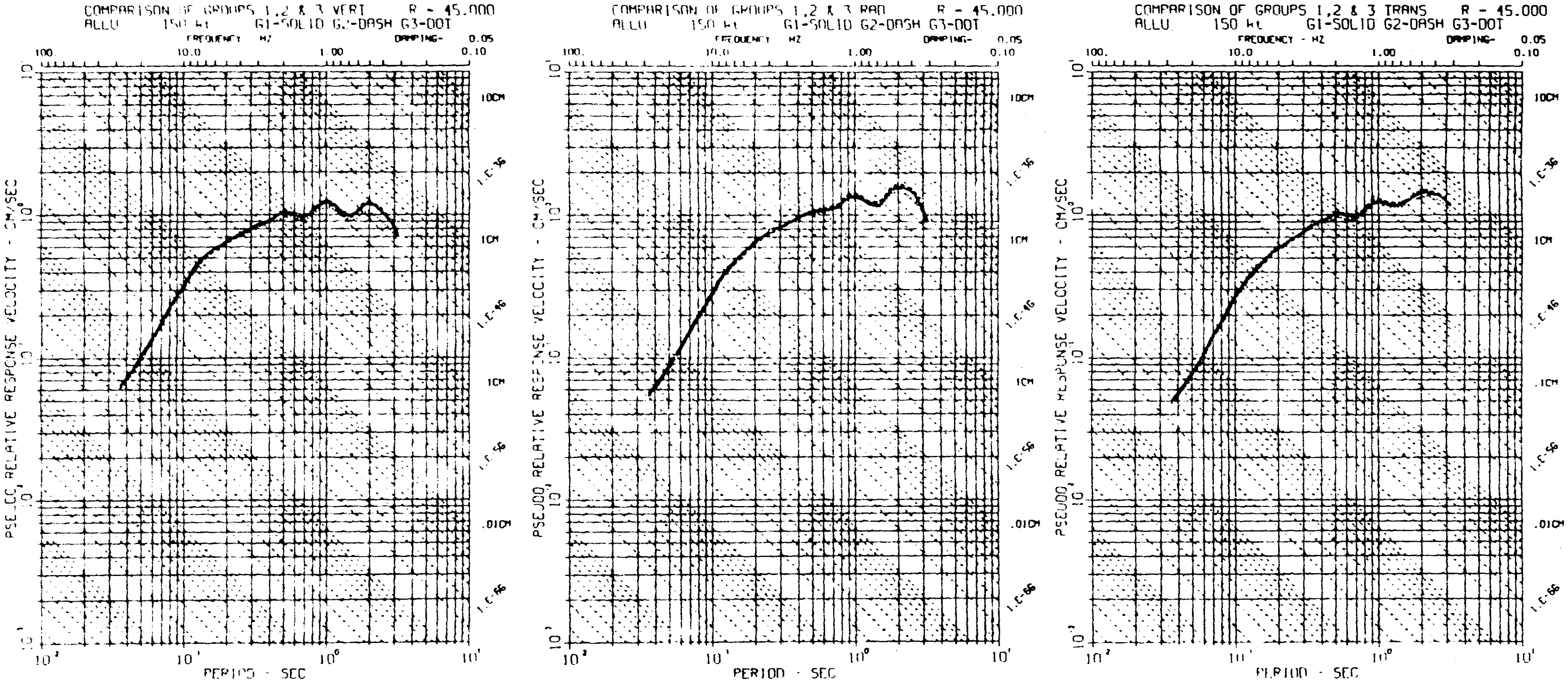
Transverse

Figure 3-16. Comparison of Groups I, II, and III - Rock & alluvium geologies for the design basis UNE



Vertical　*Radial*　*Transverse*

Figure 3-17. Comparison of Groups I, II, and III - Rock Geology for a typical UNE



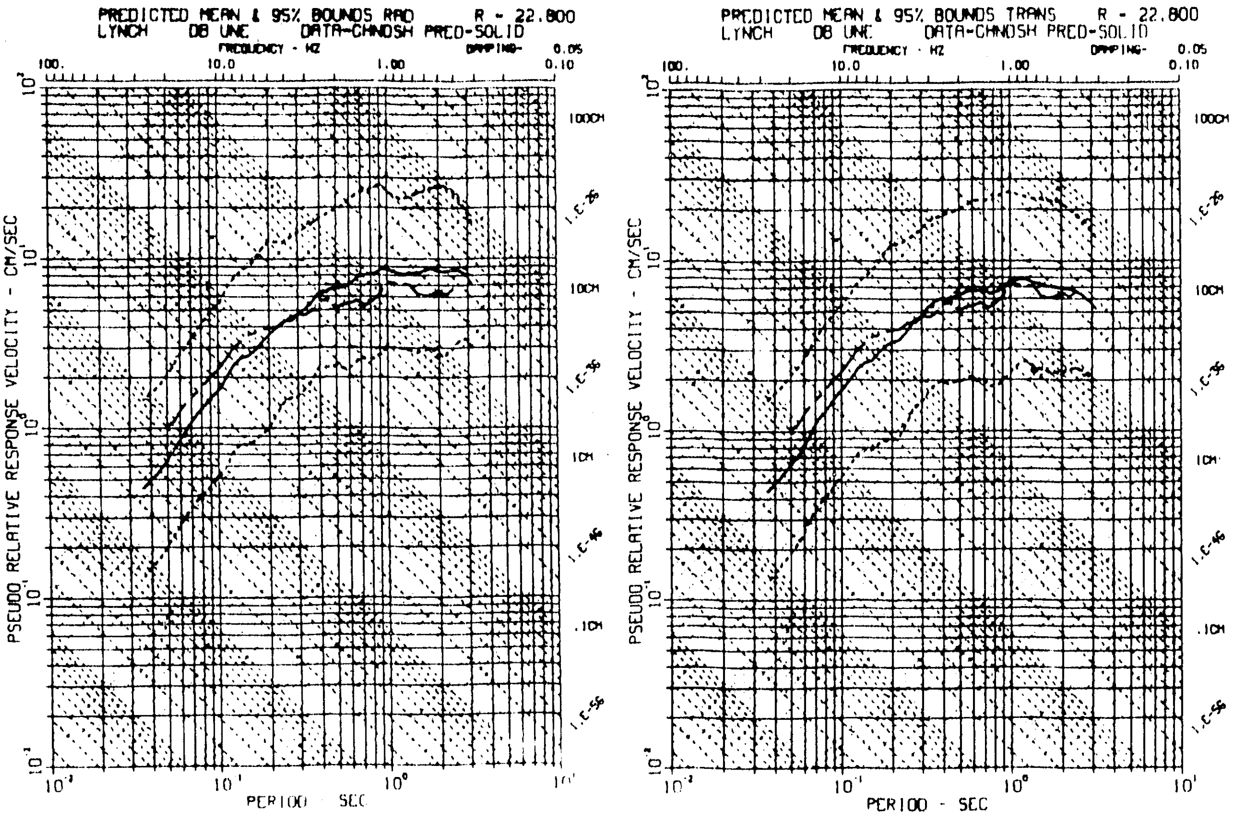
Vertical *Radial* *Transverse*

Figure 3-18. Comparison of Groups I, II, and III - Rock & alluvium geologies for a typical UNE

Based on these comparisons, it is difficult to strongly argue that any one of these groups is better than another for predictive purposes. The differences observed are not statistically significant. Based solely on judgement, exclusion of data from the Yucca Mountain stations (Group III data set) does not seem appropriate. After all, the objective of the prediction procedure is to predict ground motions at Yucca Mountain. It also appears that inclusion of the anomalous stations (Group I data set) is inappropriate. The factors that contribute to the anomalous observations at station W-3 do not affect Yucca Mountain at all. The factors that contribute to the anomalous observations at station W-6 do not appear to significantly influence the ground motions observed in the Yucca Mountain area. Therefore, Group II regressions are selected as the recommended equations. For stations founded on rock, the "rock only" subgroup equations should be used. Predictions of stations installed in an alluvium geology should be performed with the "rock and alluvium" subgroup equations.

As a consistency check, the recommended regression equations were compared to an earlier prediction model. This earlier model was developed for horizontal ground motions from UNEs conducted in Pahute Mesa (Lynch, 1969). Lynch incorporated data from 11 UNEs that were recorded at a total of 64 stations. The yield maximum of the data set was 1200 kt and the variation in source-to-station distances was from 4.4 to 551 km. The comparison of the two procedures for the design basis UNE (for a station on a rock geology) is shown in Figure 3-19. The best estimate and the 95% confidence intervals for the prediction equations developed in this effort are represented by the solid and dashed lines, respectively. The Lynch prediction procedure is represented by the chain dashed line. The two procedures compare favorably both in shape and amplitude.

The regression coefficients and an evaluation of the predictions are given in Chapter 4.



Radial

Transverse

Figure 3-19. Comparison of recommended prediction procedure and an earlier procedure for the design basis UNE

3.4 Downhole Motions

Analysis of component surface and downhole PSRVs was reported by Phillips (1987). Ratios of surface to downhole pseudo velocity were calculated as a function of frequency. Each station, with companion surface and downhole instrumentation, was studied on an individual basis. The stations analyzed were W-12/30, W-25, W-28 and W-29 (see Figure 2-2 for station locations). Ground motion from all UNEs available at the time of the analysis were included in the analysis. The conclusions from that study that are of interest here are as follows:

- For each station and each component there was a characteristic shape to the ratio versus frequency curve. Therefore, an average ratio was calculated for every component at every station.

- There is insufficient data to develop an empirically based general depth-attenuation model for the Yucca Mountain area. The best that can be done is to predict downhole motions at existing station locations using the ratios determined in the study.

The average ratios reported by Phillips (1987) were incorporated into the prediction procedure. These average ratios were applied to the best estimate and the 95% confidence intervals, developed for surface ground motions, to produce the downhole PSRV prediction. The use of the average ratio and the surface 95% confidence intervals is not a "true" estimate of the 95% confidence intervals of the downhole motions. In reality, the uncertainty in the prediction of downhole PSRVs is both a function of the uncertainty in the surface PSRVs and the standard deviation of the average ratio. Inclusion of the standard deviation of the average ratio will increase the spread of the uncertainty bounds on the prediction of downhole PSRVs. This additional accuracy was not considered necessary at this point in time. The predicted PSRVs generated by this approach will be evaluated in Chapter 4.

3.5 Summary

The results of the data analyses presented in this chapter are summarized below.

1. Two anomalous stations were identified. Station W-3 produced PSRVs that were always below average for all frequencies and station W-6 produced ground motions at frequencies greater than 2 Hz that were always greater than average. The causes of these anomalies were judged not to be a factor in the observed ground motions at Yucca Mountain. Therefore, ground motions that were observed at these stations were excluded in the development of the recommended prediction equations.

2. Yucca Mountain stations W-14, W-21, W-22, and W-23 produced PSRVs that were generally greater than the average. This amplification appears to be related to the surface topography at the stations.

3. There was very little difference in the results of regressions performed on the various data groups. Based primarily on judgement, the regression equations developed for Group II were selected as the recommended prediction equations. Predictions for stations founded on "rock" should be made with the regressions from the "rock only" subgroup of Group II. For stations placed on alluvium, the appropriate prediction equations are from the "rock and alluvium" subgroup of Group II.

4. Downhole PSRVs may be predicted at stations W-12/30, W-25, W-28, and W-29 using the results of an earlier analysis. A general method for the prediction of downhole motions in the Yucca Mountain area does not exist at this time.

4.0 PREDICTIONS

4.1 Equation Coefficients

The prediction procedure developed from the analyses discussed in Chapter 3 is summarized and evaluated here. The prediction of a PSRV consists of the best estimate and a measure of the uncertainty on that best estimate. In this effort the 95% confidence intervals (2 standard deviations) were selected for the uncertainty bounds. Note, this corresponds to the 97.5% nonexceedance probability level. Because of the relatively large number of equations (144) necessary to generate a prediction and the usefulness of the computer-generated tripartite plot, this procedure was automated. The source listing of this code and general instructions for its use are given in Appendix B.

The coefficients for the best estimate and 95% confidence bounds for stations on rock and alluvium are presented in Tables 4-1 through 4-6. Recall, the regression equation of the form:

$$P = K\, W^{a}\, R^{b} \tag{4-1}$$

where
W is the yield of the UNE - kt
R is the source-to-station slant distance - km
P is pseudo velocity - cm/s
K, a, b are the parameters listed in the tables.

TABLE 4-1 SUMMARY OF PREDICTION COEFFICIENTS FOR VERTICAL PSRVs FOR STATIONS ON ALLUVIUM.

Frequency	Best Estimate Equations			Lower Bound Equations			Upper Bound Equations		
(Hz)	a	b	K	a	b	k	a	b	K
0,314	0,609	-1,116	2,410	0,663	-1,214	1,007	0,556	-1,018	5,763
0,345	0,564	-1,105	3,532	0,616	-1,206	1,439	0,513	-1,005	8,670
0,380	0,526	-1,112	4,968	0,575	-1,217	1,958	0,476	-1,008	12,608
0,418	0,507	-1,116	6,083	0,555	-1,221	2,384	0,459	-1,011	15,521
0,459	0,499	-1,121	6,955	0,544	-1,223	2,794	0,453	-1,019	17,314
0,505	0,490	-1,127	7,710	0,534	-1,228	3,116	0,445	-1,025	19,078
0,556	0,505	-1,161	7,825	0,549	-1,262	3,156	0,461	-1,059	19,401
0,612	0,562	-1,214	6,475	0,608	-1,314	2,676	0,516	-1,115	15,668
0,673	0,634	-1,253	4,835	0,682	-1,348	2,077	0,586	-1,158	11,258
0,740	0,709	-1,244	3,330	0,761	-1,336	1,476	0,657	-1,153	7,511
0,814	0,726	-1,242	3,246	0,781	-1,336	1,397	0,670	-1,147	7,538
0,895	0,686	-1,266	4,775	0,739	-1,364	2,003	0,633	-1,169	11,381
0,985	0,628	-1,309	7,915	0,675	-1,409	3,257	0,580	-1,209	19,237
1,083	0,615	-1,350	9,558	0,661	-1,452	3,855	0,568	-1,248	23,695
1,192	0,631	-1,379	9,096	0,676	-1,479	3,730	0,585	-1,279	22,179
1,311	0,677	-1,405	7,122	0,725	-1,503	2,972	0,630	-1,307	17,071
1,442	0,696	-1,419	6,542	0,745	-1,519	2,700	0,647	-1,320	15,850
1,586	0,652	-1,427	8,481	0,699	-1,530	3,398	0,605	-1,324	21,173
1,745	0,601	-1,433	11,887	0,645	-1,538	4,676	0,557	-1,329	30,220
1,919	0,610	-1,416	10,863	0,656	-1,521	4,259	0,565	-1,311	27,708
2,111	0,643	-1,406	8,514	0,692	-1,512	3,288	0,594	-1,299	22,048
2,322	0,674	-1,402	6,716	0,727	-1,512	2,528	0,621	-1,292	17,845
2,555	0,697	-1,398	5,622	0,752	-1,510	2,083	0,641	-1,287	15,177
2,810	0,677	-1,404	6,022	0,732	-1,518	2,170	0,622	-1,289	16,714
3,091	0,672	-1,392	5,641	0,728	-1,509	1,974	0,615	-1,274	16,118
3,400	0,628	-1,395	6,730	0,683	-1,517	2,273	0,573	-1,274	19,926
3,740	0,584	-1,393	7,883	0,637	-1,518	2,589	0,532	-1,268	24,005
4,114	0,592	-1,381	6,922	0,647	-1,509	2,211	0,537	-1,253	21,667
4,526	0,588	-1,376	6,620	0,644	-1,508	2,050	0,532	-1,245	21,377
4,978	0,589	-1,400	6,776	0,645	-1,534	2,043	0,532	-1,265	22,476
5,476	0,570	-1,415	7,461	0,626	-1,552	2,181	0,515	-1,278	25,119
6,024	0,581	-1,401	6,269	0,638	-1,538	1,835	0,524	-1,263	21,413
6,626	0,601	-1,369	4,681	0,662	-1,507	1,361	0,540	-1,230	16,097
7,289	0,635	-1,353	3,409	0,701	-1,493	0,980	0,569	-1,214	11,854
8,018	0,643	-1,352	2,946	0,709	-1,491	0,855	0,577	-1,214	10,153
8,820	0,613	-1,380	3,342	0,674	1,519	0,974	0,551	1,242	11,473
9,702	0,604	-1,397	3,213	0,663	-1,534	0,947	0,545	-1,260	10,899
10,672	0,615	-1,402	2,681	0,675	-1,537	0,801	0,556	-1,266	8,976
11,739	0,655	-1,411	1,951	0,718	-1,545	0,591	0,593	-1,277	6,447
12,913	0,672	-1,432	1,643	0,735	-1,566	0,498	0,609	-1,298	5,421
14,204	0,676	-1,458	1,499	0,737	-1,591	0,457	0,614	-1,325	4,915
15,625	0,667	-1,479	1,440	0,727	-1,611	0,443	0,607	-1,346	4,688
17,187	0,666	-1,496	1,307	0,724	1,628	0,405	0,607	1,365	4,220
18,906	0,669	-1,515	1,179	0,727	-1,646	0,366	0,611	-1,383	3,801
20,796	0,683	-1,521	0,963	0,742	-1,653	0,295	0,623	-1,388	3,139
22,876	0,682	-1,535	0,880	0,741	-1,668	0,268	0,623	-1,401	2,890
25,164	0,692	-1,544	0,763	0,752	-1,678	0,231	0,632	-1,410	2,528
27,680	0,709	-1,542	0,617	0,771	-1,677	0,184	0,647	-1,406	2,065

TABLE 4-2 SUMMARY OF PREDICTION COEFFICIENTS FOR VERTICAL PSRVS FOR STATIONS ON ROCK.

Frequency	Best Estimate Equations			Lower Bound Equations			Upper Bound Equations		
(Hz)	a	b	K	a	b	K	a	b	K
0,314	0,629	-1,050	1,913	0,702	-1,171	0,670	0,557	-0,929	5,461
0,345	0,582	-1,030	2,808	0,652	-1,154	0,959	0,512	-0,906	8,221
0,380	0,535	-1,030	4,078	0,602	-1,157	1,348	0,469	-0,902	12,336
0,418	0,510	-1,038	5,231	0,574	-1,168	1,689	0,446	-0,908	16,195
0,459	0,498	-1,065	6,438	0,558	-1,193	2,119	0,438	-0,937	19,558
0,505	0,479	-1,109	8,169	0,533	-1,234	2,760	0,425	-0,984	24,176
0.556	0,500	-1,158	8,285	0,554	-1,282	2,813	0,446	-1,033	24,400
0,612	0,569	-1,211	6,394	0,627	-1,333	2,212	0,512	-1,088	18,487
0,673	0,644	-1,252	4,696	0,705	-1,371	1,673	0,583	-1,133	13,184
0,740	0,731	-1,253	3,056	0,798	-1,369	1,124	0,664	-1,138	8,306
0,814	0,766	-1,242	2,633	0,839	-1,361	0,940	0,692	-1,123	7,376
0,895	0,736	-1,252	3,543	0,809	-1,375	1,215	0,664	-1,128	10,329
0,985	0,680	-1,282	5,642	0,747	-1,410	1,873	0,613	-1,155	16,998
1,083	0,658	-1,341	7,390	0,722	-1,471	2,380	0,594	-1,210	22,940
1,192	0,659	-1,400	8,063	0,720	-1,528	2,661	0,599	-1,273	24,432
1,311	0,698	-1,442	6,818	0,759	-1,568	2,282	0,637	-1,316	20,366
1,442	0,726	-1,468	6,104	0,789	-1,595	2,023	0,663	-1,340	18,420
1,586	0,691	-1,476	7,605	0,752	-1,605	2.469	0,630	-1,346	23,424
1,745	0,629	-1,473	11,171	0,686	-1,606	3.504	0,572	-1,339	35,617
1,919	0,629	-1,449	10,606	0,687	-1,584	3,306	0,570	-1,315	34,027
2,111	0,659	-1,449	8,589	0,720	-1,584	2,670	0,598	-1,315	27,633
2,322	0,685	-1,455	7,079	0,750	-1,591	2,163	0,621	-1,318	23,163
2,555	0,726	-1,455	5,382	0,794	-1,592	1,642	0,658	-1,318	17,635
2,810	0,710	-1,475	5,823	0,776	-1,611	1,783	0,644	-1,338	19,017
3,091	0,707	-1,470	5,426	0,774	-1,607	1,642	0,641	-1,332	17,927
3,400	0,659	-1,479	6,726	0,722	-1,619	2,006	0,597	-1,340	22,549
3,740	0,618	-1,484	7,883	0,677	-1,626	2,296	0,558	-1,342	27,065
4,114	0,623	-1,473	7,013	0,684	-1,618	1,999	0,562	-1,328	24,609
4,526	0,622	-1,466	6,590	0,684	-1,614	1,828	0,559	-1,319	23.761
4,978	0,621	-1,488	6,734	0,684	-1,638	1,830	0,558	-1,337	24,783
5,476	0,595	-1,508	7,690	0,656	-1,660	2,052	0,535	-1,356	28,816
6,024	0,602	-1,485	6,490	0,664	-1,637	1,734	0,541	-1,333	24,293
6,626	0,614	-1,454	5,099	0,678	-1,606	1,363	0,549	-1,302	19,080
7,289	0,642	-1,437	3,811	0,710	-1,590	1,011	0,573	-1,284	14,371
8,018	0,644	-1,422	3,290	0,714	-1,574	0,874	0,575	-1,269	12,379
8,820	0,616	-1,441	3,629	0,682	-1,596	0,948	0,550	-1,286	13,896
9,702	0,608	-1,455	3,448	0,672	-1,609	0,901	0,543	-1,300	13,188
10,672	0,618	-1,469	2,940	0,682	-1,623	0,776	0,553	-1,316	11,139
11,739	0,667	-1,473	1,996	0,737	-1,626	0,529	0,598	-1,319	7,527
12,913	0,690	-1,492	1,614	0,761	-1,646	0,424	0,619	-1,338	6,136
14,204	0,700	-1,518	1,421	0,771	-1,673	0,373	0,629	-1,364	5,411
15,625	0,692	-1,535	1,350	0,761	-1,688	0,356	0,623	-1,381	5.117
17,187	0,691	-1,553	1,229	0,759	-1,705	0,328	0,623	-1,401	4.610
18,906	0,700	-1,573	1,077	0,767	-1,724	0,290	0,633	-1,422	3,998
20,796	0,714	-1,589	0,900	0,783	-1,741	0,240	0,646	-1,437	3,371
22,876	0,716	-1,606	0,820	0,784	-1,759	0,218	0,648	-1,453	3,091
25,164	0,727	-1,622	0,713	0,797	-1,776	0,187	0,658	-1,467	2.717
27,680	0,744	-1,624	0.584	0,816	-1,780	0,151	0,673	-1,468	2.254

TABLE 4-3 SUMMARY OF PREDICTION COEFFICIENTS FOR RADIAL PSRVS FOR STATIONS ON ALLUVIUM.

Frequency	Best Estimate Equations			Lower Bound Equations			Upper Bound Equations		
(Hz)	a	b	K	a	b	K	a	b	K
0.314	0.658	-1.303	4.843	0.706	-1.400	2.144	0.609	-1.207	10.938
0.345	0.617	-1.246	6.232	0.666	-1.346	2.680	0.567	-1.146	14.493
0.380	0.529	-1.247	11.573	0.573	-1.351	4.806	0.485	-1.142	27.865
0.418	0.441	-1.293	23.488	0.478	-1.401	9.485	0.404	-1.186	58.163
0.459	0.392	-1.332	36.201	0.423	-1.439	14.672	0.360	-1.225	89.318
0.505	0.390	-1.371	41.932	0.420	-1.476	17.354	0.360	-1.267	101.319
0.556	0.427	-1.382	35.502	0.459	-1.484	15.092	0.396	-1.281	83.514
0.612	0.449	-1.462	37.576	0.480	-1.563	16.025	0.418	-1.361	88.114
0.673	0.493	-1.504	31.700	0.526	-1.605	13.589	0.460	-1.404	73.946
0.740	0.507	-1.484	27.297	0.541	-1.583	11.819	0.473	-1.385	63.047
0.814	0.505	-1.466	26.348	0.539	-1.564	11.510	0.471	-1.368	60.313
0.895	0.492	-1.453	28.692	0.526	-1.554	12.253	0.457	-1.352	67.186
0.985	0.489	-1.458	31.210	0.523	-1.559	13.316	0.455	-1.358	73.153
1.083	0.473	-1.499	39.073	0.505	-1.602	16.372	0.440	-1.396	93.249
1.192	0.457	-1.532	44.836	0.488	-1.635	18.740	0.426	-1.429	107.275
1.311	0.501	-1.529	32.497	0.534	-1.632	13.663	0.467	-1.427	77.289
1.442	0.540	-1.495	22.689	0.577	-1.599	9.452	0.502	-1.391	54.461
1.586	0.490	-1.498	28.830	0.524	-1.602	12.068	0.456	-1.395	68.871
1.745	0.462	-1.507	33.437	0.493	-1.608	14.271	0.431	-1.406	78.345
1.919	0.484	-1.483	26.786	0.515	-1.580	11.743	0.452	-1.385	61.100
2.111	0.508	-1.434	19.354	0.543	-1.534	8.344	0.472	-1.334	44.894
2.322	0.522	-1.407	15.559	0.559	-1.508	6.652	0.485	-1.307	36.389
2.555	0.555	-1.389	11.746	0.595	-1.490	5.016	0.515	-1.288	27.506
2.810	0.512	-1.410	14.839	0.550	-1.516	6.076	0.473	-1.304	36.239
3.091	0.504	-1.434	15.725	0.543	-1.543	6.249	0.466	-1.325	39.570
3.400	0.513	-1.431	13.967	0.553	-1.543	5.450	0.473	-1.320	35.794
3.740	0.515	-1.401	11.999	0.556	-1.514	4.650	0.474	-1.289	30.962
4.114	0.520	-1.404	11.023	0.562	-1.516	4.262	0.478	-1.291	28.512
4.526	0.516	-1.399	10.463	0.560	-1.519	3.787	0.471	-1.279	28.908
4.978	0.511	-1.409	10.469	0.557	-1.536	3.578	0.465	-1.282	30.631
5.476	0.514	-1.423	9.929	0.561	-1.553	3.315	0.467	-1.294	29.743
6.024	0.534	-1.397	7.408	0.583	-1.528	2.460	0.484	-1.267	22.302
6.626	0.549	-1.381	5.857	0.601	-1.512	1.947	0.497	-1.251	17.615
7.289	0.597	-1.388	4.285	0.653	-1.516	1.446	0.542	-1.259	12.697
8.018	0.607	-1.381	3.540	0.663	-1.508	1.211	0.552	-1.254	10.345
8.820	0.597	-1.406	3.542	0.650	-1.532	1.219	0.543	-1.279	10.289
9.702	0.586	-1.439	3.589	0.636	-1.561	1.274	0.536	-1.316	10.110
10.672	0.608	-1.451	2.915	0.660	-1.574	1.032	0.556	-1.328	8.232
11.739	0.627	-1.474	2.457	0.680	-1.597	0.871	0.575	-1.352	6.927
12.913	0.638	-1.494	2.147	0.690	-1.616	0.770	0.586	-1.373	5.985
14.204	0.644	-1.519	1.941	0.695	-1.639	0.710	0.594	-1.400	5.306
15.625	0.635	-1.540	1.880	0.684	-1.658	0.696	0.587	-1.423	5.079
17.187	0.634	-1.572	1.792	0.682	-1.690	0.663	0.587	-1.454	4.846
18.906	0.637	-1.593	1.624	0.683	-1.710	0.607	0.590	-1.476	4.347
20.796	0.638	-1.605	1.450	0.684	-1.722	0.539	0.591	-1.488	3.898
22.876	0.638	-1.631	1.391	0.684	-1.749	0.516	0.592	-1.514	3.747
25.164	0.649	-1.644	1.220	0.695	-1.762	0.450	0.602	-1.526	3.312
27.680	0.655	-1.654	1.092	0.702	-1.774	0.397	0.607	-1.535	3.001

TABLE 4-4 SUMMARY OF PREDICTION COEFFICIENTS FOR RADIAL PSRVS FOR STATIONS ON ROCK.

Frequency	Best Estimate Equations			Lower Bound Equations			Upper Bound Equations		
Hz	a	b	K	a	b	K	a	b	K
0.314	0.713	-1.233	3.089	0.778	-1.344	1.240	0.649	-1.121	7.694
0.345	0.660	-1.180	4.318	0.725	-1.296	1.683	0.596	-1.065	11.082
0.380	0.575	-1.177	7.912	0.634	-1.298	2.958	0.516	-1.057	21.162
0.418	0.487	-1.227	16.294	0.537	-1.353	5.852	0.437	-1.102	45.369
0.459	0.439	-1.269	25.222	0.483	-1.397	8.908	0.395	-1.142	71.415
0.505	0.430	-1.310	30.450	0.471	-1.435	10.974	0.389	-1.184	84.494
0.556	0.468	-1.320	25.468	0.511	-1.440	9.540	0.425	-1.200	67.988
0.612	0.507	-1.409	24.965	0.551	-1.530	9.274	0.463	-1.287	67.208
0.673	0.545	-1.457	22.042	0.591	-1.579	8.123	0.499	-1.334	59.811
0.740	0.558	-1.434	18.881	0.604	-1.553	7.147	0.511	-1.315	49.883
0.814	0.557	-1.427	18.392	0.602	-1.542	7.154	0.512	-1.311	47.286
0.895	0.543	-1.422	20.399	0.587	-1.538	7.896	0.498	-1.306	52.698
0.985	0.527	-1.432	24.097	0.571	-1.551	9.154	0.483	-1.313	63.431
1.083	0.511	-1.464	29.640	0.555	-1.589	10.626	0.467	-1.338	82.678
1.192	0.508	-1.495	31.513	0.552	-1.624	11.063	0.465	-1.367	89.763
1.311	0.546	-1.491	23.649	0.593	-1.620	8.319	0.499	-1.363	67.225
1.442	0.579	-1.455	17.084	0.631	-1.585	5.949	0.528	-1.326	49.062
1.586	0.532	-1.453	21.040	0.579	-1.582	7.356	0.485	-1.324	60.178
1.745	0.508	-1.459	23.596	0.552	-1.584	8.511	0.465	-1.334	65.419
1.919	0.519	-1.446	20.615	0.562	-1.566	7.764	0.476	-1.326	54.736
2.111	0.546	-1.391	14.381	0.594	-1.512	5.358	0.499	-1.270	38.599
2.322	0.562	-1.369	11.609	0.611	-1.489	4.353	0.512	-1.248	30.960
2.555	0.590	-1.362	9.161	0.642	-1.482	3.443	0.538	-1.242	24.375
2.810	0.557	-1.408	11.472	0.606	-1.530	4.209	0.509	-1.285	31.263
3.091	0.557	-1.451	12.131	0.605	-1.576	4.371	0.509	-1.326	33.668
3.400	0.561	-1.462	11.428	0.609	-1.589	4.069	0.512	-1.336	32.097
3.740	0.570	-1.436	9.513	0.620	-1.562	3.405	0.520	-1.310	26.579
4.114	0.573	-1.446	9.025	0.623	-1.572	3.237	0.523	-1.321	25.164
4.526	0.566	-1.446	8.725	0.619	-1.581	2.905	0.513	-1.311	26.208
4.978	0.556	-1.462	9.073	0.611	-1.605	2.815	0.502	-1.318	29.245
5.476	0.554	-1.482	8.922	0.607	-1.624	2.798	0.500	-1.340	28.450
6.024	0.562	-1.480	7.391	0.615	-1.618	2.384	0.510	-1.341	22.914
6.626	0.580	-1.458	5.682	0.636	-1.598	1.807	0.524	-1.317	17.868
7.289	0.627	-1.452	4.151	0.686	-1.600	1.346	0.568	-1.324	12.807
8.018	0.632	-1.444	3.445	0.693	-1.583	1.109	0.571	-1.305	10.705
8.820	0.621	-1.472	3.445	0.681	-1.612	1.098	0.562	-1.331	10.813
9.702	0.602	-1.516	3.762	0.656	-1.652	1.238	0.548	-1.380	11.136
10.672	0.630	-1.522	2.919	0.687	-1.659	0.952	0.573	-1.384	8.152
11.739	0.651	-1.542	2.419	0.709	-1.681	0.781	0.592	-1.404	7.491
12.913	0.671	-1.552	1.952	0.730	-1.689	0.639	0.612	-1.415	5.967
14.204	0.687	-1.572	1.652	0.746	-1.707	0.549	0.628	-1.437	4.967
15.625	0.679	-1.586	1.569	0.736	-1.720	0.525	0.621	-1.452	4.687
17.187	0.682	-1.615	1.465	0.739	-1.751	0.482	0.624	-1.479	4.452
18.906	0.687	-1.638	1.319	0.743	-1.773	0.440	0.630	-1.504	3.949
20.796	0.686	-1.656	1.210	0.742	-1.791	0.402	0.630	-1.521	3.641
22.876	0.686	-1.687	1.178	0.741	-1.823	0.390	0.631	-1.552	3.559
25.164	0.702	-1.700	1.006	0.759	-1.837	0.328	0.645	-1.562	3.083
27.680	0.708	-1.712	0.903	0.766	-1.851	0.289	0.650	-1.572	2.321

TABLE 4-5 SUMMARY OF PREDICTION COEFFICIENTS FOR TRANSVERSE PSRVS FOR STATIONS ON ALLUVIUM

Frequency	Best Estimate Equations			Lower Bound Equations			Upper Bound Equations		
(Hz)	a	b	K	a	b	K	a	b	K
0.314	0.468	-0.999	5.065	0.519	-1.108	2.031	0.417	-0.890	12.633
0.345	0.445	-1.042	7.575	0.491	-1.152	3.016	0.398	-0.933	19.024
0.380	0.448	-1.080	9.111	0.493	-1.187	3.674	0.403	-0.972	22.593
0.418	0.457	-1.131	10.846	0.500	-1.238	4.421	0.414	-1.024	26.610
0.459	0.416	-1.180	16.678	0.454	-1.288	6.735	0.378	-1.072	41.300
0.505	0.389	-1.244	24.044	0.423	-1.353	9.599	0.354	-1.135	60.224
0.556	0.405	-1.291	25.304	0.439	-1.400	10.115	0.371	-1.182	63.301
0.612	0.418	-1.365	28.958	0.451	-1.471	11.776	0.385	-1.258	71.207
0.673	0.468	-1.405	24.738	0.503	-1.511	10.088	0.432	-1.298	60.662
0.740	0.484	-1.426	24.401	0.519	-1.530	10.189	0.449	-1.323	58.440
0.814	0.520	-1.418	19.855	0.558	-1.522	8.242	0.482	-1.313	47.832
0.895	0.520	-1.417	20.232	0.559	-1.523	8.277	0.481	-1.310	49.455
0.985	0.471	-1.433	28.548	0.507	-1.541	11.531	0.435	-1.325	70.676
1.083	0.425	-1.476	41.369	0.456	-1.584	16.610	0.393	-1.367	103.037
1.192	0.402	-1.537	53.928	0.430	-1.645	21.647	0.373	-1.428	134.345
1.311	0.437	-1.550	43.051	0.467	-1.657	17.520	0.407	-1.443	105.786
1.442	0.487	-1.529	29.483	0.522	-1.636	11.952	0.453	-1.422	72.732
1.586	0.486	-1.511	27.476	0.522	-1.620	10.963	0.451	-1.401	68.659
1.745	0.488	-1.481	24.723	0.523	-1.587	10.130	0.453	-1.375	60.336
1.919	0.471	-1.444	23.967	0.505	-1.548	9.982	0.437	-1.340	57.546
2.111	0.487	-1.447	21.047	0.523	-1.552	8.715	0.452	-1.342	50.832
2.322	0.519	-1.455	17.408	0.557	-1.562	7.075	0.480	-1.346	42.833
2.555	0.550	-1.429	13.137	0.591	-1.536	5.329	0.509	-1.322	32.387
2.810	0.548	-1.420	12.372	0.591	-1.531	4.866	0.506	-1.309	31.455
3.091	0.536	-1.432	12.940	0.578	-1.546	4.957	0.493	-1.318	33.714
3.400	0.518	-1.439	13.202	0.560	-1.553	5.039	0.477	-1.324	34.590
3.740	0.545	-1.418	10.043	0.590	-1.535	3.750	0.500	-1.301	26.693
4.114	0.496	-1.429	12.552	0.537	-1.550	4.565	0.454	-1.309	34.674
4.526	0.475	-1.430	13.109	0.517	-1.555	4.533	0.434	-1.306	37.411
4.978	0.512	-1.399	9.209	0.559	-1.528	3.108	0.465	-1.270	27.293
5.476	0.543	-1.393	7.098	0.593	-1.521	2.422	0.493	-1.265	20.707
6.024	0.561	-1.386	5.658	0.611	1.511	1.979	0.510	-1.261	16.172
6.626	0.557	-1.374	5.045	0.607	-1.499	1.763	0.508	-1.249	14.441
7.289	0.592	-1.374	3.820	0.645	-1.498	1.339	0.538	-1.249	10.902
8.018	0.623	-1.360	2.786	0.681	-1.486	0.961	0.565	-1.233	8.093
8.820	0.636	-1.369	2.355	0.695	-1.496	0.809	0.577	-1.242	6.856
9.702	0.642	-1.391	2.151	0.700	-1.517	0.746	0.584	-1.266	6.199
10.672	0.658	-1.416	1.873	0.717	-1.542	0.649	0.599	-1.290	5.406
11.739	0.671	-1.432	1.572	0.730	-1.559	0.549	0.611	-1.305	4.567
12.913	0.680	-1.455	1.390	0.749	-1.581	0.483	0.622	-1.329	4.001
14.204	0.693	-1.475	1.190	0.751	-1.599	0.419	0.635	-1.351	3.378
15.625	0.669	-1.510	1.281	0.723	-1.632	0.457	0.615	1.368	3.584
17.187	0.642	-1.554	1.443	[illegible]	-1.675	0.522	[illegible]	1.433	3.340
18.906	0.653	[illegible]	[illegible]	[illegible]	-1.708	0.476	[illegible]	-1.4[illegible]	[illegible]
20.796	0.662	-1.593	[illegible]	0.720	-1.720	0.387	0.619	[illegible]	[illegible]
22.876	0.663	-1.611	0.926	0.735	-1.732	0.344	0.632	-1.490	2.567
25.154	0.632	-1.628	0.833	0.744	-1.750	[illegible]	[illegible]	-1.506	2.324
27.680	0.591	-1.646	0.790	0.743	-1.768	0.252	0.640	-1.523	2.215

TABLE 4-6 SUMMARY OF PREDICTION COEFFICIENTS FOR TRANSVERSE PSRVS FOR STATIONS ON ROCK.

Frequency	Best Estimate Equations			Lower Bound Equations			Upper Bound Equations		
(Hz)	a	b	K	a	b	K	a	b	K
0.314	0.511	-0.986	3.999	0.575	-1.110	1.469	0.447	-0.863	10.888
0.345	0.489	-1.035	5.986	0.548	-1.160	2.159	0.429	-0.910	16.595
0.380	0.488	-1.077	7.440	0.544	-1.201	2.719	0.432	-0.953	20.356
0.418	0.480	-1.128	9.779	0.533	-1.251	3.571	0.427	-1.004	26.782
0.459	0.449	-1.173	14.200	0.497	-1.299	5.119	0.401	-1.048	39.390
0.505	0.436	-1.226	18.401	0.482	-1.356	6.413	0.390	-1.097	52.800
0.556	0.454	-1.264	18.726	0.501	-1.394	6.504	0.408	-1.134	53.918
0.612	0.467	-1.324	20.747	0.513	-1.453	7.264	0.422	-1.195	59.258
0.673	0.515	-1.369	18.092	0.564	-1.499	6.237	0.466	-1.238	52.479
0.740	0.535	-1.397	17.652	0.584	-1.526	6.164	0.485	-1.268	50.546
0.814	0.573	-1.399	14.438	0.626	-1.528	5.041	0.520	-1.269	41.350
0.895	0.563	-1.409	15.813	0.617	-1.542	5.356	0.510	-1.276	46.690
0.985	0.513	-1.415	21.868	0.562	-1.552	7.212	0.463	-1.279	66.310
1.083	0.459	-1.444	32.051	0.502	-1.581	10.477	0.415	-1.306	98.050
1.192	0.443	-1.502	39.729	0.484	-1.639	13.036	0.403	-1.365	121.075
1.311	0.478	-1.519	32.222	0.520	-1.655	10.671	0.435	-1.383	97.301
1.442	0.539	-1.476	20.007	0.589	-1.613	6.589	0.489	-1.340	60.754
1.586	0.539	-1.456	18.433	0.590	-1.594	5.987	0.488	-1.318	56.749
1.745	0.550	-1.419	15.408	0.602	-1.553	5.165	0.498	-1.285	45.965
1.919	0.521	-1.387	16.069	0.571	-1.520	5.452	0.471	-1.254	47.358
2.111	0.531	-1.385	14.489	0.581	-1.517	4.972	0.480	-1.254	42.219
2.322	0.563	-1.408	12.268	0.616	-1.541	4.139	0.510	-1.274	36.360
2.555	0.607	-1.391	8.772	0.665	-1.523	2.993	0.549	-1.259	25.712
2.810	0.609	-1.393	8.296	0.668	-1.528	2.771	0.550	-1.258	24.833
3.091	0.600	-1.411	8.647	0.657	-1.547	2.854	0.542	-1.275	26.202
3.400	0.582	-1.438	9.235	0.637	-1.574	3.043	0.527	-1.301	28.028
3.740	0.611	-1.432	7.132	0.669	-1.569	2.332	0.552	-1.294	21.812
4.114	0.561	-1.459	9.281	0.616	-1.602	2.911	0.506	-1.317	29.587
4.526	0.530	-1.462	10.233	0.583	-1.608	3.108	0.477	-1.315	33.691
4.978	0.558	-1.429	7.496	0.617	-1.581	2.172	0.498	-1.277	25.866
5.476	0.581	-1.428	6.079	0.641	-1.576	1.820	0.521	-1.279	20.305
6.024	0.598	-1.427	4.900	0.659	-1.570	1.526	0.538	-1.284	15.739
6.626	0.597	-1.409	4.241	0.657	-1.552	1.328	0.536	-1.267	13.541
7.289	0.637	-1.394	3.017	0.701	-1.535	0.954	0.572	-1.252	9.545
8.018	0.661	-1.385	2.314	0.729	-1.527	0.727	0.593	-1.243	7.360
8.820	0.668	-1.409	2.078	0.735	-1.550	0.660	0.601	-1.268	6.544
9.702	0.674	-1.436	1.918	0.740	-1.578	0.604	0.607	-1.294	6.089
10.672	0.695	-1.452	1.581	0.763	-1.594	0.497	0.627	-1.310	5.034
11.739	0.710	-1.463	1.298	0.780	-1.608	0.397	0.639	-1.317	4.244
12.913	0.727	-1.471	1.067	0.798	-1.616	0.328	0.655	-1.326	3.474
14.204	0.743	-1.482	0.876	0.815	-1.626	0.271	0.671	-1.338	2.832
15.625	0.724	-1.515	0.917	0.792	-1.657	0.288	0.656	-1.373	2.913
17.187	0.699	-1.557	1.017	0.763	-1.698	0.321	0.636	-1.415	3.222
18.906	0.716	-1.593	0.909	0.781	-1.737	0.281	0.651	-1.448	2.947
20.796	0.730	-1.605	0.777	0.796	-1.753	0.236	0.664	1.463	2.536
22.876	0.745	-1.626	0.661	0.812	-1.772	0.2[illegible]1	0.678	1.480	2.168
25.164	0.757	-1.641	0.583	0.825	-1.769	0.175	0.688	-1.493	1.949
27.680	0.756	-1.661	0.557	0.824	-1.810	0.164	0.6[illegible]4	-1.511	1.867

4.2 Evaluation of Predictions

The predictive capability of the derived equations at this point is unproven. In an effort to determine their usefulness as a predictive tool, comparisons of PSRVs calculated from these equations and PSRVs measured in four UNEs were made. These four UNEs were not included in the data base used to derive the equations discussed in this report or the surface-downhole ratios derived in Phillips (1987). These comparisons are discussed below.

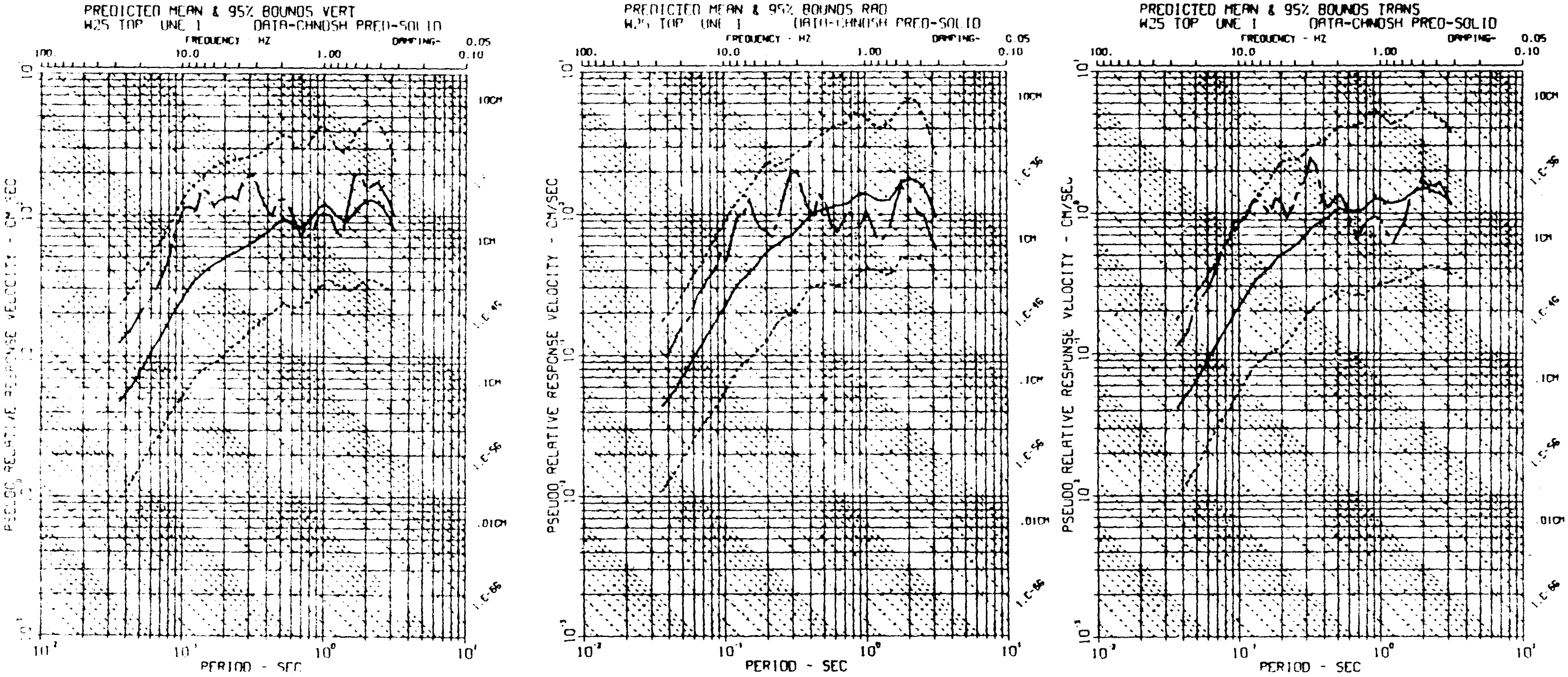
The first UNE used is a recent event (80 to 150 kt yield) recorded at the Yucca Mountain stations (source-to-station distances between 40 and 50 km). Measured and predicted PSRVs for this event are shown in Figures 4-1 through 4-8. The predictions are shown on these plots as a solid line (best estimate) and dashed lines (95% confidence intervals). The data are shown as the chain dashed lines. All three components for a particular station are shown on a single figure. The conclusions drawn from these figures are listed below.

1. In general, the prediction procedure accurately describes the observed ground motions at Yucca Mountain. All measured PSRVs are within the 95% confidence intervals of the best estimate of the predictions.

2. Of all Yucca Mountain stations active on this UNE, station W-25 had the largest deviation between measured and predicted PSRVs. This deviation occurred in frequencies greater than 2 Hz. At frequencies less than 2 Hz, the data and the prediction are in reasonable agreement. Additional study needs to be done to understand the station effects at this location.

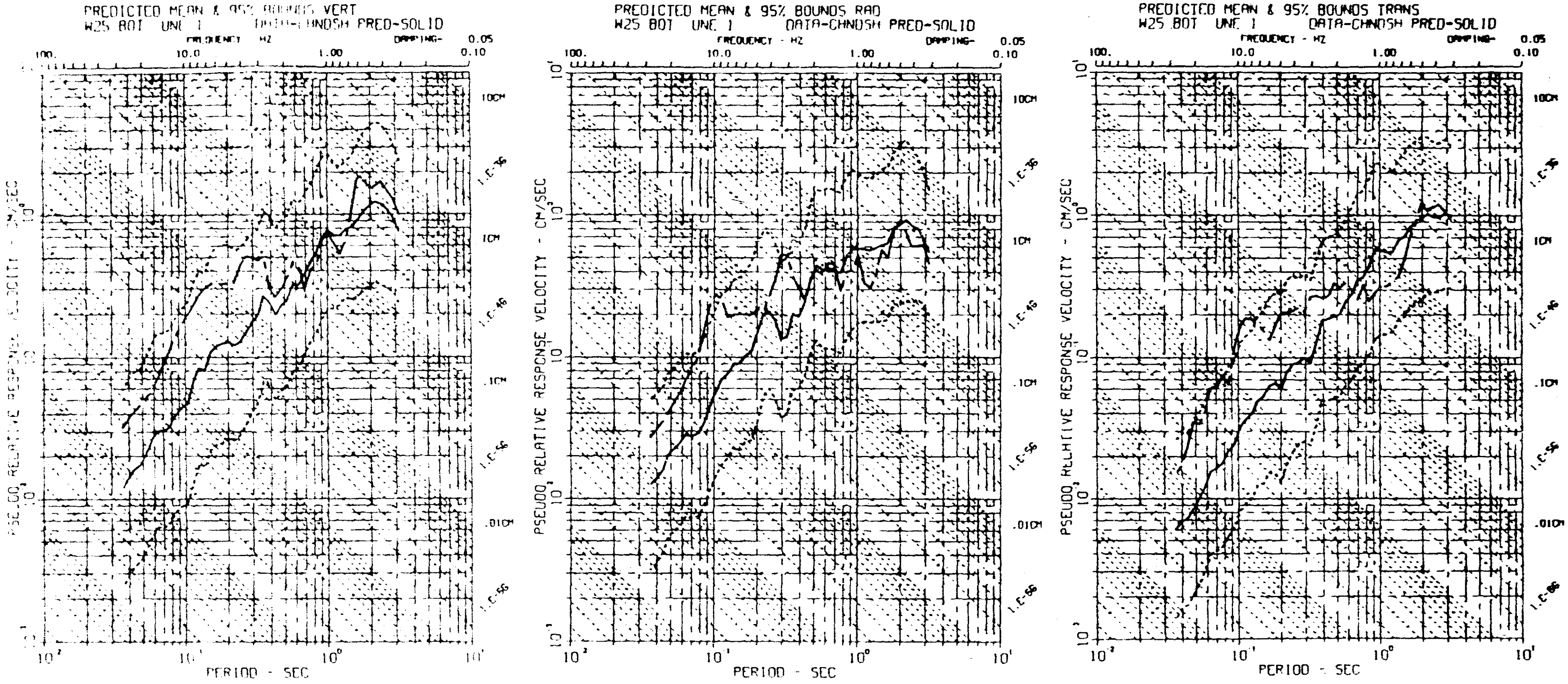
3. The technique used to predict downhole PSRVs produces satisfactory results. Predicted spectra shapes and amplitudes agree reasonably well with the observed values.

The second UNE used for evaluation purposes was also a recent event with the same general parameters as the UNE discussed above. The comparisons of the predicted and measured values are shown in Figures 4-9 and 4-16. The conclusions reached from these figures are similar to those listed above. The predictions for this UNE do not compare as favorably with the measured PSRVs, however. In general, the measured surface PSRVs have a higher frequency content and greater amplitudes than the predictions. The largest difference between measured and predicted PSRVs occurred at W-25 again. The predicted downhole PSRVs mirror the shape of the measured PSRVs, but are lower in amplitude, due in part to the underprediction of the surface amplitudes. In most cases, the measured PSRVs are within the 95% confidence intervals.



Vertical **Radial** **Transverse**

Figure 4-1. **Comparison of the predicted and measured PSRVs for a recent UNE (UNE1) recorded at Yucca Mountain station W-25 surface. (Station geology classified as rock.)**

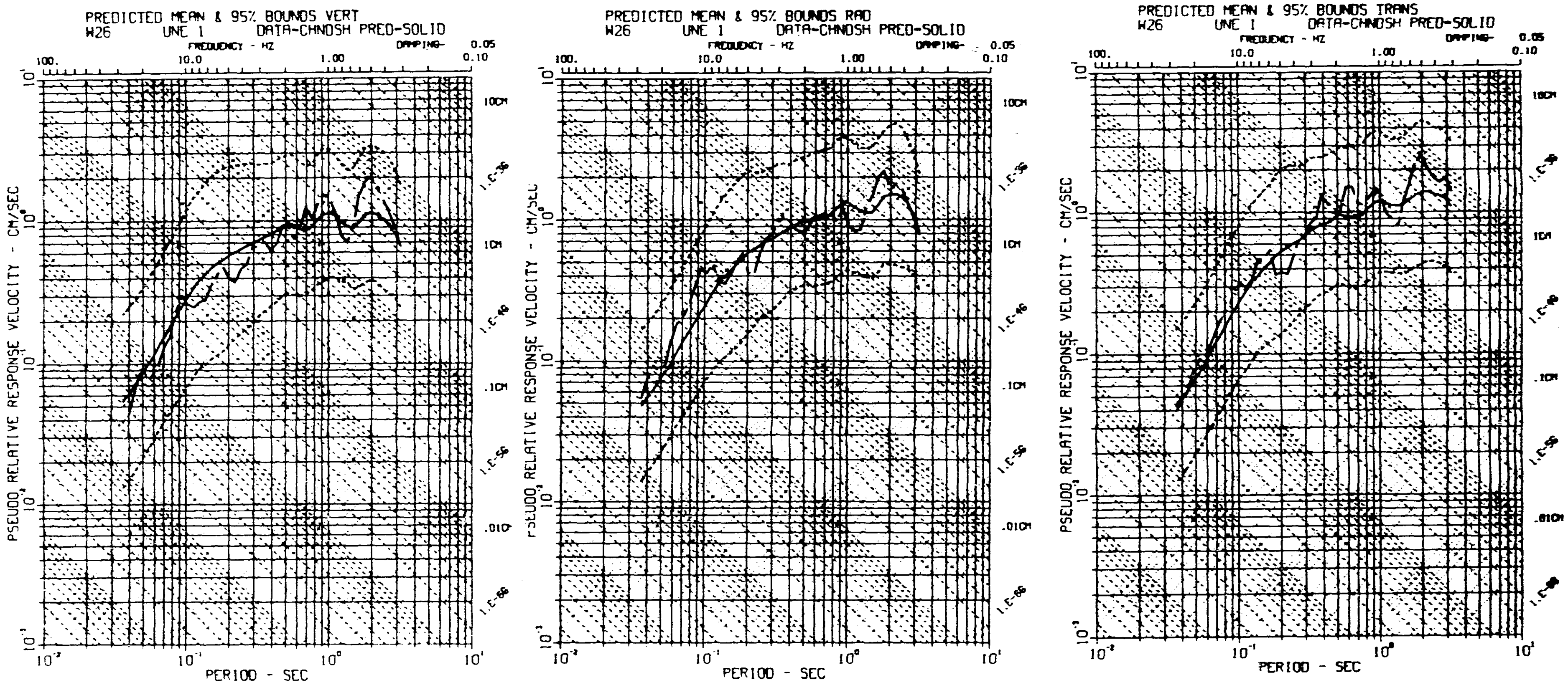


Vertical

Radial

Transverse

Figure 4-2. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-25 downhole. (station geology classified as rock) - UNE1

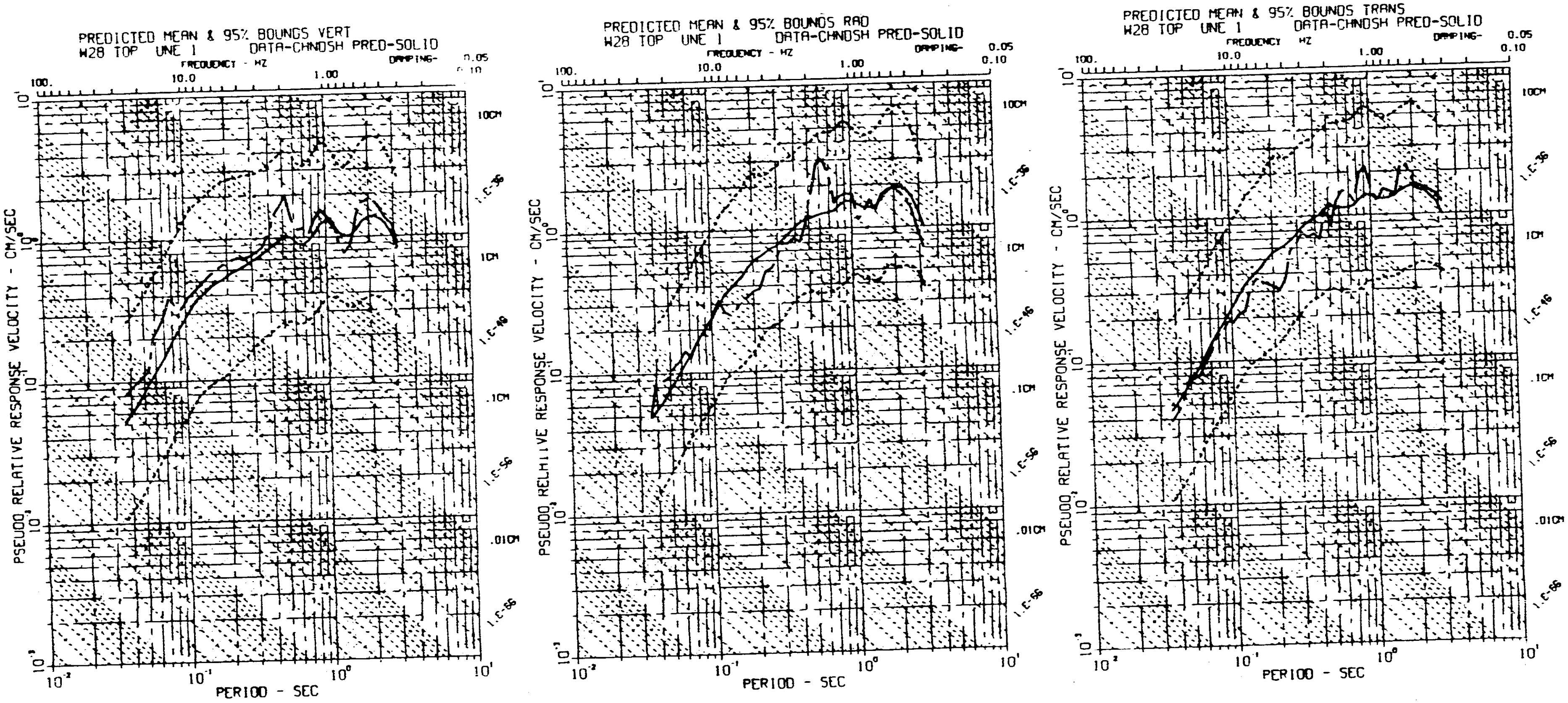


Vertical

Radial

Transverse

Figure 4-3. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-26. (station geology classified as alluvium) - UNE1

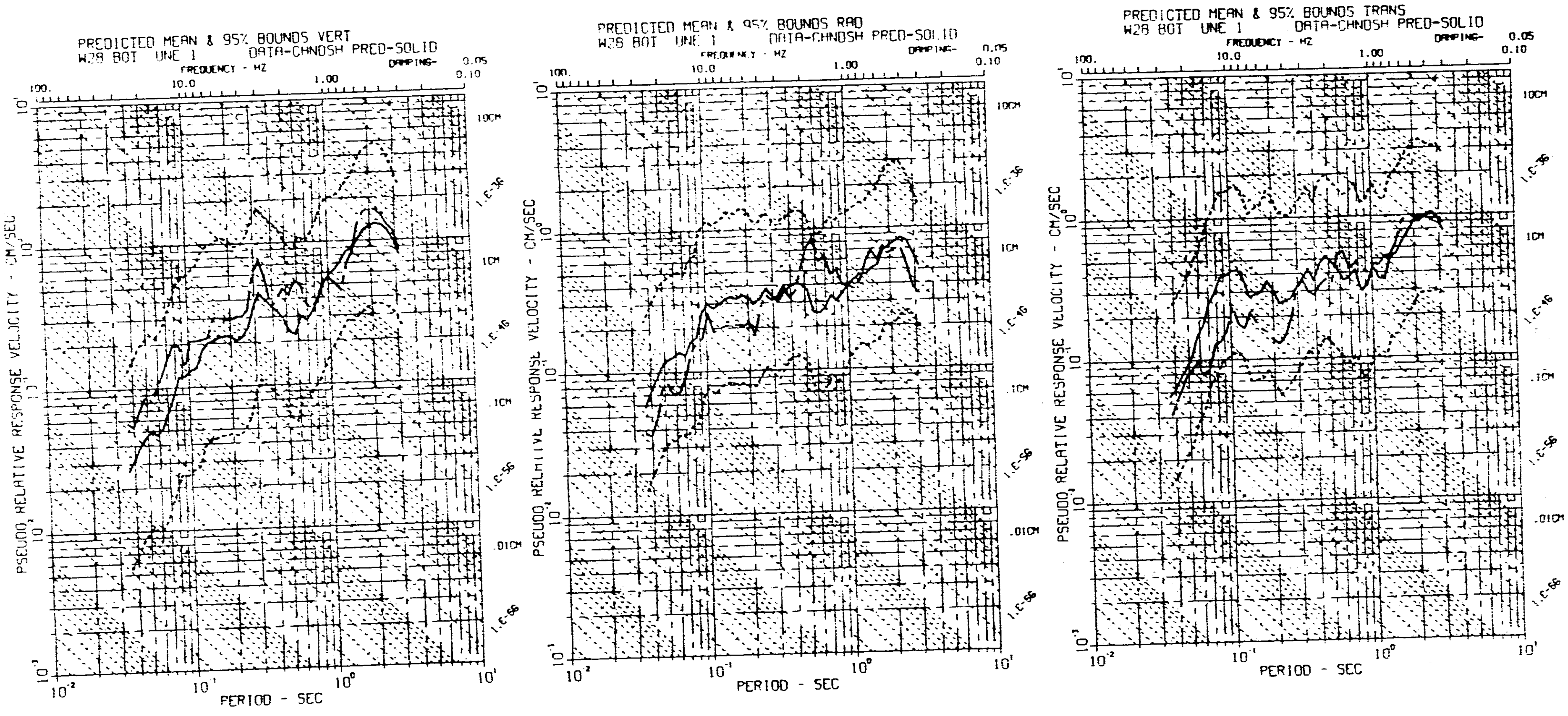


Vertical

Radial

Transverse

Figure 4-4. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-28 surface. (station geology classified as rock)- UNE1

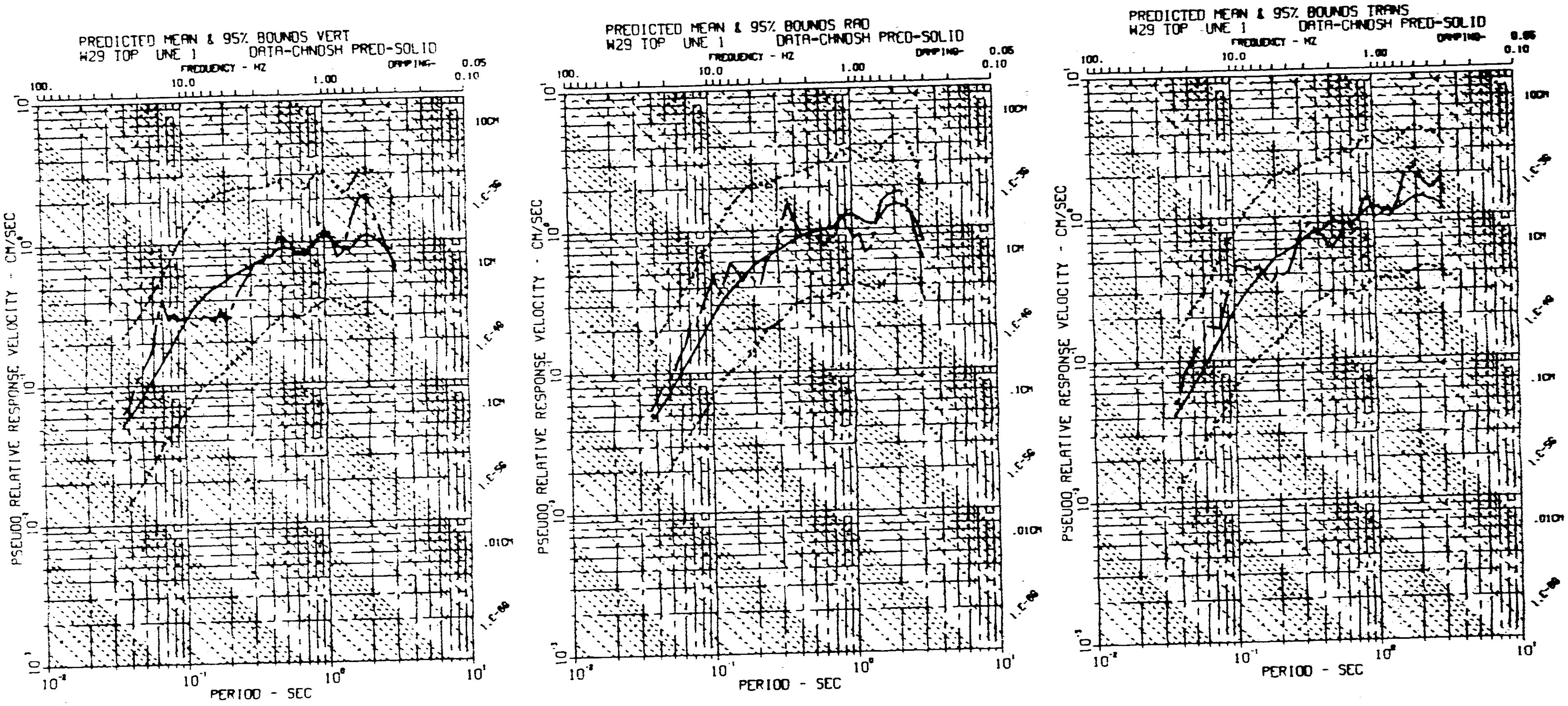


Vertical

Radial

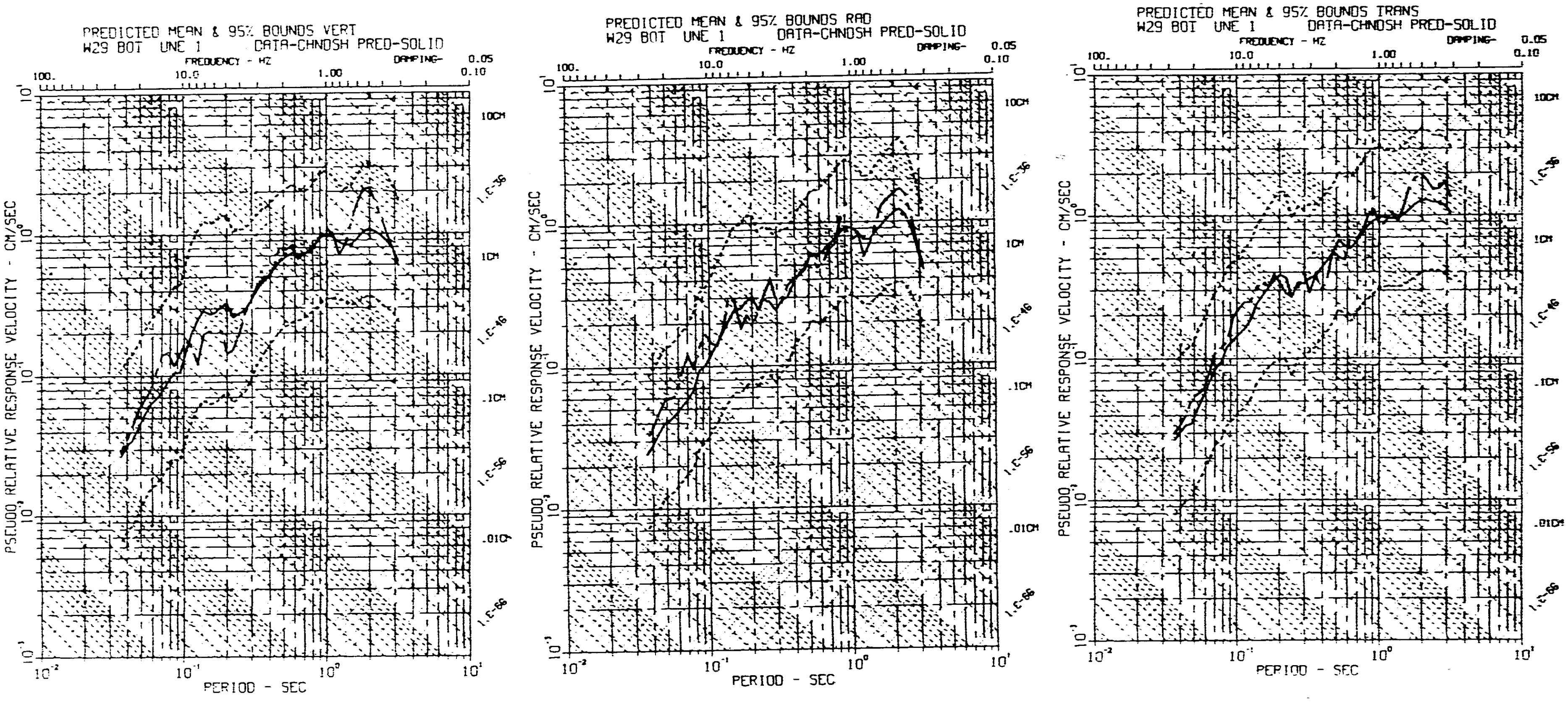
Transverse

Figure 4-5. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-28 downhole. (station geology classified as rock) - UNE1



Vertical *Radial* *Transverse*

Figure 4-6. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-29 surface. (station geology classified as alluvium) - UNE1

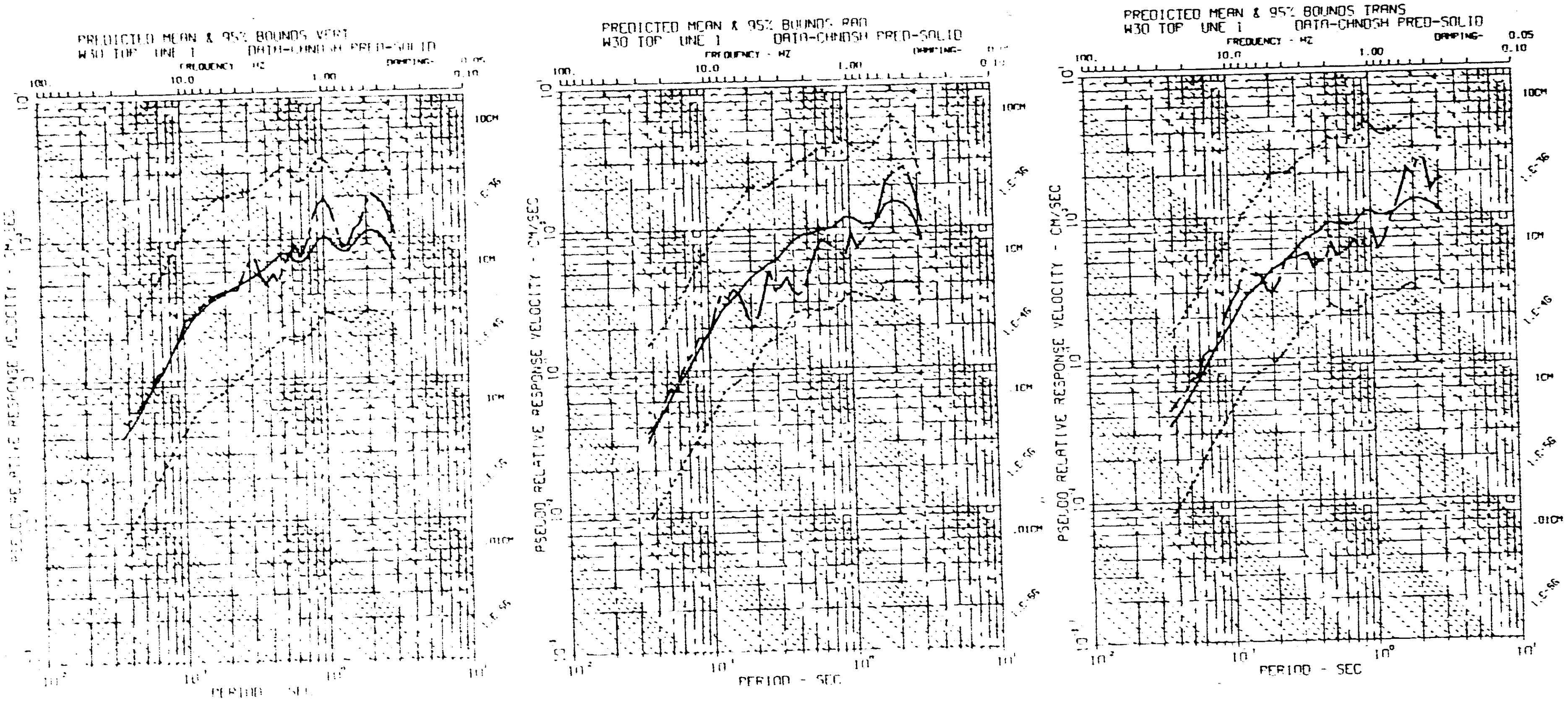


Vertical

Radial

Transverse

Figure 4-7. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-29 downhole. (station geology classified as alluvium) - UNE1

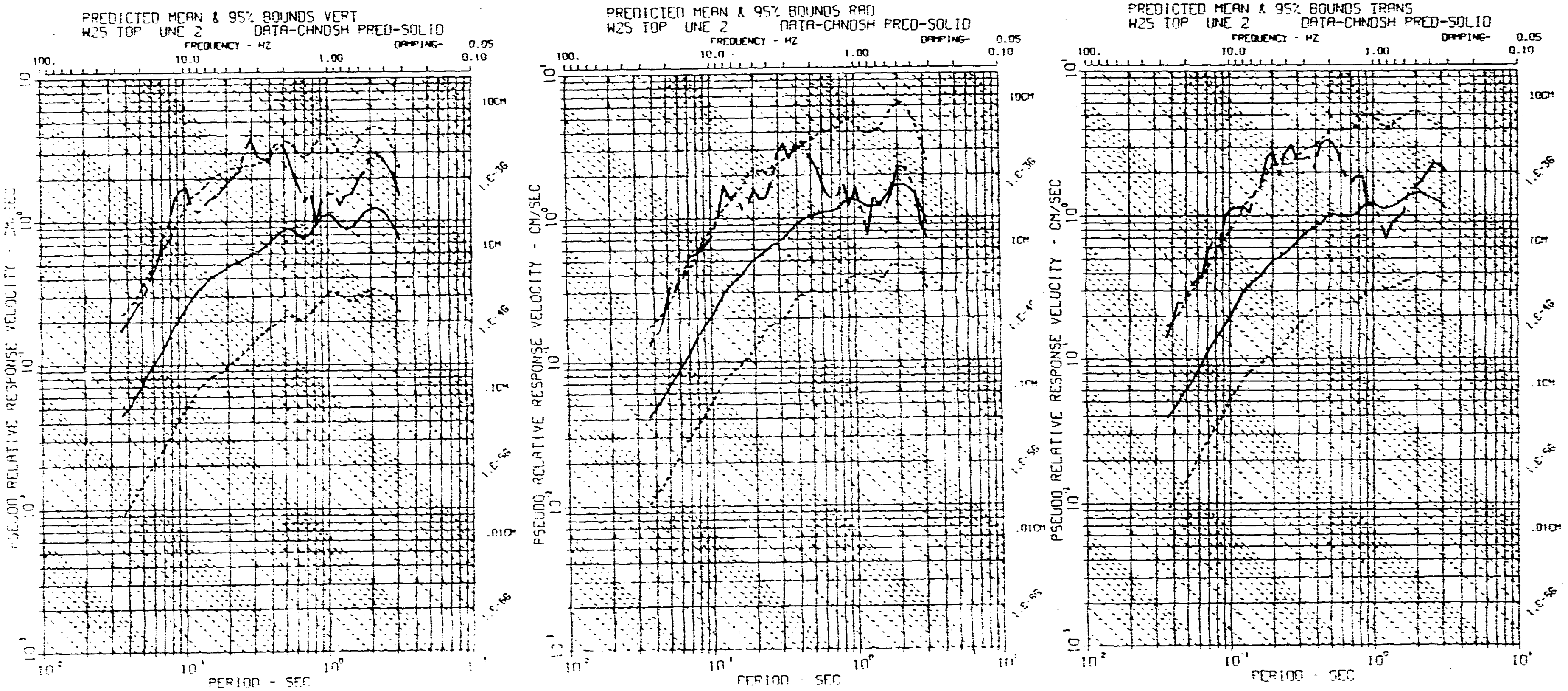


Vertical

Radial

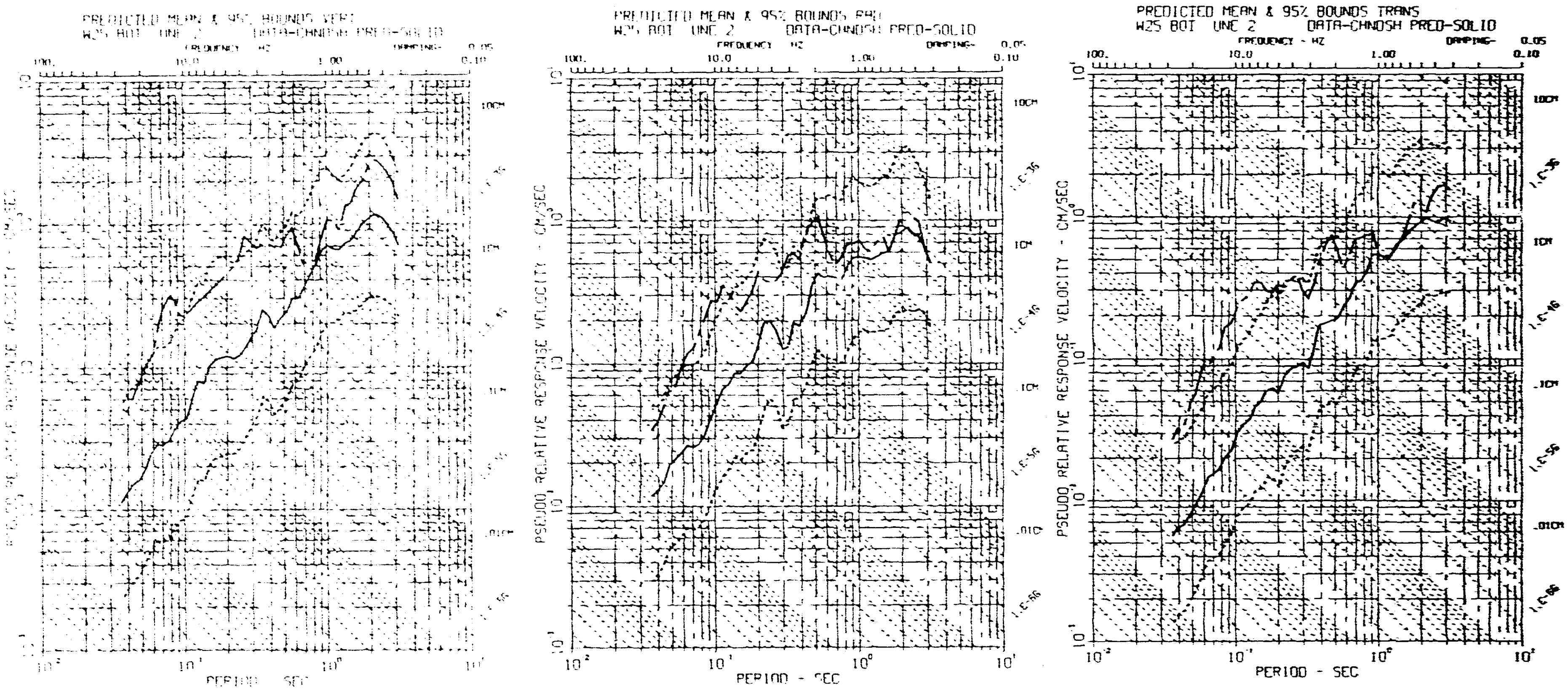
Transverse

Figure 4-8. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-30 surface. (station geology classified as rock) - UNE1



Vertical Radial Transverse

Figure 4-9. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-25 surface. (station geology classified as rock) - UNE2

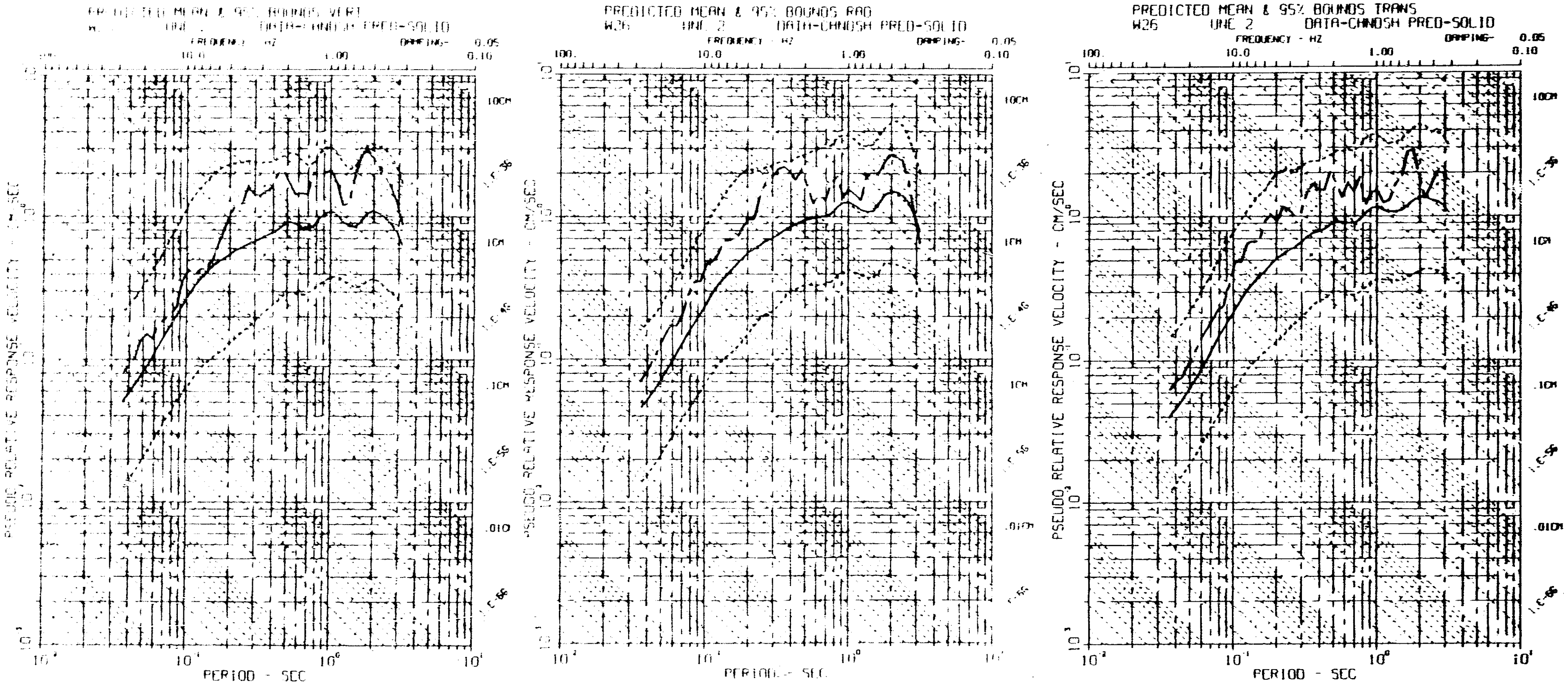


Vertical

Radial

Transverse

Figure 4-10. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-25 downhole. (station geology classified as rock) - UNE2

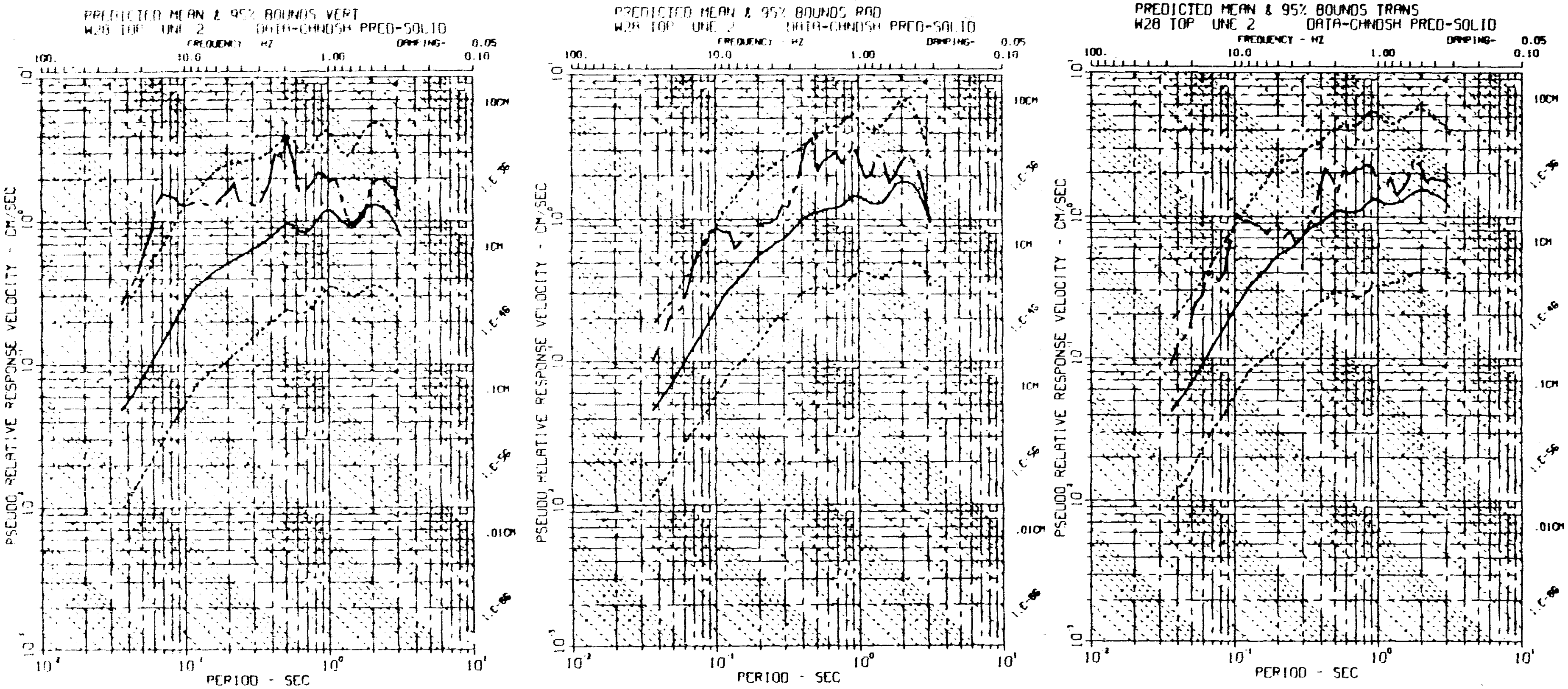


Vertical

Radial

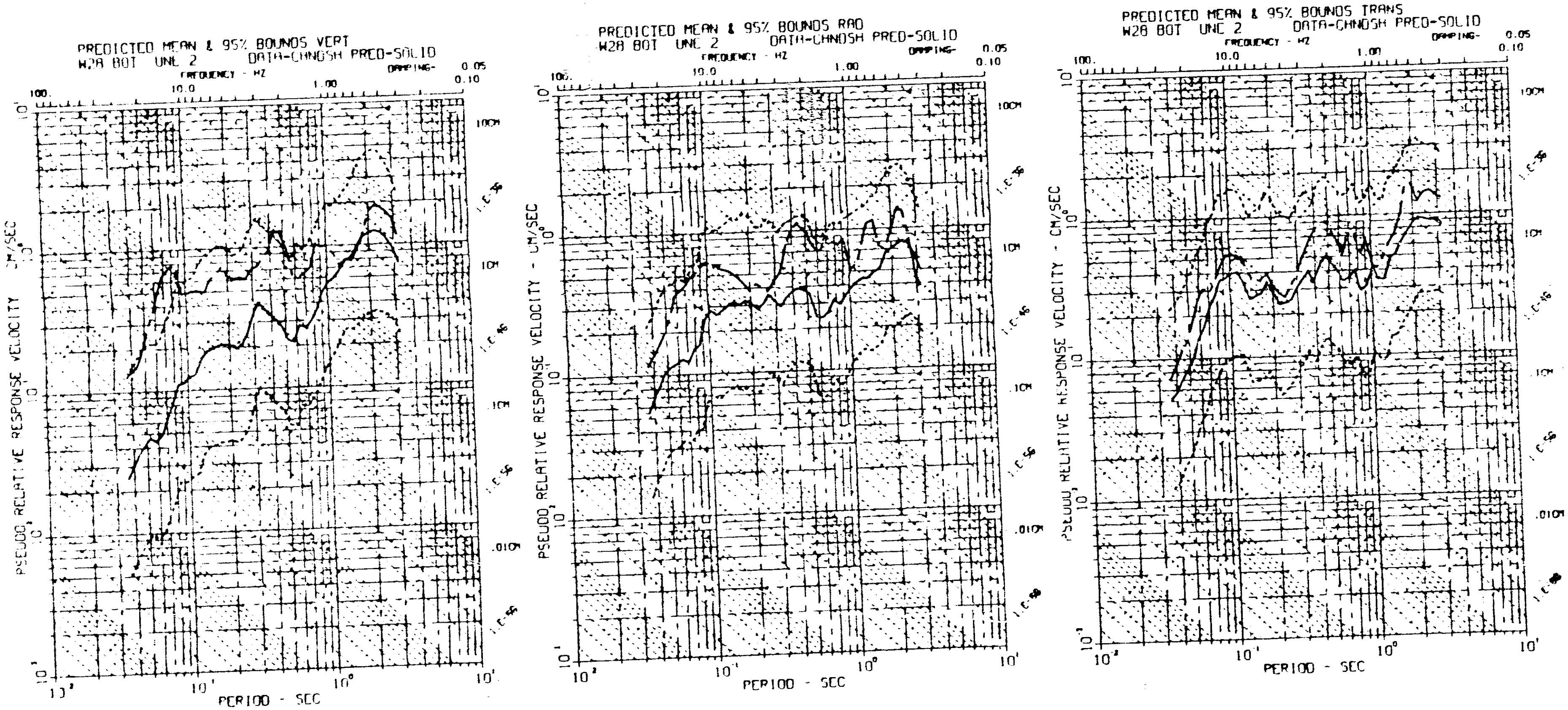
Transverse

Figure 4-11. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-26. (station geology classified as alluvium) - UNE2



Vertical *Radial* *Transverse*

Figure 4-12. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-28 surface. (station geology classified as rock) - UNE2

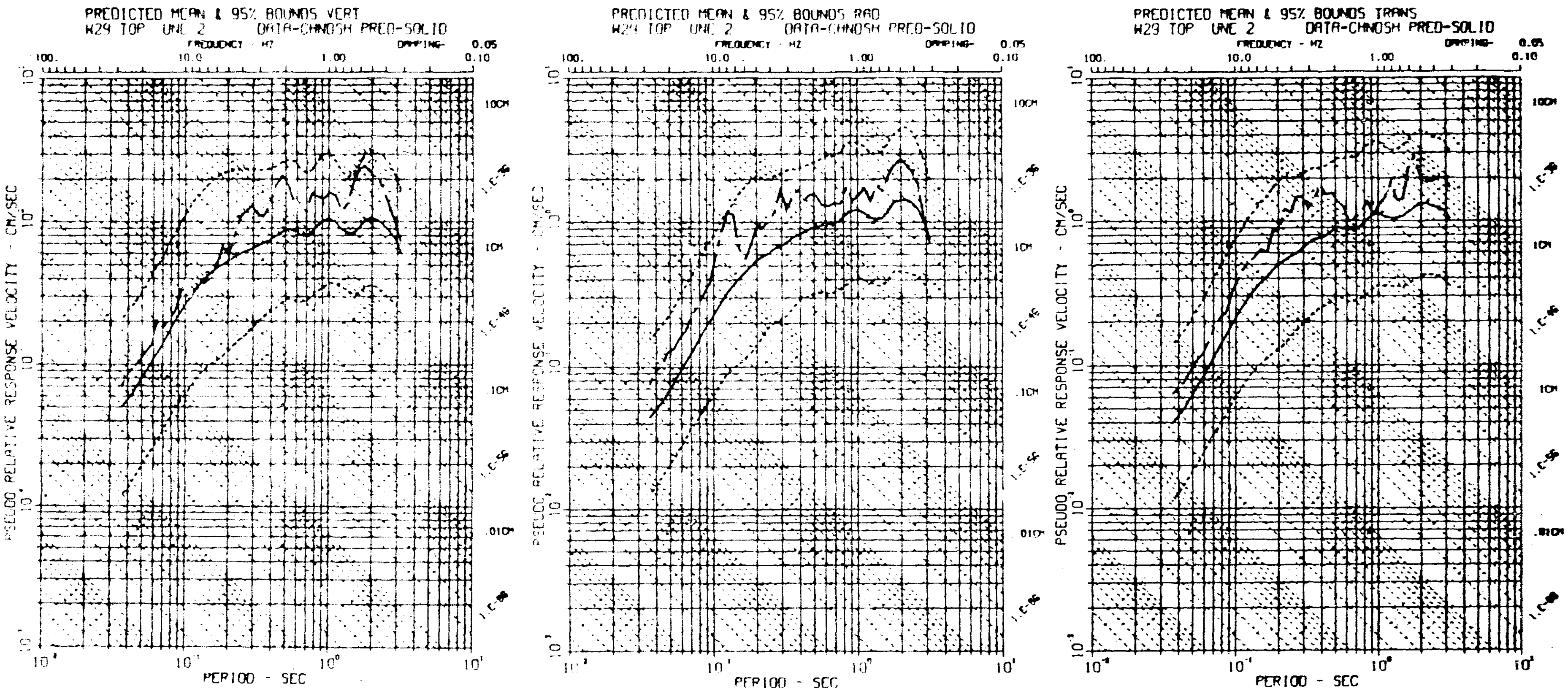


Vertical

Radial

Transverse

Figure 4-13. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-28 downhole. (station geology classified as rock) - UNE2

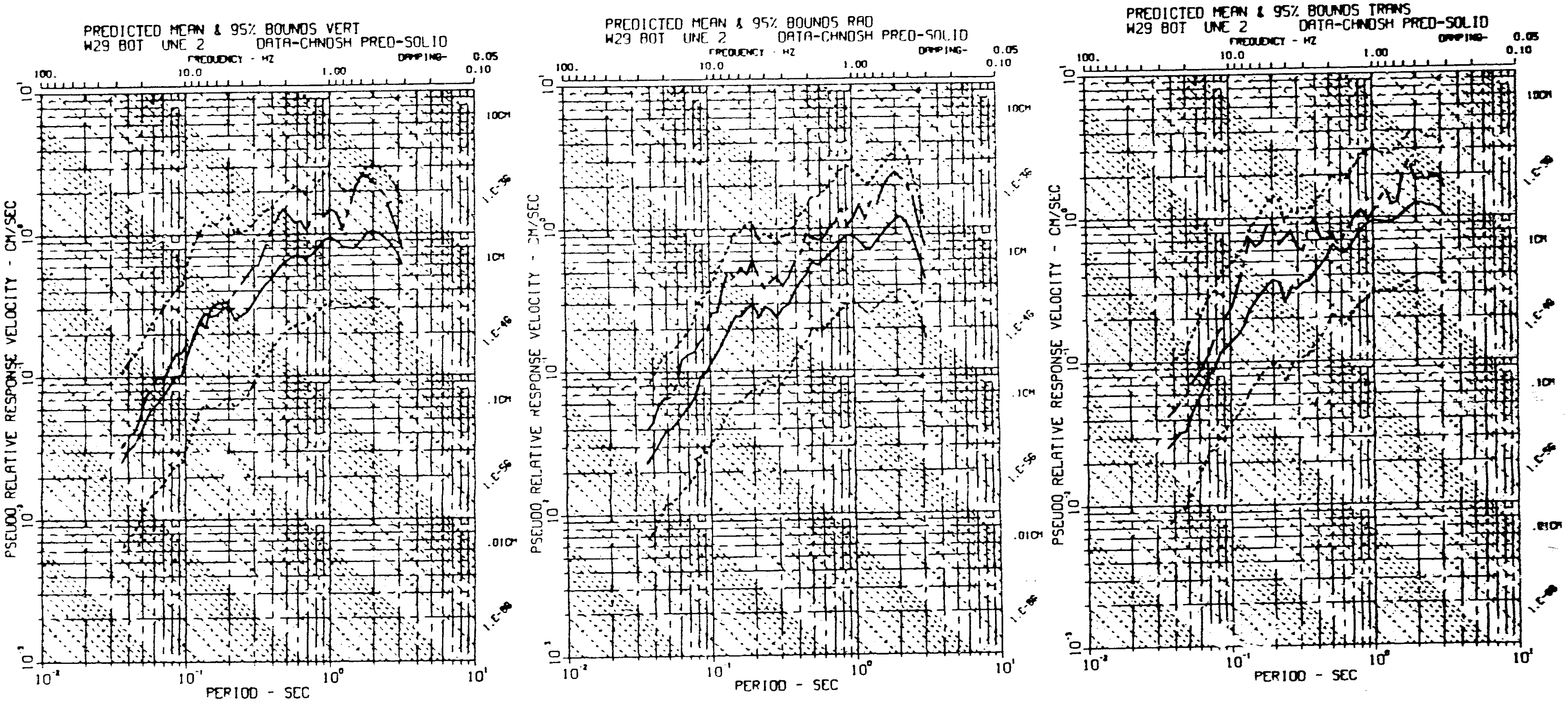


Vertical

Radial

Transverse

Figure 4-14. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-29 surface. (station geology classified as alluvium) - UNE2

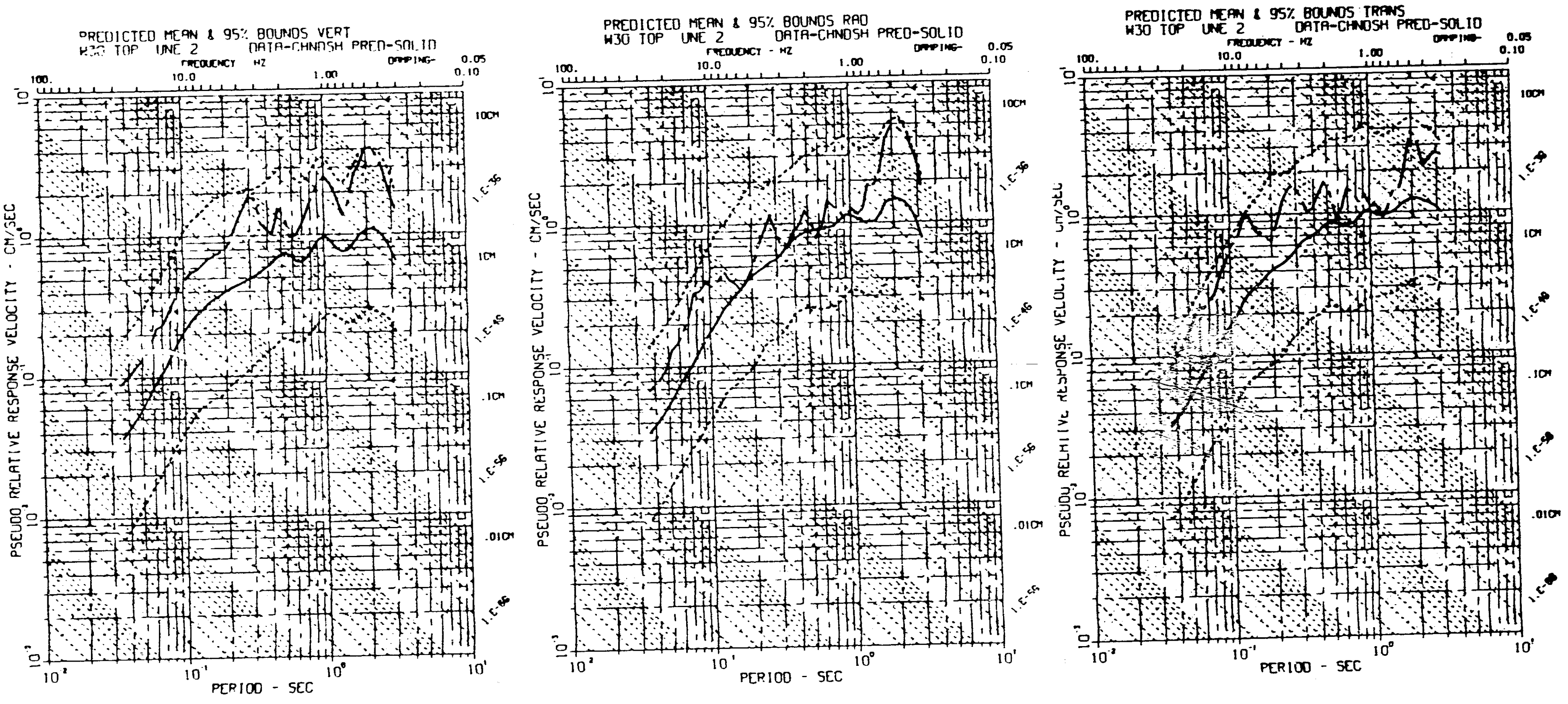


Vertical

Radial

Transverse

Figure 4-15. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-29 downhole. (station geology classified as alluvium) - UNE2



Vertical

Radial

Transverse

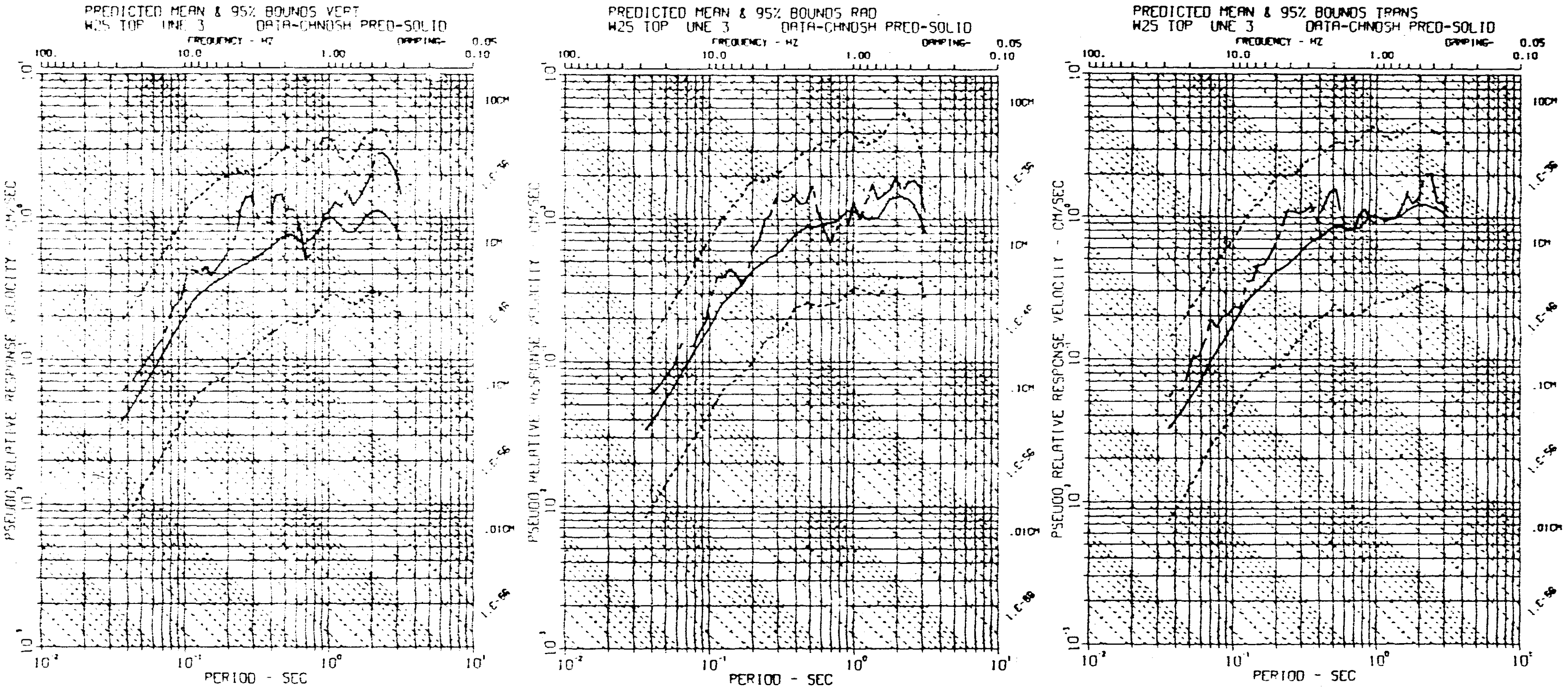
Figure 4-16. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain station W-30 surface. (station geology classified as rock) - UNE2

The third event used for evaluation of the prediction equations was also a recent event. The comparisons of the predicted and measured values are shown in Figures 4-17 through 4-24. As in the other comparisons, the measured PSRVs always fall within the 95% confidence interval on the prediction. In general, the predicted surface PSRVs compare favorably with the measured PSRVs. Downhole PSRVs at Stations W25 and W29 (Figure 4-18 and 4-23) are fairly well predicted. The downhole behavior at W28 (Figure 4-21) was poorly predicted. Inspection of the time histories recorded at this station for this event revealed that the surface and the downhole ground motions were essentially the same amplitude for the entire waveform for all three components. Downhole ground motions observed at this station have shown an amplification in radial and transverse components at the higher frequencies of 8-20 Hz (Phillips, 1987). The behavior observed in this event is different in that it affects all components for all frequencies. The field and digitizing records for this station have been checked and the data are apparently correct. This behavior is curious and will receive further study. It should be remembered that an empirical prediction will predict the "average" event. A substantial deviation from the average will not be accurately predicted by the empirical method.

The overall conclusion from these comparisons is that the prediction procedure for PSRVs produces reasonably accurate predictions for this event.

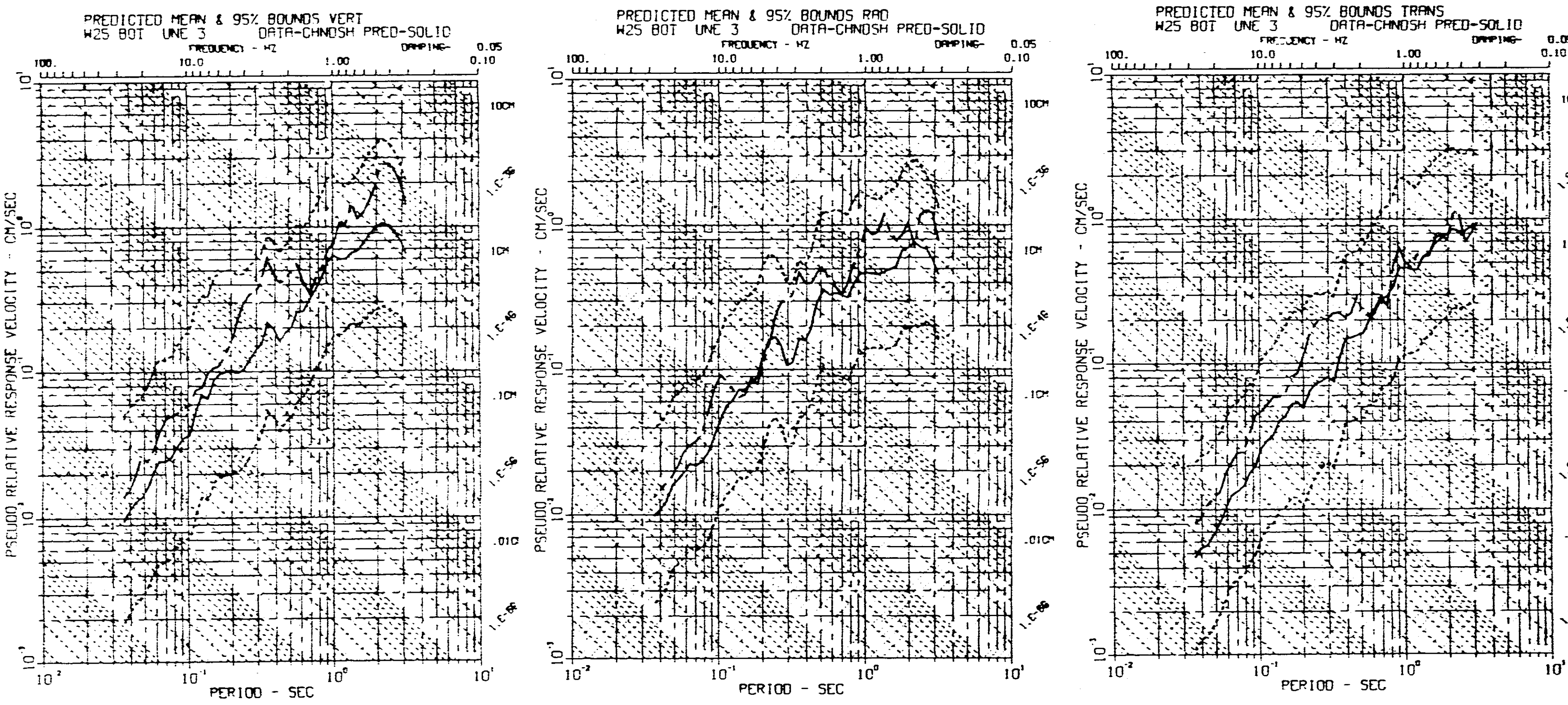
The fourth UNE used for the evaluation of the PSRV prediction procedure was an older large yield event (>500) event with a station at a distance similar to the design basis UNE. This comparison is shown in Figure 4-25. The symbols and format of this figure are the same as defined for the previous figures. The same general conclusions made above for the recent events are noted here (note the PSRV amplitudes are an order of magnitude larger than those shown in previous comparisons). The prediction procedure developed for PSRVs is reasonably accurate.

The objective of this effort was to develop a credible empirical prediction technique for PSRVs from underground nuclear explosions. An empirical prediction consists of a best estimate (a measure of the average of a collection of data) and an estimate of the uncertainty (standard deviation) on that estimate. The measure of the credibility of a prediction procedure is how well the predicted values (both best estimate and uncertainties) compare to the measured values. The comparisons shown in this section indicate that, for the most part, predicted values compare reasonably well with the observed values. In most cases the observed PSRVs are within the 95% confidence intervals on the best estimate. The data base used to develop this procedure had a larger number of low-yield events than high-yield events. Some effort was made to use as many high-yield events as possible in the data base to avoid biasing the prediction procedures to these low-yield events. The fact that the procedure works as well for the low-yield event at the larger distances (40 to 50 km) as it does for an event similar to the design basis UNE indicates that this bias has been avoided.



Vertical *Radial* *Transverse*

Figure 4-17. Comparison of the predicted and measured PSRVs for a recent UNE (UNE3) recorded at Yucca Mountain Station W25 surface. (station geology classified as rock.)

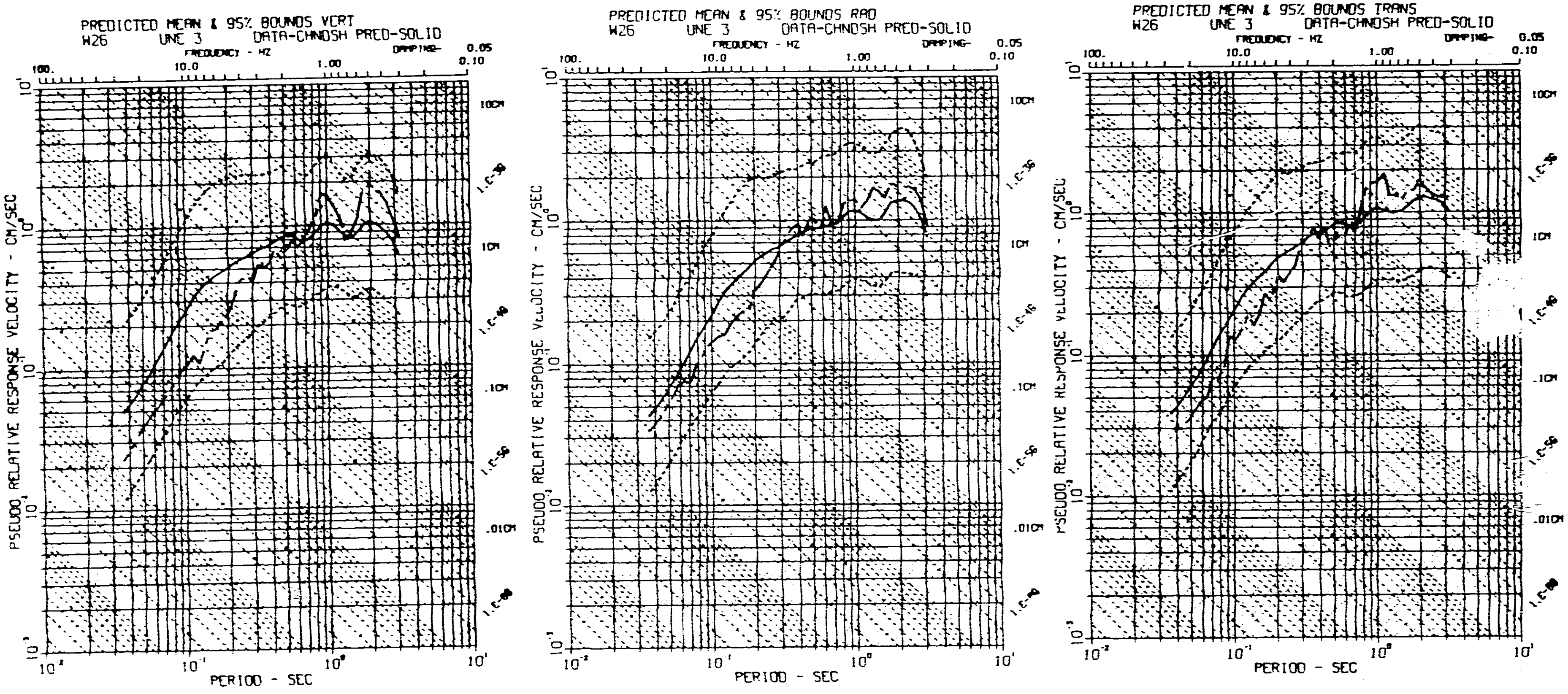


Vertical

Radial

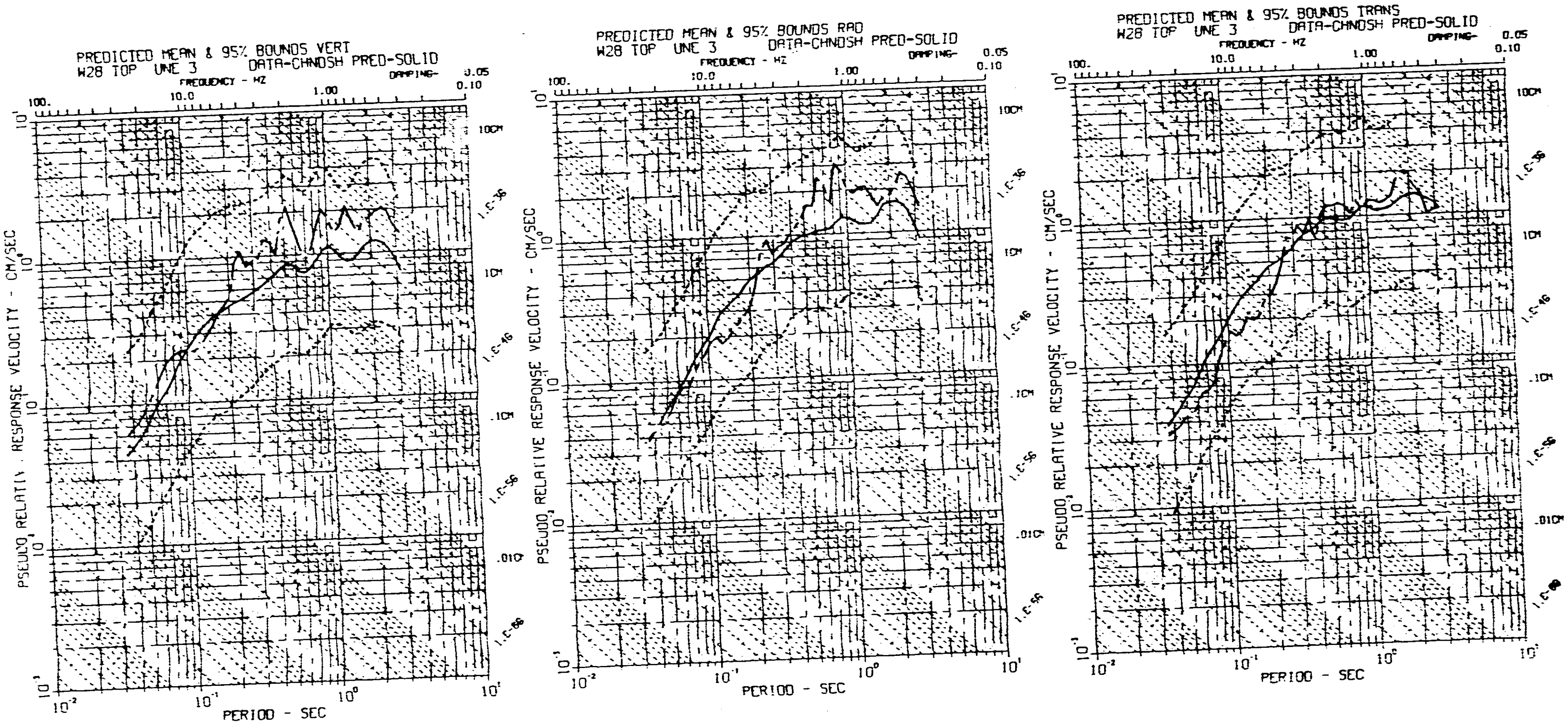
Transverse

Figure 4-18. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain Station W25 downhole station geology classified as rock) - UNE3



Vertical *Radial* *Transverse*

Figure 4-19. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain Station W26. (station geology classified as alluvium) - UNE3

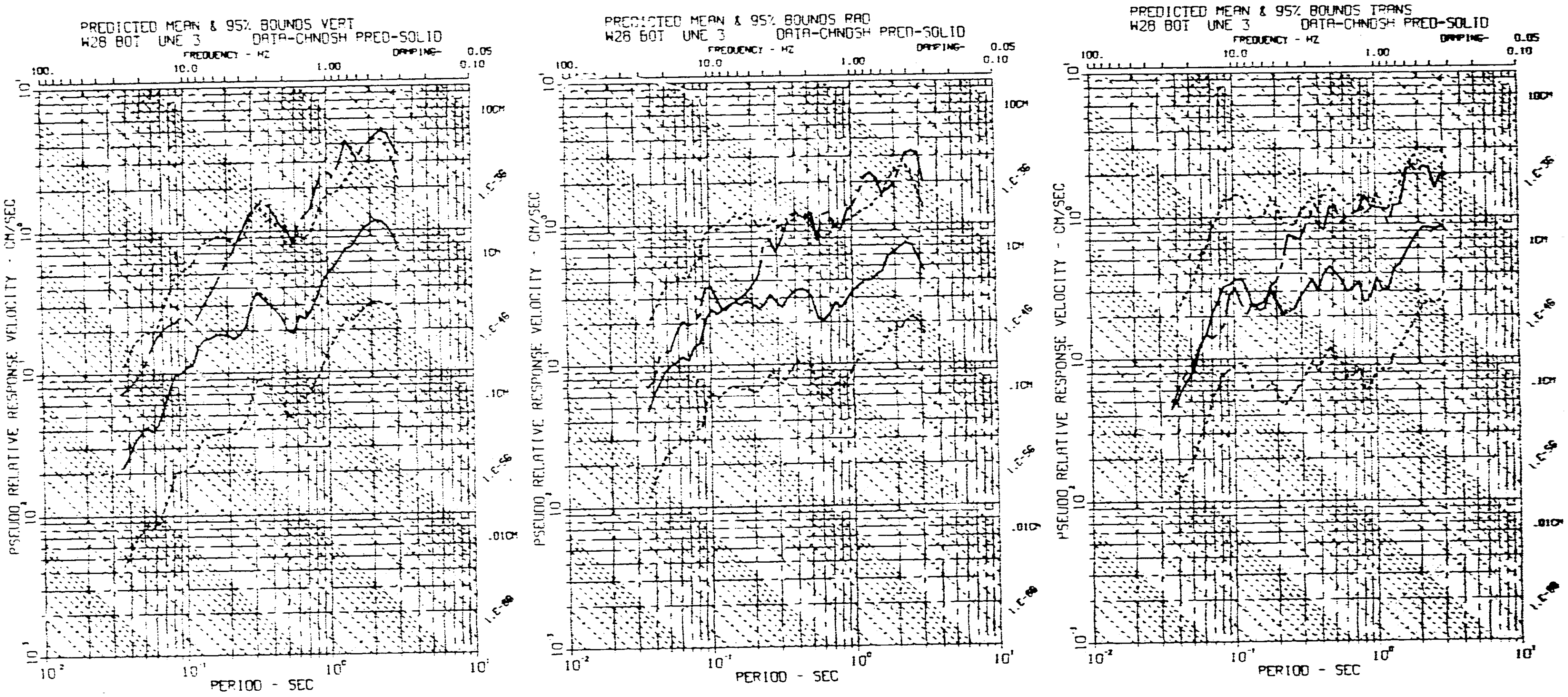


Vertical

Radial

Transverse

Figure 4-20. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain Station W28 surface. (station geology classified as rock) - UNE3

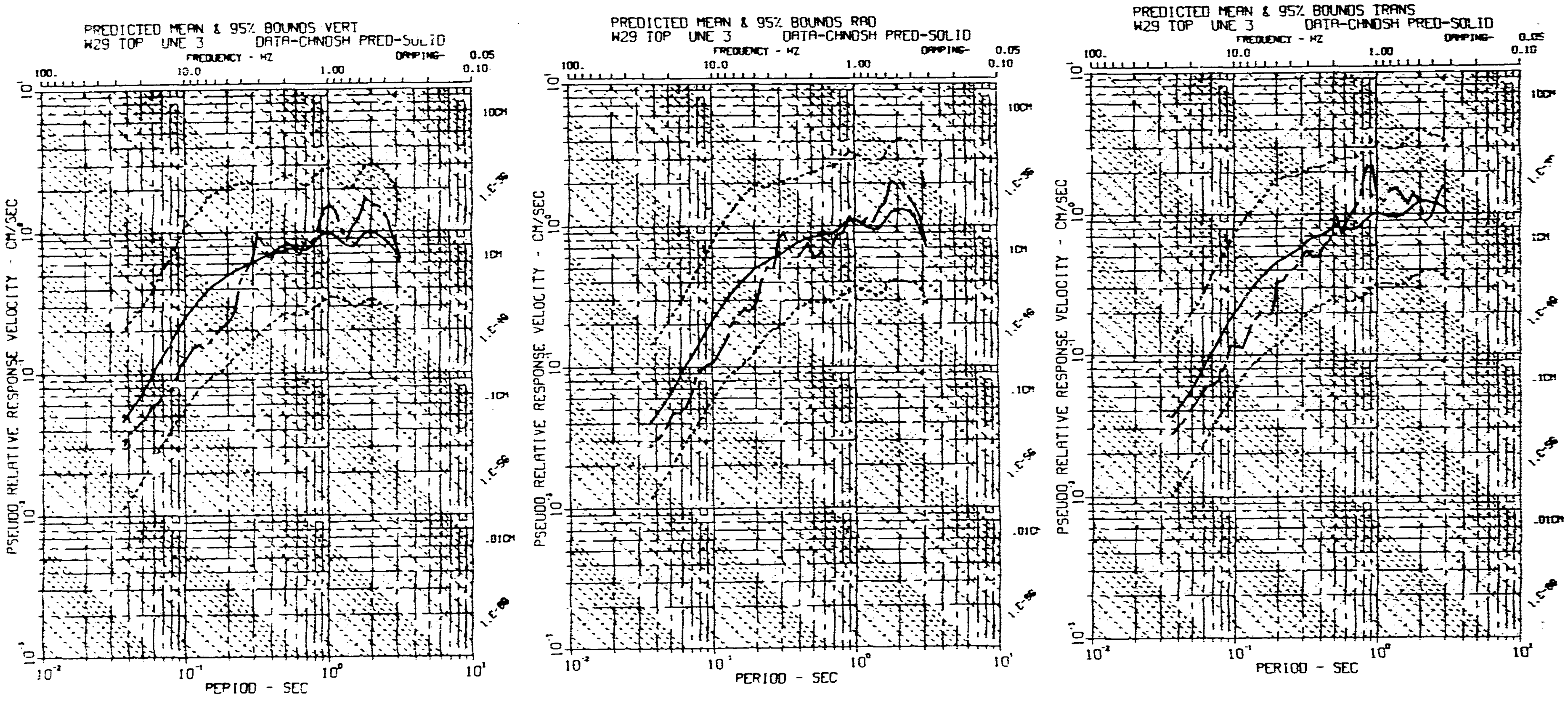


Vertical

Radial

Transverse

Figure 4-21. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain Station W28 downhole. (station geology classified as rock) - UNE3

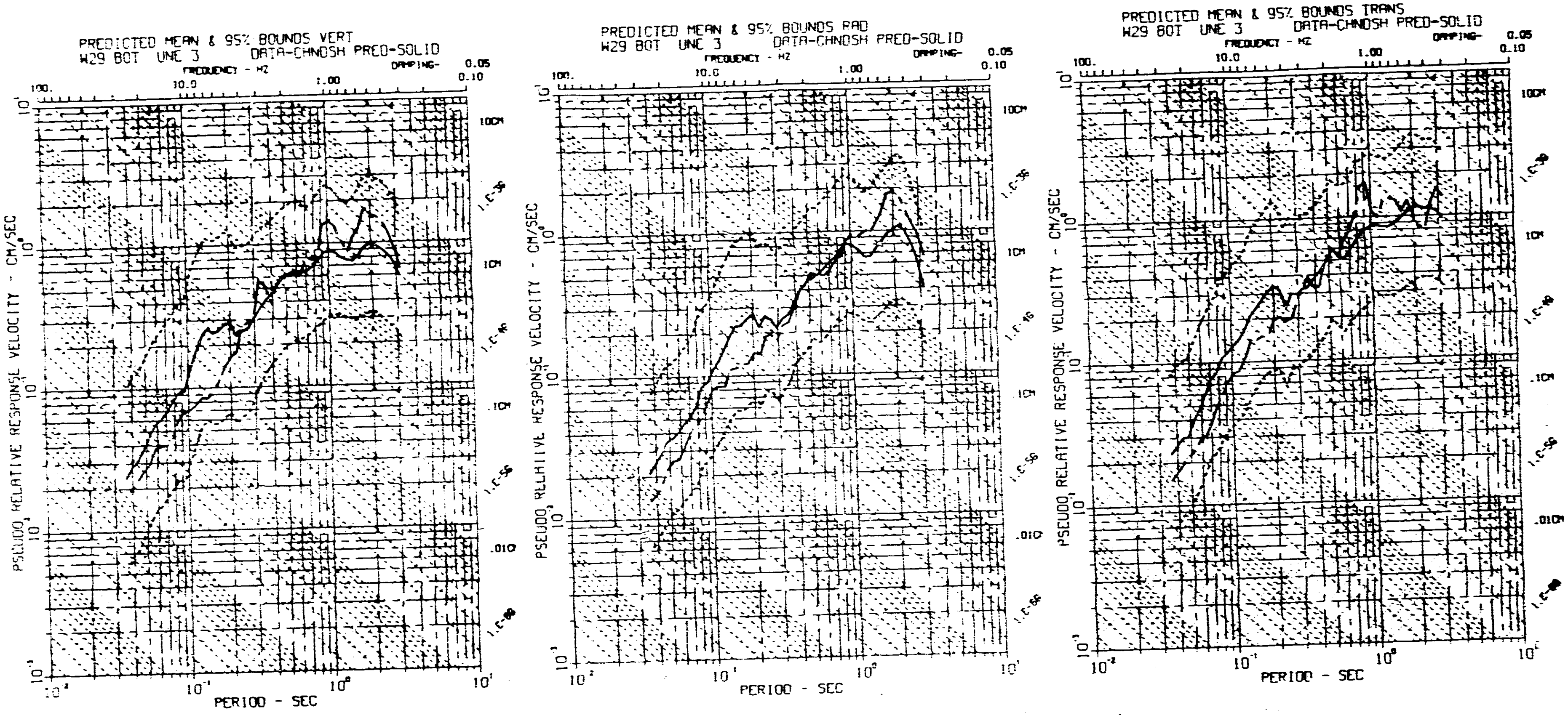


Vertical

Radial

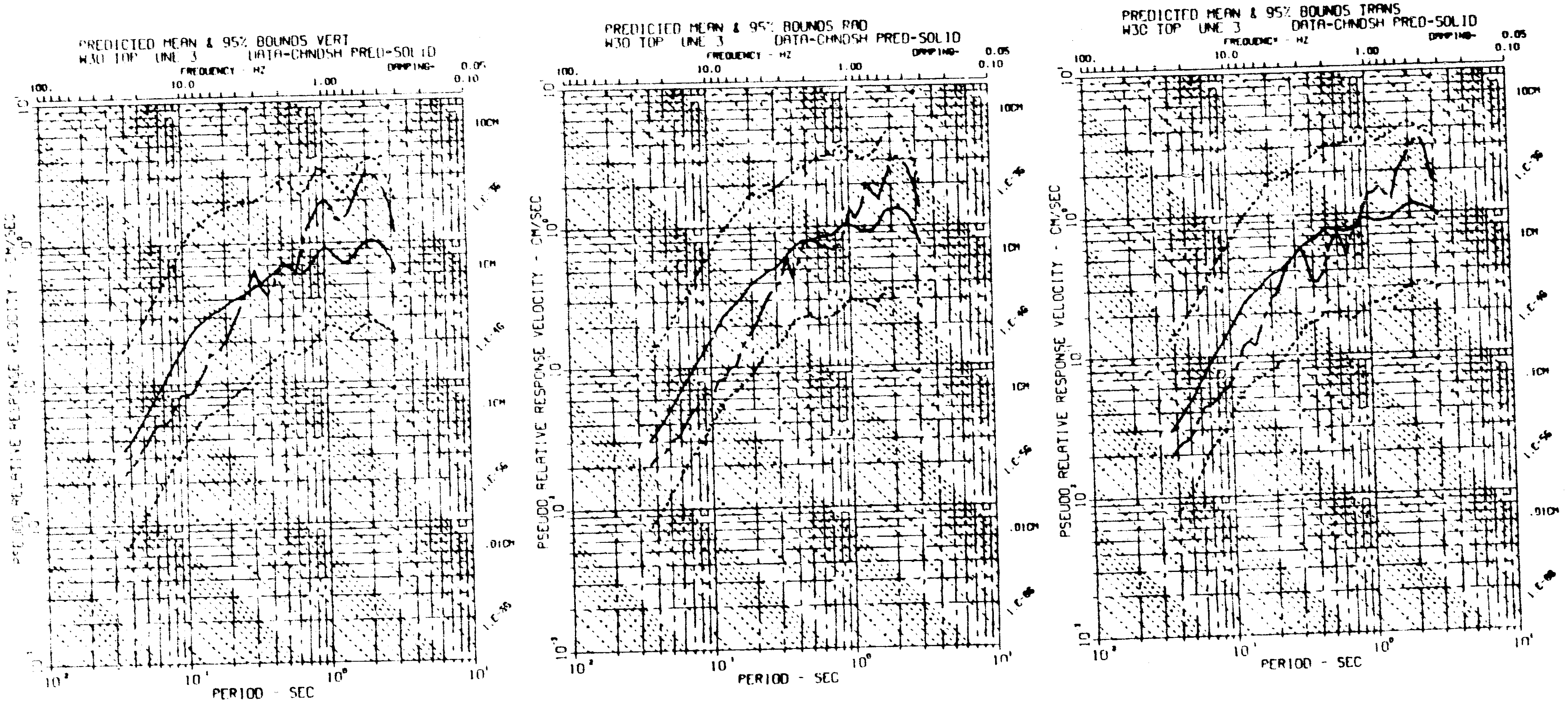
Transverse

Figure 4-22. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain Station W29 surface. (station geology classified as alluvium) - UNE3



Vertical *Radial* *Transverse*

Figure 4-23. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain Station W29 downhole. (station geology classified as alluvium) - UNE3

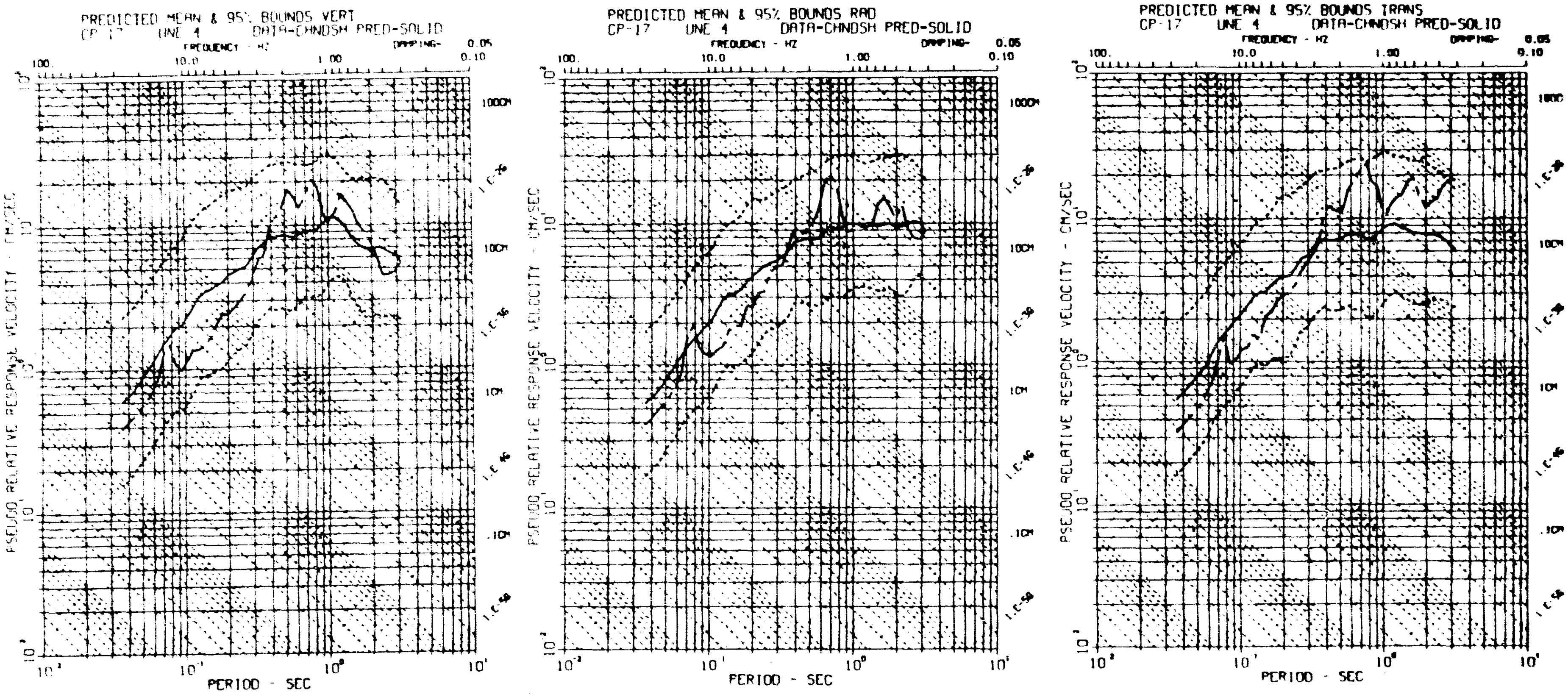


Vertical

Radial

Transverse

Figure 4-24. Comparison of the predicted and measured PSRVs for a recent UNE recorded at Yucca Mountain Station W30. (station geology classified as rock) - UNE3



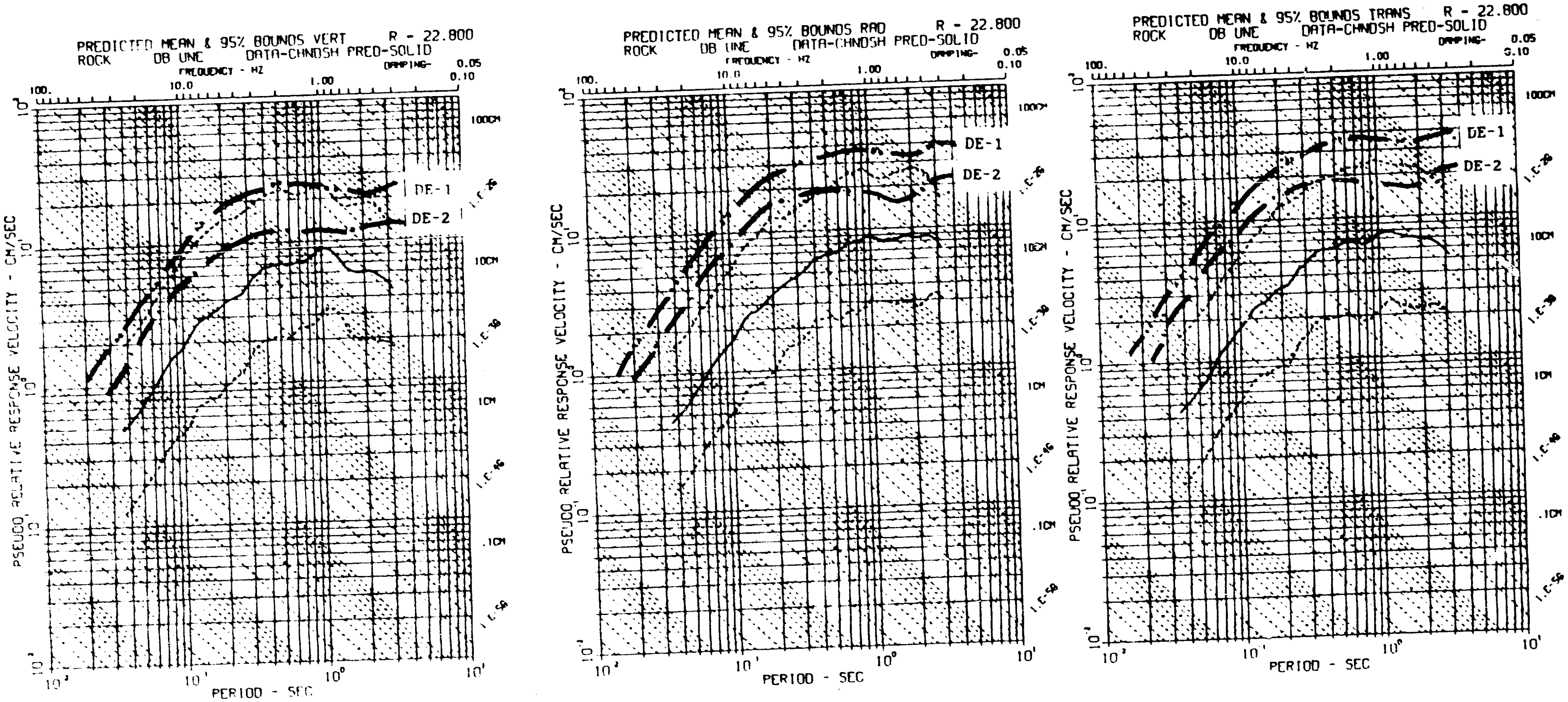
Vertical Radial Transverse

Figure 4-25. Comparison of the predicted and measured PSRVs for a large yield event (>500 kt). (Station geology is classified as rock) - UNE4

4.3 Comparison of the Prediction of the Design Ground Motions

The predicted PSRVs for the design basis UNE are shown in Figure 4-26. These predictions were performed for a rock geology. To provide a frame of reference, the design earthquakes determined in an earlier study of ground motion at Yucca Mountain (URS/Blume & Associates, 1986) are also shown on this figure. These earthquakes were determined via probabilistic methods. Design Earthquake 1 (DE-1) was based on a return period of 2000 years. The peak horizontal ground acceleration was estimated to be 0.4g and 0.27g was the estimated value of the peak vertical ground acceleration. Design Earthquake 2 (DE-2) was based on a return period of 500 years. The peak horizontal and vertical ground accelerations were estimated to be 0.25 and 0.17g, respectively. Both DE-1 and DE-2 spectra have greater amplitudes (by factors of 3 to 4) than the best estimate UNE spectrum. UNE generated ground motions generally have larger (relative to horizontal components) vertical components than do earthquake generated ground motions. This is observed in Figure 4-26. DE-1 is generally greater than or equal to the upper bound of the UNE production. DE-2 falls within the upper bound value of the vertical UNE production, but generally above the upper bound on the horizontal UNE predictions. The shape of the earthquake and UNE spectra are similar. The earthquake spectra contain more high frequencies than the UNE spectrum.

Based on these comparisons, it is clear that the earthquake motions will govern the design of the repository facilities. This is especially true when it is considered that only the best estimate earthquake spectra is presented. This spectrum has uncertainties associated with it that will more than likely drive the design earthquake motions even higher, creating a larger separation between UNE and earthquake motions.



Vertical

Radial

Transverse

Figure 4-26 Comparison of the prediction of the design basis UNE and design earthquakes 1 and 2 (URS/Blume, 1986) for a rock site.

4.4 Comparison of UNE and Earthquake PSRVs

In an effort to determine the similarities and differences in earthquake and UNE ground motions, a comparison of predicted PSRVs for an "equivalent" UNE earthquake pair was made. The equivalency between the two sources was determined in the following manner. First the explosion energy had to be expressed in terms of earthquake magnitude. This was accomplished by use of equation 4-2 from Vortman (1991). This equation was derived from a fit of announced Pahute Mesa UNEs (the limits on this equation are yields from 20 to 1200 kt and magnitudes from 4.7 to 6.2).

$$m = 3.603 + 0.3774 \ln W \tag{4-2}$$

where

m is equivalent body wave magnitude
W is the yield of the explosion.

The body wave magnitude was then converted to a moment magnitude by use of the following relationship (Houston and Kanamori, 1986):

$$M_w = (m' - 2.7) / 0.53 \tag{4-3}$$

where

M_w is the moment magnitude
m' is the body wave magnitude.

(m' is determined from the entire short period P-Wave train rather than the maximum amplitude of the first few cycles (as is m). For explosions, these two magnitudes should be similar.)

To calculate the earthquake PSRV the technique from Joyner and Boore (1982) was used. This procedure was developed from analysis of earthquakes in western North America with moment magnitudes greater than 5.0 and fault ruptures less than 20 km deep. The prediction equations were developed for 5% damped PSRVs for periods between 0.1 and 4.0 s (0.25 to 10 hz). In addition, predictions may be made for either rock or soil sites. The predictions made for the comparisons shown here are for the "larger of the two horizontal components" (which compares to the UNE radial motion) at a rock site.

For convenience, the design basis UNE was chosen for this comparison. The key parameters are the yield (700 kt) and the source-to-station distance (22.8 km). Using Equations 4-2 and 4-3, the 700 kt yield converts to an equivalent moment magnitude earthquake of 6.37. These parameters were used in both prediction techniques to produce the comparisons shown in Figure 4-27 and 4-28.

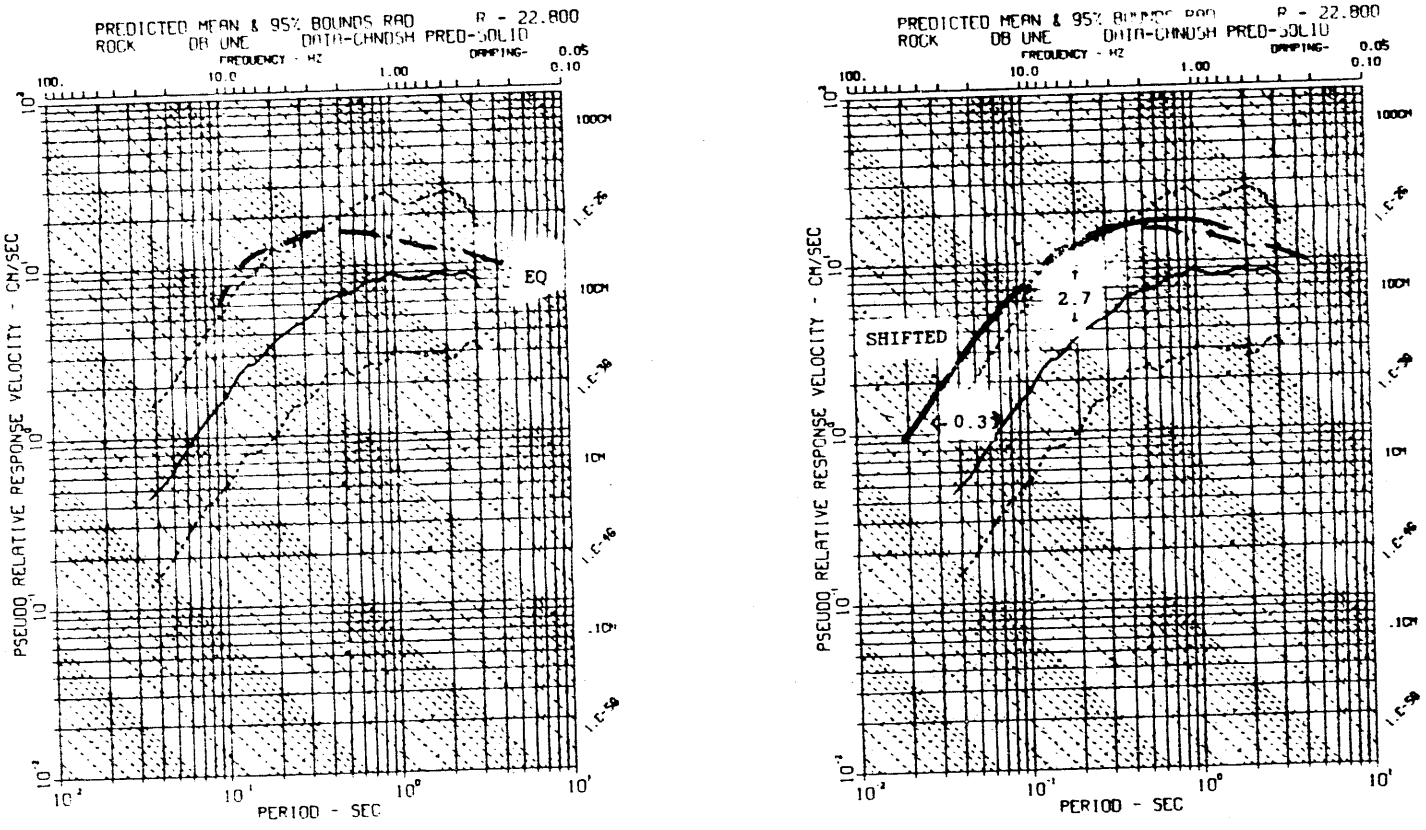


Figure 4-27. Comparison of the prediction of PSRVs from an "equivalent" UNE, earthquake pair for a rock geology, radial motion

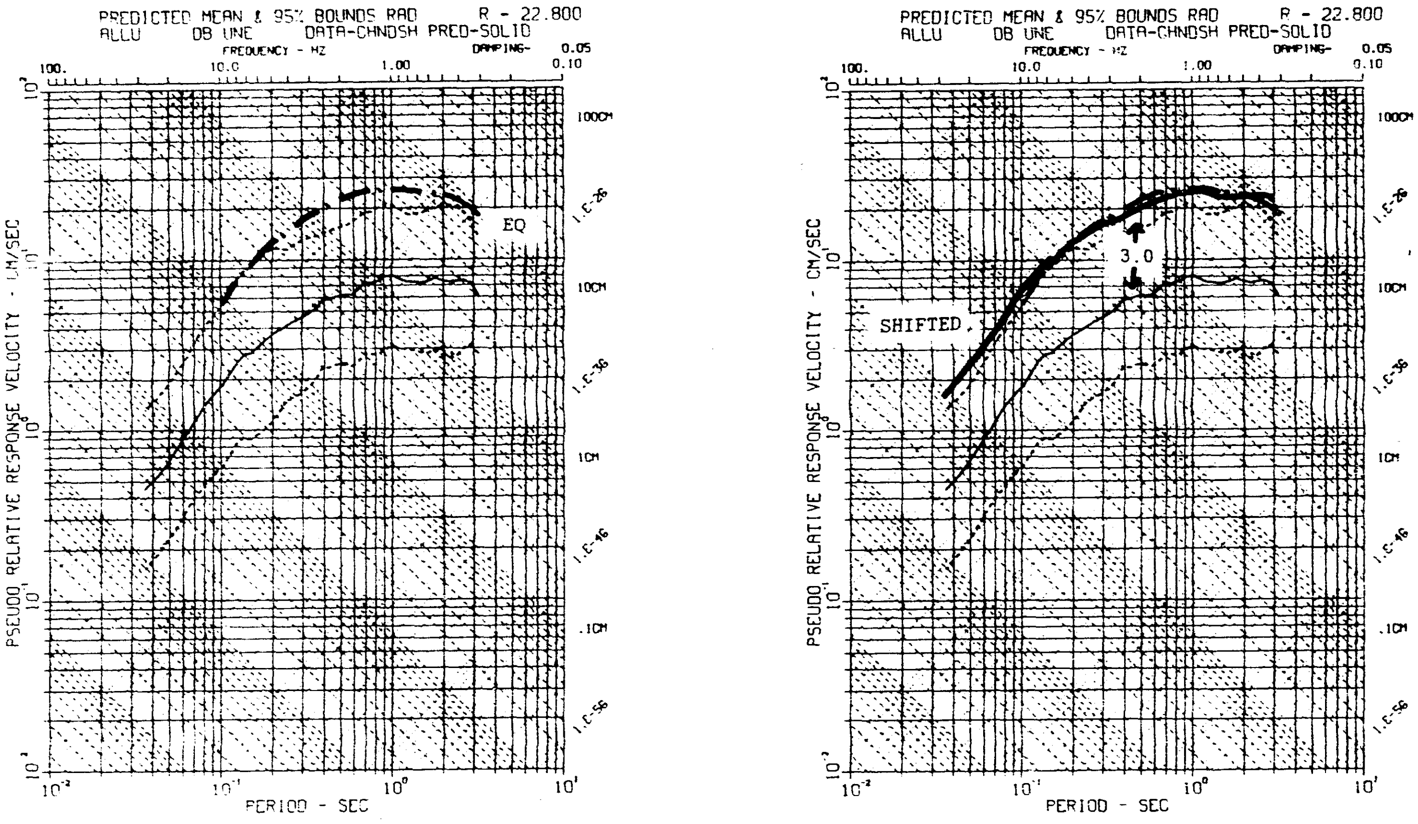


Figure 4-28 Comparison of the prediction of PSRVs from an "equivalent" UNE, earthquake pair for a rock geology, radial motion.

For the rock geology, the predicted earthquake PSRV is of greater amplitude but similar in shape to the UNE PSRV. The UNE PSRV can be modified to agree with the earthquake PSRV by multiplying the period by 0.3 and the amplitude by about 2.7. The shifted UNE prediction is also shown in Figure 4-27.

Figure 4-28 shows the comparisons of the predicted earthquake and UNE PSRVs for an alluvial or soil station geology. As was the case with the previous comparisons, the earthquake PSRV is of larger amplitude than the UNE PSRV. The frequency contents of the two predictions are more similar, however. The UNE PSRV can be modified to agree with the earthquake PSRV by multiplying the amplitude by about 3.0. The shifted UNE PSRV is also shown in Figure 4-28.

Assuming that the earthquake PSRV prediction procedure is representative of the actual earthquake ground motion in western North America (including Nevada) and the UNE prediction procedure is representative of actual ground motion behavior at NTS, these comparisons are interesting in that they indicate the possibility of a simple shift between UNE and earthquake PSRVs. If this shift was determined to be systematic over a wide range of "equivalent" UNE earthquake pairs, then an empirical method could be developed to generate "equivalent NTS earthquake" PSRVs from the UNE data base. Further study is required to determine the feasibility of further analysis along these lines.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions from this study are as follows:

(1). A credible prediction procedure for UNE PSRVs has been developed. This procedure provides reasonable predictions at Yucca Mountain and for NTS in general. This procedure also provides results consistent with earlier work.

(2). Observed amplification at Yucca Mountain stations W-14, W-21, W-22, and W-23 may be explained, at least in part, by topography near the stations. All of these stations were installed on ridges. Ground motions with wavelengths on the order of mountain width were amplified at these stations. Significant amplification of ground motions at the other Yucca Mountain stations was not observed in this study.

(3). Prediction of downhole PSRVs can be accomplished at specific stations by use of the surface/downhole ratios developed in an earlier study. A general depth attenuation model for Yucca Mountain does not exist at this point.

(4). Comparison of predictions of earthquake PSRVs from earlier work and UNE PSRVs for design basis events at Yucca Mountain indicate that the best estimate of the UNE ground motion is a factor of 3 to 4 below the earthquake motion. Predicted earthquake motions were generally at or above the upper 95% confidence bound (97.5% non-exceedance probability level) of the UNE prediction.

The recommendations that result from this study are as follows:

(1). A general depth attenuation model for the Yucca Mountain area should be developed.

(2). Topographic and other site effects at Yucca Mountain should be studied in more detail and quantified.

(3). More detailed study is needed to determine the feasibility of developing a method to modify UNE- generated ground motions to simulate earthquake- generated ground motions for the Yucca Mountain area.

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Walck, M. C., 1988, Modeling of Anomalous Ground Motion Observed at Jackass Flats, Nevada Test Site, Seismological Research Letters (NNA.891106.0220)

Walck, M. C., 1989, Two-Dimensional Velocity Models for Paths from Pahute Mesa and Yucca Flat to Yucca Mountain, SAND88-3033, Sandia National Laboratories, Albuquerque, NM (NNA.901005.0051)

APPENDIX A: COMPUTER CODES USED TO DEVELOP PREDICTION PROCEDURE

A.1 Introduction

The purpose of this appendix is to provide the background information on the codes used to develop the prediction procedure discussed in the main body of this report. Included here will be a short description of the processing scheme used as well as source code listings and verification and validation studies.

The procedure used to process these data is summarized as follows. In general, PSRVs were calculated on an event-by-event, component-by-component basis. The disk files containing the PSRV amplitudes calculated for individual events were stored off-line on a Compaq 286 system until all calculations were completed. These numerous output files were then combined into one file for each component (vertical, radial, or transverse) by use of the COPY utility in MS/DOS (Version 3) or the APPEND utility on the VAX 8650. (These large files are now stored on magnetic tape through the use of the BACKUP utility on the VAX 8650.) These large files are the input files for the FIT program.

The overall logic used in processing these data is shown in the flow chart in Figure A-1. The digital UNE ground motion are stored on magnetic tape at Sandia National Laboratories. These data were read onto a disk file on a VAX 8650. This, file along with an input file that provides the source-to-station distance, is used by the PSRV code to calculate and plot PSRVs. In addition, the PSRV code saves the psuedo velocity amplitudes on disk file for incorporation into the data base. This amplitude file may be further processed by the SORT code or used directly in the PREPRO code. The SORT code can be used to sort the data by station geology or to eliminate stations. The PREPRO code converts the PSRV data from a station/event basis to a format where all amplitudes, yields, and distances for a specific frequency are listed together. The output of the PREPRO code is used directly as input into the FIT code. The FIT code performs the linear regression for each input frequency and plots and lists the results (these are listed in Appendix C). In addition, FIT creates a disk file that contains the equation coefficients in a format readable by the predicition code (discussed in Appendix B). A code named COMPARE was used to compare regression results with observed data. This code evolved into the prediction code. Separate versions of FIT, SORT and PREPRO were written to handle the single-event analysis.

The codes SORT, PREPRO, and COMPARE are considered to be auxiliary software (or calculational non-SES codes, as defined in Green (1988). The results of these codes were checked by visual inspection of the files they produced during the initial debug phase

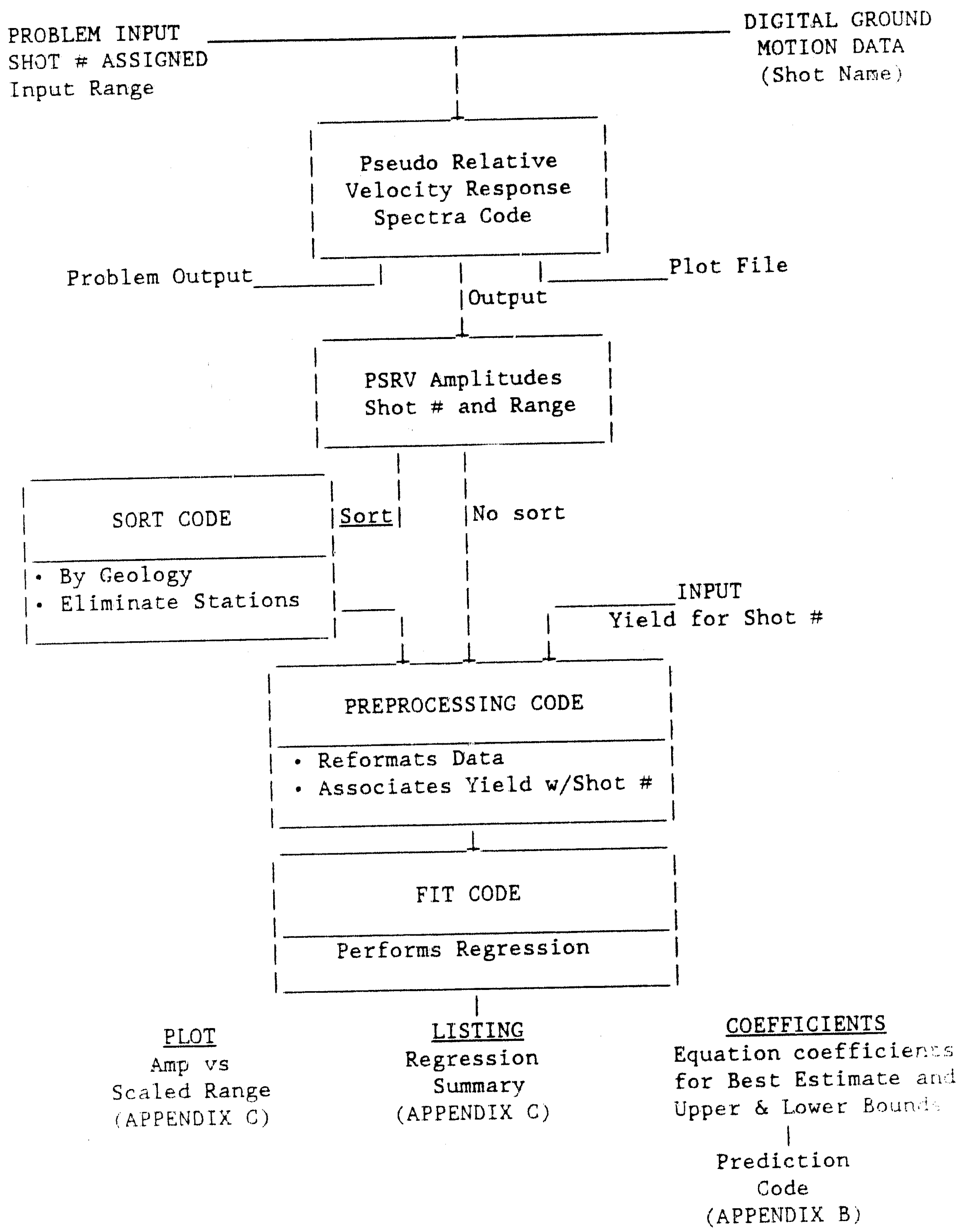

Figure A.1 Processing Scheme Used for Handling Ground Motion Data in This Study as well as during the actual analysis effort. There was no documentation of this check as such, but when errors were found they were corrected. Because these programs only manipulate data and do not calculate any values they will not be discussed further. The source code listings for these codes are given in Section A of this appendix.

The PSRV and FIT codes fit the definition of Scientific and Engineering Software (SES) as given in Green (1988). These codes perform calculations with the data and will require verification and validation to ensure that they provide correct results. Documentation for these codes is given in Section A and the source code listings are given in Section A.

A <u>Verification and Validation of PSRV and FIT</u>

A.2.1 <u>PSRV Code</u>

The calculational aspects of this code were documented and verified in Sanders (1987). Some changes were made specifically for this study, however. The major modification was to move the code from the computer system described in Sanders (1987) (NOS/VE) to the VAX 8650. Other modifications concerned the input/output (I/O) aspects of the program. None of the calculational routines were modified. These changes are discussed below.

The PSRV code is written in ANSI standard FORTRAN 5. Because both computers (NOS/VE and VAX) both have FORTRAN 5 compilers, this consisted of changing minor details in the coding (e.g, " was changed to ' and the format of some of the plotting commands was changed). The primary concern was of numerical accuracy. To determine the difference in the numerical results from one machine to another the same data file was run through both systems. A plot of the two PSRVs and the difference between them is shown in Figure A-2. Figure A-3 shows an enlarged plot of the differences. The maximum difference is about 7% at 14 Hz. This problem is associated with the numerical precision (rounding off) of the individual machines and was considered to be within acceptable accuracy for this study.

The modifications to the I/O aspects of the program consisted of addition of station name, source-to-station distance and station geology as input parameters. In addition, an output file containing the PSRV amplitudes was created and saved on disk, for further manipulation.

PSRVs have been used in building codes and by structural designers as a way to specify seismic ground motions for several years. Using PSRVs in the study of UNE-generated ground motions has been done for several years as well and this work is an extension of well accepted engineering practice.

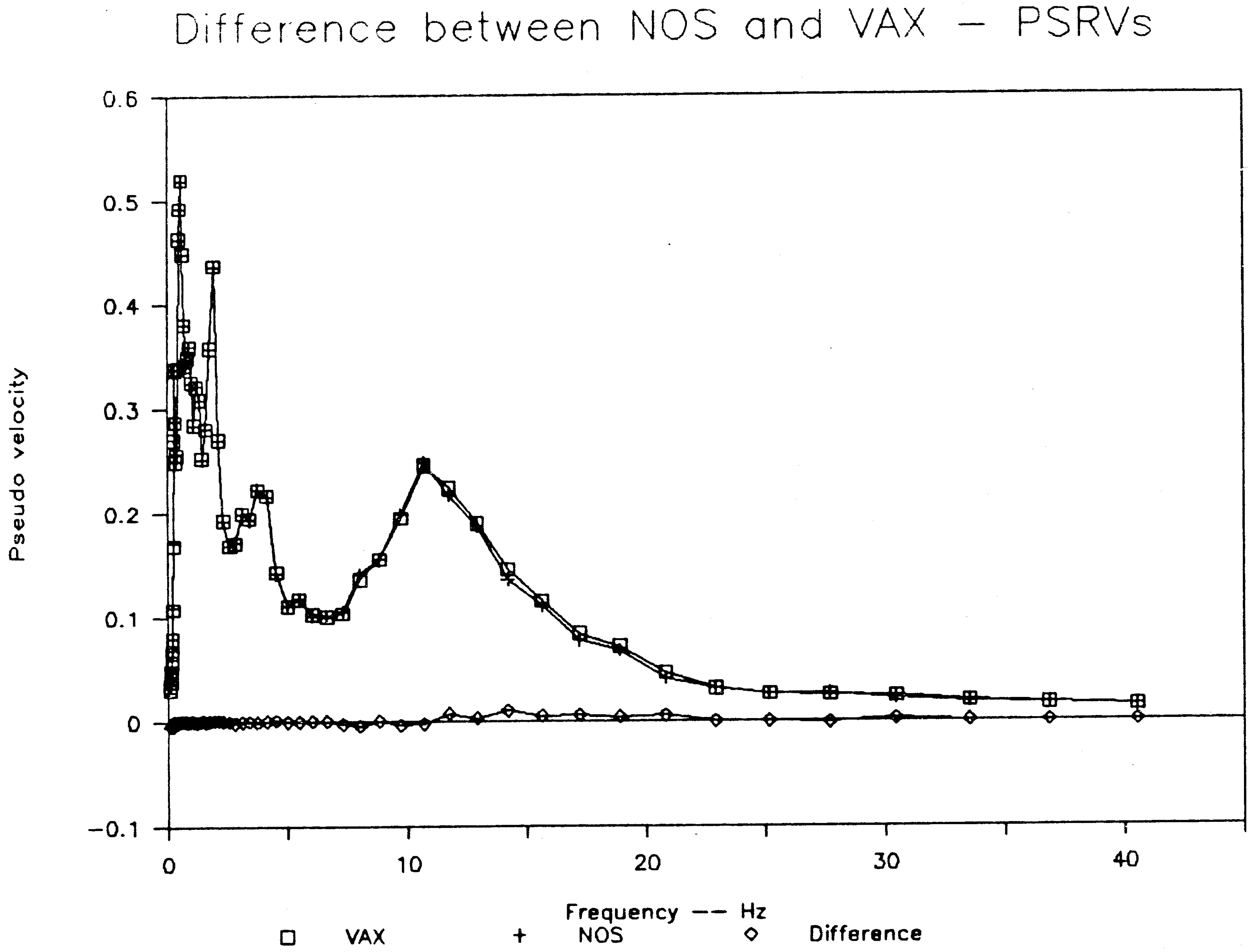

Figure A.2. Difference between NOS and VAX - PSRVs

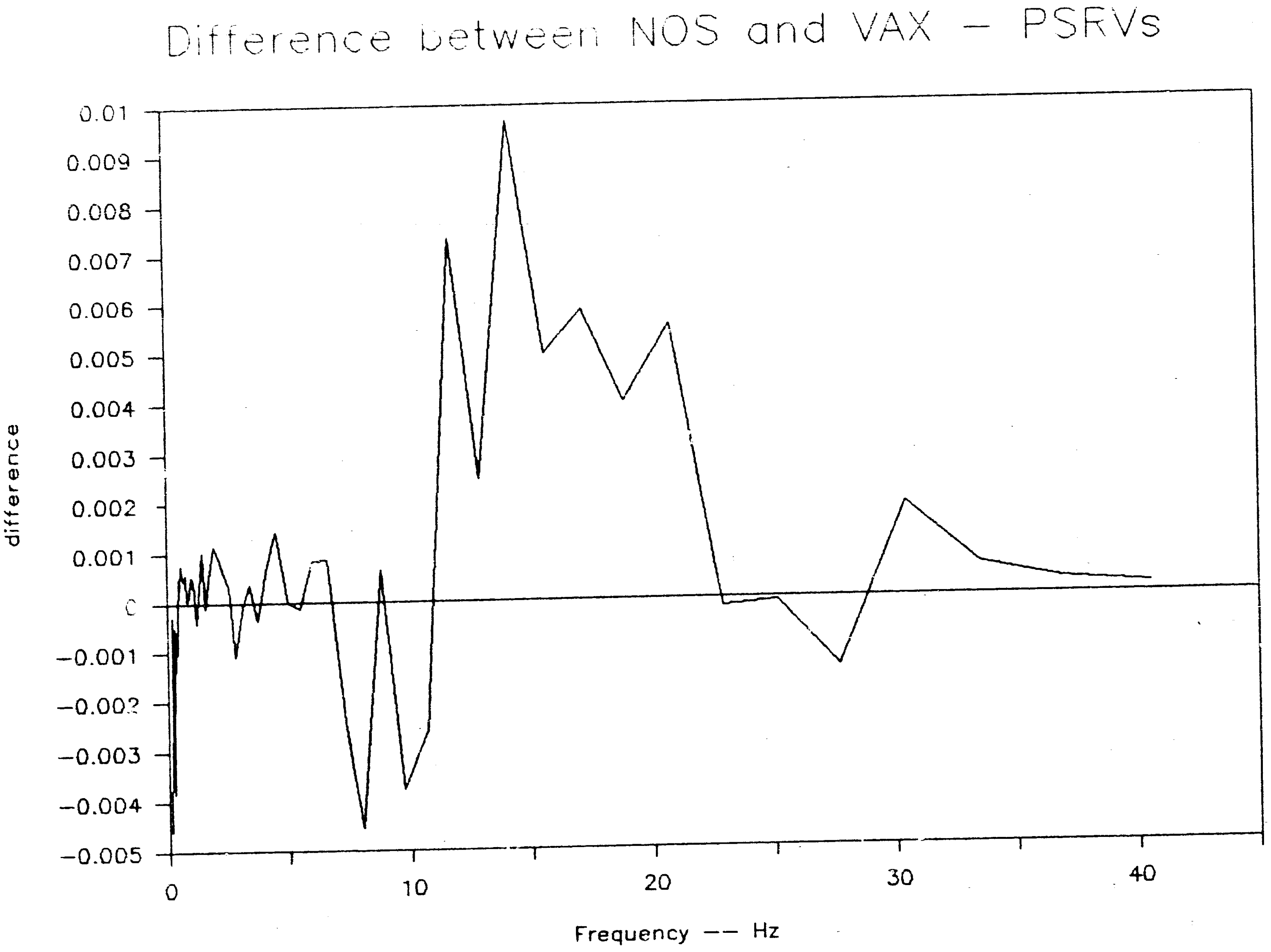

Figure A.3. Difference between NOS and VAX - PSRVs

A2.2 FIT Code

The FIT code was written specifically for this effort. Existing programs were not used because they would have required extensive revision to meet the requirements of this study. This code was built around subroutines from International Mathematical and Statistical Libraries, Inc. (IMSL, 1984). The logic flow, subroutines and their function is shown in Figure A-4. The verification of the results generated by this code was acomplished by inputing data known to regress to a line. The equation of this line was:

$$A = 10.0\ W^{0.333}\ R^{-1.0} \tag{A-1}$$

The program used to generate the data file is shown in Figure A-5. The output of FIT from this file is shown in Figure A-6 (Note that the format of this listing is somewhat different than those shown in Appendix C, further refinements were accomplished after this check was done.) The FIT program calculated the coefficient on W as 0.332979, the coefficient on R as -0.999838, and the constant as 10.0481. The plot of the regression is shown in Figure A-7. These results verify that this program is operating correctly.

This approach is the standard method used in the analysis of UNE ground motion data (See Environmental Research Corporation, 1984, for good example of the use of this approach.) Therefore, validation of this approach and use of the FIT code for this work is based on past work by many analysts.

1. READ in all data and set up arrays.
2. For a single frequency
    a. CALL Subroutine TOLOG
       Transform data to log-log space
    b. CALL IMSL Subroutine BECOVM
       Sets up matrix of the independent and dependent variables.
    c. CALL IMSL Subroutine RLMUL
       Performs multiple regression at the 95% confidence level
    d. CALL Subroutine FROMLOG
       Transforms regression coefficients to arithmetic values
    e. CALL Subroutine OUT
       Prints regression information to output file and regression coefficients to a separate file
    f. CALL Subroutine SETPLOT
       Sets up plotting
        i) CALL Subroutine PREDICT
           Determines points on the best fit, upper bound and lower bound for plotting
        ii) CALL Subroutine PLT
            Plots data and regression lines
3. Loop through 2. for all frequencies

Figure A-4. Logic Flow and Subroutine Description of FIT

```
      PROGRAM TEST
      DIMENSION W(11),R(11),A(11),N(11)
      CHARACTER*5 SITE
      OPEN(UNIT=6,FILE='TAPE96',STATUS='OLD')
      SITE = 'ROCK'
      NE =11
      N(1) = 1
      N(2) = 2
      N(3) = 3
      N(4) = 4
      N(5) = 5
      N(6) = 6
      N(7) = 7
      N(8) = 8
      N(9) = 9
      N(10) = 10
      N(11) = 11
      W(1) = 1000.
      W(2) = 100.
      W(3) = 50.
      W(4) = 30.
      W(5) = 150.
      W(6) = 90.
      W(7) = 1000.
      W(8) = 500.
      W(9) = 750.
      W(10) = 300.
      W(11) = 10.
      R(1) = 1.0
      R(2) = 0.928
      R(3) = 1.472
      R(4) = 2.64
      R(5) = 5.313
      R(6) = 8.96
      R(7) = 40.
      R(8) = 67.49
      R(9) = 90.9
      R(10) = 133.8
      R(11) = 215.4
      A(1) = 100.
      A(2) = 50.
      A(3) = 25.
      A(4) = 12.
      A(5) = 10.
      A(6) = 5.
      A(7) = 2.5
      A(8) = 1.2
      A(9) = 1.
      A(10) = .5
      A(11) = .1
      F = 0.1
      WRITE(6,100) NE, SITE
      DO 1000 K=1,73
      WRITE(6,300) F
      WRITE(6,200)  (N(I),W(I),R(I),A(I),I=1,11)
      F = 1.1 * F
1000  CONTINUE
100   FORMAT(1X,I5,1X,A5)
200   FORMAT(3(I4,3E12.6))

300   FORMAT(F10.5)
      END
```

Figure A.5. Test data used for FIT

```
FREQUENCY IS      0.10000

REGRESSION COEFFICIENTS CALCULATED FOR THIS FREQUENCY

YIELD COEFFICIENT =  0.332979E+00

RANGE COEFFICIENT = -0.999838E+00

INTERCEPT =  0.100481E+02

LOWER CONFIDENCE LIMITS FOR:

YIELD =  0.329466E+00  RANGE = -0.100242E+01  INTERCEPT =  0.965871E+01

UPPER CONFIDENCE LIMITS FOR:

YIELD =  0.336492E+00  RANGE = -0.997253E+00  INTERCEPT =  0.102431E+02

STANDARD ERROR FOR:

YIELD =  0.188901E-02  RANGE =  0.138989E-02  INTERCEPT =  0.101039E+01

ADJUSTED SUMS OF SQUARES FOR:

YIELD =     0.481525E+00  RANGE =  0.801958E+01  INTERCEPT =  0.100000E+01

PARTIAL F-TEST VALUES FOR:

YIELD =  0.310717E+05  RANGE =  0.517485E+06  INTERCEPT =  0.100000E+01


P(EXCEEDING F UNDER HO)

YIELD =  0.000000E+00  RANGE =  0.000000E+00  INTERCEPT =  0.100000E+01

ANALYSIS OF VARIANCE

DEGREES OF FREEDOM

REGRESSION =  0.200000E+01  RESIDUAL =  0.800000E+01CORRECTED TOTAL =  0.100000E+02

UMS OF SQUARES

REGRESSION =  0.822916E+01  RESIDUAL =  0.123978E-03  CORRECTED TOTAL =  0.822929E+01

EAN SQUARES

REGRESSION =  0.411458E+01  RESIDUAL =  0.154972E-04

-VALUE

REGRESSION =  0.265505E+06

(EXCEEDING F UNDER HO)

REGRESSION =  0.000000E+00

PERCENTAGE VARIATION EXPLAINED BY THE ESTIMATED MODEL IS  0.999985E+02

STANDARD DEVIATION OF THE RESIDUALSIS  0.393665E-02

RESIDUAL STANDARD DEVIATION AS A % OF THE RESPONSEMEAN IS  0.614129E+00

NUMBER OF DECIMAL DIGITS OF ACCURACY IN THEREGRESSION COEFFICIENTS IS  0.400000E+01
```

Figure A.6. Output from Problem FIT

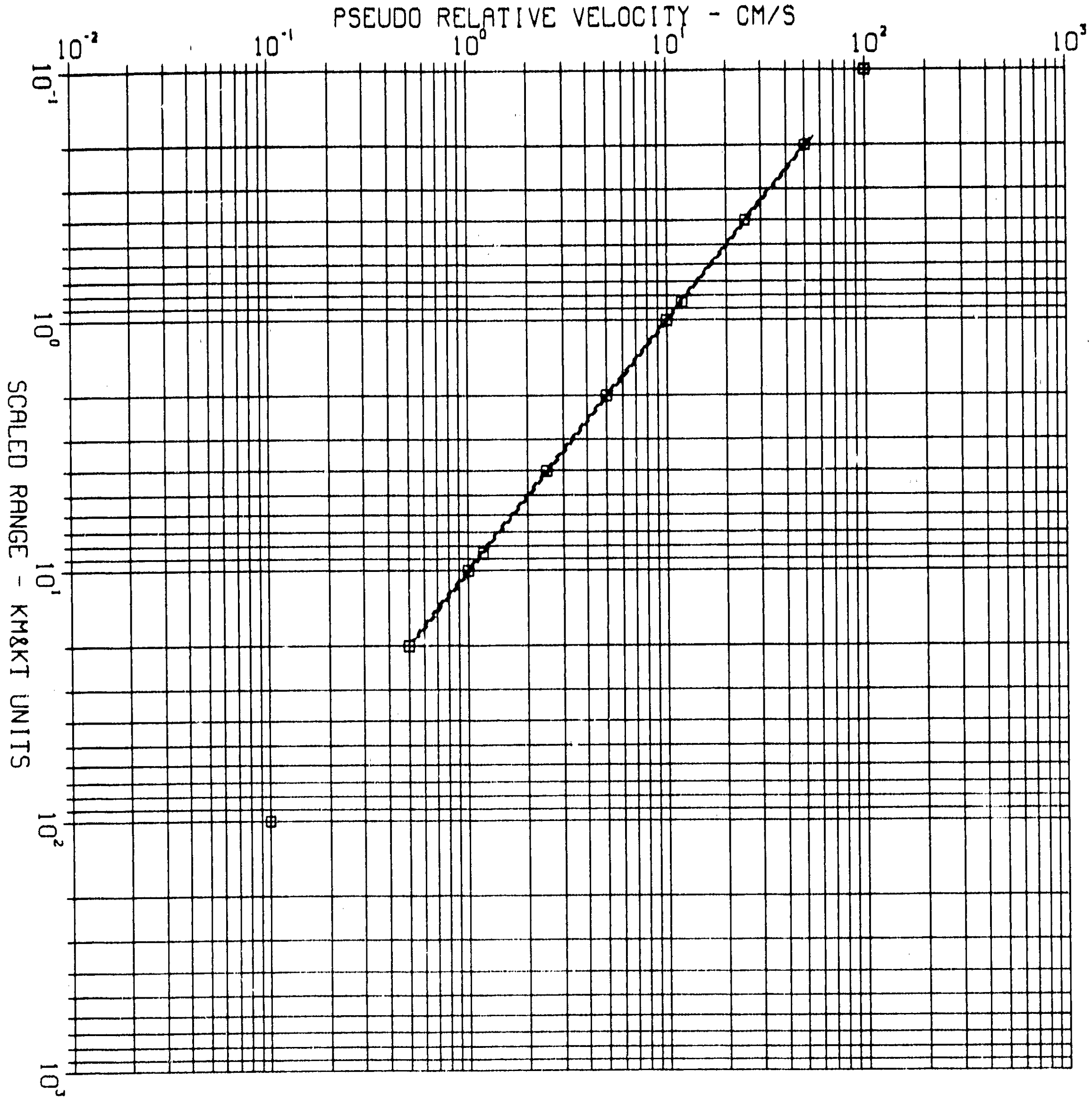

Figure A.7. Plot of results from test run on FIT Code

A.3 Source Code Listings

The source code listings for the programs discussed in this appendix are given in this Appendix. These codes are presented in the following order:

1. PSRV
2. FIT Multiple Event Version
3. FIT Single Event Version
4. SORT
5. PREPRO
6. COMPARE

"PSRV CODE"

```
***   PSRV - CALCULATE PSEUDO RELATIVE VELOCITY RESPONSE SPECTRUM
*            FOR ACCELERATION DATA.
*     D. L. DOWNS.      08/08/83.
*     J. W. LONG.       10-12-83  ALLOWS A SPECIAL RUN WITH PSRV'S FROM
*                                 TWO DIFFERENT EVENTS PRESENTED ON THE
*                                 SAME PLOT.
*     M. L. SANDERS.    09/22/86. NOS/VE VERSION.
*     J. S. PHILLIPS  11/87 VAX VERSION FOR NNWSI
*                           PSRV STUDY
***
*         PSRV CALCULATES PSEUDO RELATIVE VELOCITY RESPONSE
*     FOR ACCELERATION DATA.  PLOTS ARE GENERATED FOR EACH FILE OF
*     ACCELERATION DATA IN EACH MULTI-FILE FILE ACCESSED.
*
*     INPUT
*
*         CARD 1 -  INPUT FILE
*                   CHAR*8
*
*         CARD 2 -  START TIME
*                   DEFAULT -  0.0
*
*         CARD 3 -  END TIME
*                   DEFAULT -  75.0
*
*         CARD 4 -  DAMPING FACTOR*100
*                   DEFAULT -  0.05
*
*         CARD 5 -  NUMBER OF CURVES TO PLOT ON EACH PLOT
*                   DEFAULT -  1
*
*         CARD 6 -  NUMBER OF FILES TO PROCESS
*                   DEFAULT -  ALL FILES WILL BE PROCESSED
*
*         CARD 7 -  MINIMUM FREQUENCY*10
*                   DEFAULT -  0.1 KHZ
*
*         CARD 8 -  MAXIMUM FREQUENCY
*                   DEFAULT -  100 KHZ
*
*         CARD 9 - EVENT NUMBER
*
*         CARD 10 - NUMBER OF STATIONS IN THE RUN
*
*         CARD 11 - STATION MEDIUM  A10 FORMAT
*                   STATION NAME  A10 FORMAT
*                   STATION RANGE - KM  F13.6
```

```
*               REPEAT CARD 11 FOR EACH STATION
*
*      ON INPUT, ONLY 1 CARD IS REQUIRED.  IF CARDS 2-8 ARE OMITTED,
*      THE DEFAULT VALUES WILL BE USED.  ANY OF THE PARAMETERS ON CARDS
*      2-8 MAY BE CHANGED; HOWEVER, ANY PRECEDING DATA CARDS MUST BE
*      PRESENT.  ANY INTERVENING DATA VALUES THAT ARE DESIRED TO DEFAULT
*      MUST BE REPRESENTED BY NULLS.
*
*      NOTE : CARE MUST BE TAKEN WHEN CHANGING THE VALUES
*      OF FREQMN AND FREQMX.  THEY BOTH SHOULD BE INTEGER
*      POWERS OF 10.  FURTHER, FREQMX SHOULD BE 1000 TIMES
*      AS LARGE AS FREQMN.  OTHERWISE, THE PLOTTING ROUTINE
*      RESULTS ARE UNPREDICTABLE.
*
*      OUTPUT
*
*         TAPE77 - PLOT FILE GENERATED.  THIS FILE MUST BE DISPOSED TO
*                  A PLOTTER.
*
*      ERRORS
*
*         FILE I/O ERRORS
*
*      CALLS VSTART, VDESCP, CHKDATA, READIN, INDEX, EXPAND, SPEC, OUTPSRV,
*            SCALE, LGLGLG, DRWCUR, ENDPL, DONEPL, ABORT.
*

       LOGICAL ACCDATA,ALLDONE

       CHARACTER*8 AMPFAC,DATAOUT(200),INFIL,GAUGEOR
       CHARACTER*8 ROTANG,STATNUM,NEWVALU
       CHARACTER*10 EVNTNAM,FREQUEN,TRACK,STAMED(30),STANAM(30)

       DIMENSION PERIOD(200),PSRVAL(200),DVAL(100000),STARNG(30)

       INTEGER IVAL (100000),EVNTNUM

*****
*      INITIALIZE DISPLAY ROUTINES
*****

       CALL VSTART(0.0,0)

*         DISABLE BLANK PAGE BETWEEN PLOTS.  REFERENCE: DISSPLA USER'S GUIDE
*         FOR NOS/VE, MARCH 1986, P.17,19.

       CALL VDESCP(900,0,0)

*****
```

```
*     INITIALIZE DEFAULT VALUES FOR PSRV.
*****

      BEGTIME = 0.
      ENDTIME = 75.
      DAMPFC = .05
      NCUR   = 1
      NUMFIL = 10000
      FREQMN = .1
      FREQMX = 100.

*****
*     READ PARAMETERS.  REPLACE DEFAULT VALUES WITH ANY NEW VALUES.
*****

      OPEN(UNIT=5, FILE='TAPE5', STATUS='OLD')
      OPEN(UNIT=6, FILE='TAPE6', STATUS='NEW')
      OPEN(UNIT=95,FILE='TAPE95',STATUS='NEW')
      READ(5,'(A8)',END=30) INFIL

      READ(5,'(A8)',END=10) NEWVALU
      IF(NEWVALU.NE.'0.') READ(NEWVALU,'(F8.3)') BEGTIME

      READ(5,'(A8)',END=10) NEWVALU
      IF(NEWVALU.NE.'75.') READ(NEWVALU,'(F8.3)') ENDTIME

      READ(5,'(A8)',END=10) NEWVALU
      IF(NEWVALU.NE.'.05') THEN
         READ(NEWVALU,'(F8.3)') DAMPFC
         DAMPFC = DAMPFC/100
      ENDIF

      READ(5,'(I2)',END=10) NCUR
      READ(5,'(I5)',END=10) NUMFIL

      READ(5,'(A8)',END=10) NEWVALU
      IF(NEWVALU.NE.'.1') THEN
         READ(NEWVALU,'(F8.3)') FREQMN
         FREQMN = FREQMN/10
      ENDIF

      READ(5,'(F8.3)',END=10) FREQMX

      READ(5,'(I5)',END=10) EVNTNUM

      READ(5,'(I5)',END=10) NSTAT

      READ(5,1793)(STAMED(I),STANAM(I),STARNG(I),I=1,NSTAT)
 1793 FORMAT(2A10,F13.6)
```

```
      WRITE(6,1794) EVNTNUM
 1794 FORMAT(2X,'EVENT NUMBER =   ',I5)
      WRITE(6,1795)
 1795 FORMAT(//,2X,'STATIONS AND RANGES USED IN THIS RUN',//)
      WRITE(6,1796)(STANAM(I),STARNG(I),STAMED(I),I=1,NSTAT)
 1796 FORMAT(1X,A10,1X,F13.6,1X,A10)

 10   ICUR=NCUR

*****
*     CHECK FOR REASONABLE VALUES. SET THOSE THAT ARE NOT
*     TO DEFAULT VALUES AND WRITE ERROR MESSAGES.
*****

      CALL CHKDATA(BEGTIME,ENDTIME,NUMFIL,FREQMN,FREQMX,IERR)

      IF(IERR.NE.0) THEN

         WRITE(6,200) IERR
         CALL EXIT

      ENDIF

*****
*     ECHO PARAMETERS.
*****

      WRITE(6,210)
      WRITE(6,215) INFIL,BEGTIME,ENDTIME,DAMPFC,
     -             NUMFIL,FREQMN,FREQMX

*****
*     CALCULATE MINIMUM AND MAXIMUM PERIODS FROM
*     MAXIMUM AND MINIMUM FREQUENCIES.
*****

      XL = 1.0 / FREQMX
      XR = 1.0 / FREQMN

*****
*     OPEN INPUT FILE
*****

      OPEN(UNIT=11,FILE='INFIL',STATUS='OLD')

*****
*     READ INPUT DATA
*****
```

```
      II = 1

      DO 20 I=1,NUMFIL

      CALL READIN(ACCDATA,ALLDONE,AMPFAC,COMPCON,DATAOUT,
     -     DELTIM,DMIN,DMAX,EVNTNAM,FREQUEN,GAUGEOR,NUMDATA,
     -     ROTANG,STATNUM,STPTIM,STRTIM,TRACK,IVAL)

*****
*     CHECK FOR THE END OF INFORMATION.
*****

      IF(.NOT.ALLDONE) THEN

*****
*     PROCESS ACCELERATION DATA.
*****

          IF(ACCDATA) THEN

              NSKIP = NSKIP+1

*****
*     DETERMINE INDICES FOR CHOSEN TIME INTERVAL.
*****

              CALL INDEX(BEGTIME,DELTIM,ENDTIME,INDXBEG,
     -                   INDXEND,STPTIM,STRTIM)

*****
*     CONVERT DATA FROM COMPRESSED FORMAT
*****

              CALL EXPAND(DMIN,IVAL,DVAL,NUMDATA,COMPCON)

*****
*     COMPUTE PSRV AND PERIOD COORDINATES
*****

              CALL SPEC(DAMPFC,DELTIM,FREQMN,FREQMX,INDXBEG,INDXEND,
     -                  INDXPER,PERIOD,PSRVAL,DVAL)

*****
*     WRITE TO OUTPUT FILE
*****

              CALL OUTPSRV(1.1,BEGTIME,DAMPFC,DATAOUT,
     -                     ENDTIME,FREQMN,INDXPER,PSRVAL)
```

```
*****
*     COMPUTE LOWER AND UPPER LIMITS FOR THE Y-AXIS (PSRV-AXIS).
*****

              CALL SCALE(INDXPER,PERIOD,PSRVAL,XL,XR,YB,YT)

*****
*     CONSTRUCT LOG-LOG-LOG GRID WITH APPROPRIATE LABELS
*****

                     IF(ICUR.EQ.NCUR) THEN
                     CALL LGLGLG(AMPFAC,BEGTIME,DAMPFC,ENDTIME,EVNTNAM,
     -                    FREQUEN,GAUGEOR,ROTANG,STATNUM,TRACK,
     -                    XL,XR,YB,YT,EVNTNUM,STAMED,STARNG,II)
                     END IF
*****
*     PLOT PSRV VALUES
*****

              CALL DRWCUR(INDXPER,PERIOD,PSRVAL)

*****
*     END CURRENT PLOT.
*****
              ICUR=ICUR-1
              IF(ICUR.EQ.0) THEN
                 ICUR=NCUR
                 CALL ENDPL(-1)
              END IF

          ENDIF

      ELSE

*****
*     END OF FILE REACHED.
*****

          GO TO 40

      ENDIF


*****
*     READ NEXT DATA SET
*****

 20   CONTINUE
```

```
      GO TO 40

*****
*     ERROR PROCESSING.
*****

*     ERROR IN INPUT PARAMETERS

   30 WRITE(6,220)
      CALL EXIT

*****
*     END OF INFORMATION.
*****

 40   CLOSE(UNIT=11)
      CLOSE(UNIT=6)
      CLOSE(UNIT=95)
      WRITE(6,225) NSKIP
      CALL DONEPL
      STOP

 200  FORMAT(/,2X,'ERROR ',I5,' FROM CHKDATA.',/,2X,'PROGRAM ABORT')

 210  FORMAT(//1X,'***** PARAMETERS ARE *****')

 215  FORMAT(1X,'FNAM = ',A8,/1X,'BEGTIME = ',
     -        F9.3,/1X,'ENDTIME = ',F9.3,/1X,'DAMPFC = ',F9.3,/
     -        1X,'NUMFIL = ',I8,/
     -        1X,'FREQMN = ',F9.3,/1X,'FREQMX = ',F9.3,/)

*     PREMATURE END OF FILE ON INPUT

 220  FORMAT(/,2X,'PREMATURE END-OF-FILE WHILE READING INPUT ',
     -        'PARAMETERS.',/,2X,'PROGRAM ABORT')

 225  FORMAT(/,2X,'PSRV NORMAL TERMINATION.',/,
     -        2X,I5,' INPUT FILES PROCESSED.')

      END
```

```
      SUBROUTINE CHKDATA(BEGTIME,ENDTIME,NUMFIL,FREQMN,FREQMX)

***   CHKDATA - CHECK FOR REASONABLE INPUT PARAMETER VALUES
*     D. L. DOWNS.       08/08/83.
*     M. L. SANDERS.     09/22/86. NOS/VE VERSION.  REMOVED 'ISKIP' AS IT
*                        WAS NOT IMPLEMENTED.

***
*     THIS ROUTINE CHECKS TO SEE THAT VALUES ON THE DATA CARD
*     READ IN ARE REASONABLE.  IN PARTICULAR, THE ROUTINE
*     CHECKS THAT BEGTIME IS LESS THAN ENDTIME, THAT NUMFIL
*     IS GREATER THAN 1, AND THAT FREQMN IS LESS THAN FREQMX.
*     IF ANY OF THESE CONDITIONS DO NOT EXIST THAN DEFAULT
*     VALUES ARE RETURNED FOR THE APPROPRIATE PARAMETERS.
*
*     PARAMETERS
*
*         BEGTIME - START TIME FOR PLOT
*         ENDTIME - STOP TIME FOR PLOT
*         NUMFIL  - NUMBER OF FILES FROM INPUT FILE TO PLOT
*         FREQMN  - MINIMUM FREQUENCY
*         FREQMX  - MAXIMUM FREQUENCY
*
*     ENTRY
*
*         ALL PARAMETERS GIVEN
*
*     EXIT
*
*         PARAMETER VALUES VERIFIED AND ARE REASONABLE
*

      IF(BEGTIME.GE.ENDTIME) THEN
          WRITE(6,100)
          WRITE(6,101)
          BEGTIME = 0.0
          ENDTIME = 75.0
      ENDIF

      IF(NUMFIL.LT.1) THEN
          WRITE(6,100)
          WRITE(6,103)
          NUMFIL = 10000
      ENDIF

      IF(FREQMN.GT.FREQMX) THEN
          WRITE(6,100)
          WRITE(6,104)
          FREQMN = 0.1
```

```
          FREQMX = 100.0
      ENDIF

      RETURN

100   FORMAT(1X,'**  ERROR IN INPUT VALUES  **')

101   FORMAT(/2X,'**  STARTIME LARGER THAN ENDTIME  **',
     -         /2X,'**     DEFAULT VALUES ARE USED    **')

103   FORMAT(/2X,'**  NUMBER OF FILES TO PLOT IS LESS THAN 1 **',
     -         /2X,'**          DEFAULT VALUES ARE USED        **')

104   FORMAT(/2X,'**  FREQUENCY MIN IS GREATER THAN FREQUENCY MAX  **',
     -         /2X,'**             DEFAULT VALUES ARE USED            **')

      END
```

```
      SUBROUTINE READIN(ACCDATA,ALLDONE,AMPFAC,COMPCON,DATAOUT,
     -          DELTIM,DMIN,DMAX,EVNTNAM,FREQUEN,GAUGEOR,NUMDATA,
     -          ROTANG,STATNUM,STPTIM,STRTIM,TRACK,IVAL)

***   READIN - CHECK FOR REASONABLE INPUT PARAMETER VALUES
*     D. L. DOWNS.       08/08/83.
*     M. L. SANDERS.     09/22/86. NOS/VE VERSION.  REMOVED THE COMMON AND
*                        NOW PASS THE DATA ARRAY AS A PARAMTER.

***
*     THIS PROCEDURE READS IN THE ID SECTION AND DATA SECTION OF
*     OF AN INPUT FILE.  THE ID SECTION IS ASSUMED TO HAVE 10-80
*     CHARACTER RECORDS WITH 8 CHARACTERS PER WORD.
*     FROM THE ID SECTION THE FOLLOWING WORDS ARE READ, CONVERTED
*     INTO THEIR PROPER FORMATS, AND PASSED BACK
*
*       AMPFAC  = AMPLIFICATION FACTOR
*       COMPCON = COMPRESSION CONSTANT (WORDS 16 AND 17)
*       DELTIM  = DELTA TIME (WORD 11)
*       DMIN    = MINIMUM DATA ITEM (WORDS 12 AND 13)
*       DMAX    = MINIMUM DATA ITEM (WORDS 14 AND 15)
*       EVNTNAM = EVENT NAME (WORDS 4 AND 5)
*       STPTIM  = END TIME FOR DATA COLLECTION (WORD 10)
*       FREQUEN = FREQUENCY (WORD 8)
*       GAUGEOR = GAUGE ORIENTATION (WORD 3)
*       NUMDATA = NUMBER OF DATA ITEMS (WORD 92)
*       ROTANG  = ROTATION ANGLE (WORD 6)
*       STATNUM = STATION NUMBER (WORD 2)
*       STRTIM  = START TIME (WORD 9)
*       TRACK   = TRACK (WORD 8)
*
*     THE COMPRESSED FORM OF THE DATA IS ALSO RETURNED
*
*       IVAL    = DATA VALUES
*
*     ALSO RETURNED ARE TWO LOGICAL VARIABLES
*
*       ACCDATA = TRUE IF DATA IS ACCELERATION DATA
*       ALLDONE = TRUE IF END OF INFORMATION IS REACHED
*
*

      INTEGER IVAL(100000)

      CHARACTER*8 AMPFAC,DATAOUT(200),GAUGEOR,IDBLOCK(100)
      CHARACTER*8 ROTANG,STATNUM,MODRECS(500)
      CHARACTER*10 EVNTNAM,FREQUEN,STRING,TRACK

      LOGICAL ACCDATA,ALLDONE
```

```
      DATA INTEG/'INTEG   '/,INTEG2/'INTEG2  '/

*****
*     READ IN IDBLOCK
*****

      CALL READID(11,IDBLOCK,IEOI)

      IF(IEOI.NE.0) THEN
         ALLDONE = .TRUE.
         RETURN
      ENDIF

      ALLDONE = .FALSE.

*****
*     TRANSFER FIRST 8 WORDS TO ARRAY DATAOUT FOR OUTPUT
*     TO UNIT 41
*****

      DO 5 I=1,8
          DATAOUT(I) = IDBLOCK(I)
5     CONTINUE


*****
*     PICK OUT NECESSARY INFORMATION FROM ID BLOCK AND
*     CONVERT TO PROPER FORMAT.  IF WE DO NOT HAVE ACCELERATION
*     DATA SKIP THIS.
*****

      IF((IDBLOCK(1)(1:6).EQ.'INTEG ').OR.
     -   (IDBLOCK(1)(1:6).EQ.'INTEG2'))   THEN
          ACCDATA = .FALSE.
      ELSE
          ACCDATA = .TRUE.

          STATNUM = IDBLOCK(2)

          GAUGEOR = IDBLOCK(3)

          EVNTNAM = IDBLOCK(4)//IDBLOCK(5)(1:2)

          ROTANG = IDBLOCK(6)

          AMPFAC = IDBLOCK(7)

          TRACK = 'TRACK   '//IDBLOCK(8)(3:4)
```

```
         FREQUEN = IDBLOCK(8)(5:8)//'  K-HZ'

         READ(IDBLOCK(9),'(F8.4)')STRTIM

         READ(IDBLOCK(10),'(F8.4)')STPTIM

         READ(IDBLOCK(11),'(F8.4)')DELTIM

*     READ THE DATA MINIMUM, MAXIMUM, AND CONVERSION CONSTANT

         CALL GRMNX(IDBLOCK,DMIN,DMAX,COMPCON)

      ENDIF

      READ(IDBLOCK(91),'(I8)')NMODREC

      READ(IDBLOCK(92),'(I8)')NUMDATA

*****
*     SKIP OVER THE MODIFICATION RECORD SECTION.  THIS SECTION
*      IS NMODREC*3 RECORDS LONG.
*****

      NUMRECS = NMODREC * 3

      IF(NMODREC.GT.0)THEN
         DO 10 I=1,NUMRECS
            READ(11,'(10A8)')(MODRECS(K),K=1,10)
10       CONTINUE
      ENDIF

*****
*     READ IN DATA
*****

      CALL READDT(11,IVAL,NUMDATA,IEOI)

      IF(IEOI.NE.0) THEN
         WRITE(6,100)
         CALL EXIT
      ENDIF

      RETURN

 100  FORMAT(/,2X,'PREMATURE END-OF-FILE WHILE READING DATA.',/,2X,
     -       'PROGRAM ABORT.')
      END
```

```
      SUBROUTINE INDEX(BEGTIME,DELTIM,ENDTIME,INDXBEG,
                       INDXEND,STPTIM,STRTIM)

***   INDEX - GET FIRST AND LAST DATA POINT FOR PLOTTING
*     D. L. DOWNS.      08/08/83.

***
*     THIS ROUTINE DETERMINES INDICES FOR THE BEGINNING
*     DATA ITEM AND LAST DATA ITEM OVER THE APPROPRIATE TIME
*     INTERVAL.
*
*     USER SHOULD SUPPLY THE FOLLOWING
*
*        BEGTIME = BEGINNING TIME FOR COMPUTATIONS
*        DELTIM  = DELTA TIME
*        ENDTIME = END TIME FOR COMPUTATIONS
*        STPTIM  = END TIME FOR DATA COLLECTION
*        STRTIM  = START TIME FOR DATA COLLECTION
*
*     THE ROUTINE RETURNS THE FOLLOWING
*
*        INDXBEG = BEGINNING INDEX FOR THE DATA ARRAY
*        INDXEND = ENDING INDEX FOR THE DATA ARRAY
*
*     THE ROUTINE ALSO CHECKS TO SEE IF BEGTIME IS TOO LOW
*     OR ENDTIME IS TOO HIGH.  IF THIS IS TRUE THEN THE VALUES
*     GIVEN IN THE MULTI FILE ARE USED FOR THE REST OF THE
*     MULTI FILE.  A WARNING MESSAGE IS PRINTED.
*
*****

*****
*     CHECK IF BEGTIME AND ENDTIME ARE APPROPRIATE.
*****

      IF(BEGTIME.LT.STRTIM) THEN
          BEGTIME = STRTIM
          WRITE(6,100)
          WRITE(6,101) STRTIM
      ENDIF
      IF(ENDTIME.GT.STPTIM) THEN
          ENDTIME = STPTIM
          WRITE(6,102)
          WRITE(6,101) STPTIM
      ENDIF

*****
*     CALCULATE INDICES
*****
```

```
      INDXBEG = INT((BEGTIME-STRTIM)/DELTIM) + 1
      INDXEND = INDXBEG + INT(ENDTIME/DELTIM)
      RETURN

100   FORMAT(1X,'CHOSEN BEGTIME TOO SMALL FOR THIS FILE')
101   FORMAT(1X,'DEFAULT OF ',E9.3,' WILL BE USED')
102   FORMAT(1X,'CHOSEN ENDTIME TOO LARGE FOR THIS FILE')

      END
```

```
      SUBROUTINE SPEC(DAMPFC,DELTIM,FREQMN,FREQMX,INDXBEG,
     -                INDXEND,INDXPER,PERIOD,PSRVAL,DAT)

***   SPEC - CALCULATE PSRV'S
*     D. L. DOWNS.      08/08/83.
*     M. L. SANDERS.    09/22/86. NOS/VE VERSION.  REMOVED THE COMMON AND
*                       NOW PASS THE DATA ARRAY AS A PARAMTER.

***
*     THIS ROUTINE CALCULATES PSRV'S FOR FREQUENCIES BETWEEN
*     FREQMN AND FREQMX.  USER SHOULD SUPPLY THE FOLLOWING
*
*         DAMPFC  = DAMPING FACTOR
*         DELTIM  = DELTA TIME
*         FREQMN  = MINIMUM FREQUENCY
*         FREQMX  = MAXIMUM FREQUENCY
*         INDXBEG = BEGINNING INDEX OF DATA
*         INDXEND = ENDING INDEX OF DATA
*         DAT     = DATA VALUES
*
*     ROUTINE RETURNS THE FOLLOWING
*         INDXPER= NUMBER OF PERIOD-PSRV COORDINATES CALCULATED
*         PERIOD = AN ARRAY OF SIZE 200 WITH 0.0 IN ALL
*                  LOCATIONS WHERE PSRV HAS NOT BEEN CALCULATED
*                  AND THE APPROPRIATE PERIOD VALUES ELSEWHERE.
*         PSRVAL = AN ARRAY OF SIZE 200 WITH PSRV VALUES IN
*                  LOCATIONS CORRESPONDING TO THE LOCATIONS OF
*                  THE PERIODS IN THE ARRAY PERIOD.  PSRV IS
*                  NOT CALCULATED WHEN THE RECIPROCAL OF PERIOD
*                  IS BELOW FREQMN OR ABOVE FREQMX.
*
*

      DIMENSION PERIOD(200),PSRVAL(200),DAT(100000)

*****
*     DATA IS ASSUMED TO BE IN METERS/SECOND**2.  CONVERT DATA
*     TO DIMENSIONLESS QUANTITIES BY DIVIDING BY GRAVITY.
*****

      DO 5 I=INDXBEG,INDXEND
      DAT(I) = DAT(I) / 9.802368
5     CONTINUE

*****
*       INITIALIZE
*****

      PI=4.0 * ATAN(1.0)
```

```
      OMEGA = FREQMN * 2.0 * PI
      OMEGHI = FREQMX * 2.0 * PI
      FREQ=FREQMN

*****
*     USE NEWMARK BETA PARAMETER METHOD OF NUMERICAL INTEGRATION
*     TO SOLVE THE DIFERENTIAL EQUATION FOR DISPLACEMENT USING DIF-
*     FERENT VALUES OF OMEGA.  OMEGA REPRESENTS 2*PI/PERIOD AND RANGES
*     BETWEEN FREQMN * 2 * PI AND FREQMX * 2 * PI.
*****

      DAMP = SQRT(1.0 - DAMPFC**2)
      INDXPER = 0

      DO 20 I=1,200
      IF(OMEGA.LT.OMEGHI) THEN
          YOLD = 0.0
          Y1OLD = 0.0
          Y2OLD = 0.0
          YMAX = 0.0
          INDXPER = INDXPER + 1

          DO 10 J=INDXBEG,INDXEND
          YNEW = (DAT(J) + Y2OLD +
     -            (2.0 * DAMPFC * OMEGA + 4.0/DELTIM) * Y1OLD
     -            + (4.0 * DAMPFC * OMEGA/DELTIM
     -            + 4.0/DELTIM**2) * YOLD)/
     -           (4.0/DELTIM**2 + 4.0 * DAMPFC * OMEGA/DELTIM
     -            + OMEGA**2)
          Y2NEW = 4.0 * (YNEW - YOLD)/DELTIM**2 -
     -         4.0 * Y1OLD/DELTIM - Y2OLD
          Y1NEW = Y1OLD + DELTIM * (Y2OLD + Y2NEW)/2.0
          YMAX = AMAX1(YMAX,ABS(YNEW))
          YOLD = YNEW
          Y1OLD = Y1NEW
          Y2OLD = Y2NEW
 10       CONTINUE

          OMDAMP = OMEGA * DAMP
          A = YNEW
          B = (Y1NEW + YNEW * DAMPFC * OMEGA)/OMDAMP
          AMP = SQRT(A*A + B*B)
          IF(B.GT.1.0E-10) THEN
              PHI = ATAN(A/B)
          ELSE
              IF(A.NE.0.0) THEN
                  PHI = SIGN(1.0,A) * PI
              ELSE
                  PHI = 0.0
```

```
              ENDIF
          ENDIF
          IF(PHI.GE.PI/2.0) THEN
              C = 3.0 * PI/2.0
          ELSE
              IF(PHI.LE.-PI/2.0) THEN
                  C = -PI/2.0
              ELSE
                  C = PI/2.0
              ENDIF
          ENDIF
          YY = AMP * EXP(-DAMPFC * OMEGA * (C-PHI)/OMDAMP) * SIN(C)
          YYY = -YY * EXP(-DAMPFC * PI/DAMP)
          YMAX = AMAX1(YMAX,YY,YYY)
          PERIOD(I) = 1.0/FREQ
          FREQ = FREQ * 1.1
          PSRVAL(I) = YMAX * OMEGA * 980.2368
      ELSE
          PERIOD(I) = 0.0
      ENDIF
      OMEGA = OMEGA * 1.1
20    CONTINUE

      RETURN
      END
```

```
      SUBROUTINE OUTPSRV(AMULT,BEGTIME,DAMPFC,DATAOUT,
     -                   ENDTIME,FREQMN,INDXPER,PSRVAL)

***   OUTPSRV - CONSTRUCTS OUTPUT ARRAY
*     D. L. DOWNS.      08/08/83.
*     M. L. SANDERS.    09/22/86. NOS/VE VERSION.
*                       REPLACE 'DATE(DAY)' WITH 'DATE()'.

***
*     THIS ROUTINE FINISHES CONSTRUCTING THE CHARACTER ARRAY
*     "DATAOUT",TRANSFERS THIS INFORMATION TO 20 RECORDS ON
*     UNIT 41.  EACH RECORD IS 10 WORDS LONG WITH 8 CHARACTERS PER WORD.
*     THESE 20 RECORDS WILL COMPOSE 1 FILE.
*     USER SHOULD SUPPLY THE FOLLOWING ARGUMENTS
*
*         AMULT   = A FACTOR FROM SPEC WHICH INCREMENTS
*                   FREQUENCY.  USUALLY AMULT IS 1.1.
*         BEGTIME = BEGINNING TIME FOR PSRV CALCULATIONS
*         DAMPFC  = DAMPING FACTOR
*         DATAOUT = A 200 ELEMENT CHARACTER ARRAY WITH THE
*                   FIRST 8 ELEMENTS CONTAINING THE FIRST 8
*                   ELEMENTS OF THE NEW IDBLOCK READ IN.
*                   IN THIS ROUTINE, THE FOLLOWING WILL BE
*                   ADDED TO DATAOUT
*                     (9) = BEGTIME
*                    (10) = ENDTIME
*                    (11) = FREQMN
*                    (12) = DAMPFC
*                    (13) = AMULT
*                    (14) = INDXPER
*                    (15) = MONTH,DATE,YEAR DATA IS PROCESSD
*                    (21 TO 2*INDXPER + 20)
*                          = PSRV VALUES EACH OCCUPYING
*                            2 CONSECUTIVE ELEMENTS IN
*                            E10.4 FORMAT
*                   ALL OTHER ELEMENTS WILL GET BLANKS.
*         ENDTIME = END TIME FOR PSRV CALCULATIONS
*         FREQMN  = MINIMUM FREQUENCY
*         INDXPER = NUMBER OF PSRV COORDINATES
*         PSRVAL  = 200 ELEMENT ARRAY OF PSRV VALUES
*
*     NOTE: INDXPER MAY BE CHANGED TO 80 IF FREQMN AND FREQMX
*     WERE CHANGED ON INPUT TO VALUES THAT WERE MORE
*     THAN 10 TO THE THIRD POWER APART.
*

      DIMENSION PSRVAL(200)

      CHARACTER*8 DATAOUT(200)
```

```
      CHARACTER*10 STRING,DAT

*****
*     TRANSFER DATA TO ARRAY DATAOUT
*****

      WRITE(DATAOUT(9),'(F8.3)')BEGTIME
      WRITE(DATAOUT(10),'(F8.3)')ENDTIME
      WRITE(DATAOUT(11),'(F8.2)')FREQMN
      WRITE(DATAOUT(12),'(F8.4)')DAMPFC
      WRITE(DATAOUT(13),'(F8.2)')AMULT

*****
*     IF INDXPER IS LARGER THAN 80, THEN IT GETS SET TO 80,
*     A WARNING MESSAGE IS PRINTED, AND ONLY THE FIRST 80
*     PSRV VALUES ARE SAVED.  NORMALLY THIS WILL NOT HAPPEN.
*****

      IF(INDXPER.GT.80) THEN
          INDXPER = 80
          WRITE(6,101)
      ENDIF

      WRITE(DATAOUT(14),'(I8)')INDXPER

      CALL DATE(DAT)
      STRING = DAT
      DATAOUT(15) = STRING(1:4)//STRING(6:7)//STRING(9:10)

      DO 5 I=16,200
      DATAOUT(I) = '        '
5     CONTINUE

      DO 10 I=1,INDXPER
      WRITE(STRING,'(E10.4)')PSRVAL(I)
      DATAOUT(2*I+19) = STRING(1:8)
      DATAOUT(2*I+20) = STRING(9:10)
10    CONTINUE

      RETURN

101   FORMAT(//1X,'***** TOO MANY PSRV VALUES *****',
     -       /1X,'***** OUTPUT SHORTENED TO 80 VALUES *****')

      END
```

```
      SUBROUTINE SCALE(INDXPER,PERIOD,PSRVAL,XL,XR,YB,YT)

***   SCALE - SCALE Y AXIS FOR PLOT.
*     D. L. DOWNS.      08/08/83.

***
*     THIS ROUTINE FINDS THE MAXIMUM PSRV VALUE AND COMPUTES
*     AN APPROPRIATE SCALE FOR THE Y-AXIS.  THE USER SHOULD
*     SUPPLY THE FOLLOWING ARGUMENTS
*
*         INDXPER= NUMBER OF PERIOD-PSRV COORDINATES
*         PERIOD = A 200 ELEMENT ARRAY OF COMPUTED PERIODS
*         PSRVAL = A 200 ELEMENT ARRAY OF COMPUTED PSRV VALUES
*         XL     = LEFT-MOST X-COORDINATE
*         XR     = RIGHT-MOST X-COORDINATE
*
*     THE ROUTINE RETURNS THE FOLLOWING
*
*         YB = BOTTOM-MOST Y-COORDINATE
*         YT = TOP-MOST Y-COORDINATE
*
*     X-COORDINATES REPRESENT PERIOD AND Y-COORDINATES REPRESENT
*     PSRV.
*
*

      DIMENSION PERIOD(200),PSRVAL(200)
*****
*     FIND MAXIMUM PERIOD
*****
      PSRVMX = PSRVAL(1)

      DO 10 I=2,INDXPER
      PSRVMX = AMAX1(PSRVAL(I),PSRVMX)
10    CONTINUE
*****
*     COMPUTE ENDPOINTS
*****
      IF(ALOG10(PSRVMX).GT.0.0) THEN
          YT = 10.0**INT(ALOG10(PSRVMX) + 1)
      ELSE
          YT = 10.0**INT(ALOG10(PSRVMX))
      ENDIF
      YB = YT / 10000.0
      RETURN
      END
```

```
      SUBROUTINE DRWCUR(INDXPER,PERIOD,PSRVAL)

***   DRWCUR - PLOTS THE CURVE.
*     D. L. DOWNS.      08/08/83.

*****
*     THIS DRAWS THE PSRV CURVE.  USER SHOULD SUPPLY THE
*     COMPUTED PERIOD-PSRV COORDINATES STORED IN THE
*     200 ELEMENT ARRAYS PERIOD AND PSRV, AND THE NUMBER
*     OF COORDINATE PAIRS STORED IN INDXPER.
*****

      DIMENSION PERIOD(200),PSRVAL(200)

      WRITE (95,100) (PSRVAL(I),I=1,INDXPER)
 100  FORMAT(1X,10E13.6)
      CALL THKCRV(0.02)
      CALL CURVE(PERIOD,PSRVAL,INDXPER,0)
      CALL RESET('THKCUR')

      RETURN
      END
```

```
      SUBROUTINE LGLGLG(AMPFAC,BEGTIME,DAMPFC,ENDTIME,EVNTNAM,
     -                  FREQUEN,GAUGEOR,ROTANG,STATNUM,TRACK,
     -                  XL,XR,YB,YT,EVNTNUM,STAMED,STARNG,II)

***   LGLGLG - CONSTRUCTS A GRID.
*     D. L. DOWNS.      08/08/83.
*     M. L. SANDERS.    09/22/86. NOS/VE VERSION.
*                       REPLACE 'DATE(DAY)' WITH 'DATE()'.

***
*     THIS ROUTINE CONSTRUCTS A LOG-LOG-LOG GRID.  THE USER SHOULD
*     SUPPLY THE FOLLOWING ARGUMENTS
*
*          AMPFAC  = AMPLIFICATION FACTOR STRING
*          DAMPFC  = DAMPING FACTOR
*          BEGTIME = BEGINNING TIME FOR COMPUTATIONS
*          ENDTIME = END TIME FOR COMPUTATIONS
*          EVNTNAM = EVENT NAME STRING
*          FREQUEN = FREQUENCY STRING
*          GAUGEOR = GAUGE ORIENTATION STRING
*          ROTANG  = ROTATION ANGLE STRING
*          STATNUM = STATION NUMBER STRING
*          TRACK   = TRACK STRING
*          XL      = LEFT-MOST X-COORDINATE
*          XR      = RIGHT-MOST X-COORDINATE
*          YB      = BOTTOM-MOST Y-COORDINATE
*          YT      = TOP-MOST Y-COORDINATE
*

      CHARACTER*6 BTIMOUT,ETIMOUT
      CHARACTER*8 AUNITS(8),DUNITS(8)
      CHARACTER*8 AMPFAC,GAUGEOR,ROTANG,STATNUM,TIM
      CHARACTER*10 EVNTNAM,FREQUEN,TRACK,DAT,STAMED(30)
      CHARACTER*12 LXNAME
      CHARACTER*25 STRING,MSTRING
      CHARACTER*29 MESS3
      CHARACTER*39 MESS2
      CHARACTER*40 MESS1,MESS1A
      CHARACTER*42 LYNAME
      DIMENSION STARNG(30)

      INTEGER EVNTNUM

      DATA DUNITS/'.0001CM ','.001CM  ','.01CM   ','.1CM    ',
     -            '1CM     ','10CM    ','100CM   ','1000CM  '/

      DATA AUNITS/'1.E-8G  ','1.E-7G  ','1.E-6G  ','1.E-5G  ',
     -            '1.E-4G  ','1.E-3G  ','1.E-2G  ','1.E-2G  '/
```

```
      DATA LXNAME/'PERIOD - SEC'/,'IXNAME/12/,IYNAME/42/

      DATA LYNAME/'PSEUDO RELATIVE RESPONSE VELOCITY - CM/SEC'/

*****
*     XSIZE AND YSIZE GIVE THE SIZE OF THE PLOT REGION IN
*     INCHES.  XSIZE AND YSIZE SHOULD NORMALLY BE IN A RATIO
*     OF 3:4.
*****

      DATA XSIZE/6.0/
      DATA YSIZE/8.0/

*****
*     COMPUTE CYCLE LENGTH
*****

      CYCLE = XSIZE/(ALOG10(XR) - ALOG10(XL))

*****
*     THIS SEGMENT CONSTRUCTS THE BORDER AND THE HORIZONTAL
*     AND VERTICAL GRID LINES.
*****

      CALL PAGE(11,11)
      CALL NOBRDR
      CALL AREA2D(XSIZE,YSIZE)
      CALL XNAME(%REF(LXNAME),IXNAME)
      CALL YNAME(%REF(LYNAME),IYNAME)
      CALL LOGLOG(XL,CYCLE,YB,CYCLE)
      CALL GRID(1,1)

*****
*     THIS SEGMENT CONSTRUCTS THE LEFT DIAGONAL GRID LINES
*     REPRESENTING DISPLACEMENT.
*****

      TWOPI = ATAN(1.0) * 8.0
      CALL DASH

      DO 20 L=1,10

      DO 10 M=1,9
      DISP = YB * FLOAT(M+1) * 10.0 ** (L-4)
      Y1=TWOPI * DISP /XL
      Y2=TWOPI * DISP /XR
      IF(.NOT.(((Y1.GT.YT).AND.(Y2.GT.YT)).OR.
     -         ((Y1.LT.YB).AND.(Y2.LT.YB)))) THEN
          SLOPE=(ALOG10(Y2)-ALOG10(Y1))/(ALOG10(XR)-ALOG10(XL))
```

```
          YINT=ALOG10(Y1)-SLOPE*ALOG10(XL)
          CALL ENDPTS(SLOPE,YINT,ALOG10(XL),ALOG10(XR),
     -       ALOG10(YB),ALOG10(YT),XX1,YY1,XX2,YY2)
          XX1=10.0**XX1
          XX2=10.0**XX2
          YY1=10.0**YY1
          YY2=10.0**YY2
          CALL RLVEC(XX1,YY1,XX2,YY2,0000)
      ENDIF
10    CONTINUE

*****
*     PRINT DISPLACEMENT LABELS
*****

      INDXDIS = INT(ALOG10(YB)) + L + 2
      IF((INDXDIS.GE.1).AND.(INDXDIS.LE.8).AND.
     -   (Y2.GT.YB).AND.(Y2.LT.YT))  THEN
          CALL ANGLE(315)
          CALL HEIGHT(0.1)
          CALL RLMESS(%REF(DUNITS(INDXDIS)),8,1.2*XX2,YY2)
          CALL RESET('ANGLE')
          CALL RESET('HEIGHT')
      ENDIF

20    CONTINUE

      CALL RESET('DASH')

*****
*     THIS SEGMENT CONSTRUCTS THE RIGHT DIAGONAL GRID LINES
*      REPRESENTING ACCELERATION.
*****

      CALL DOT

      DO 40 L=1,10

      DO 30 M=1,9
      ACCEL = YB * FLOAT(M+1) * 980.2368 * 10.0 ** (L-5)
      Y1=ACCEL * XL /TWOPI
      Y2=ACCEL * XR /TWOPI
      IF(.NOT.(((Y1.GT.YT).AND.(Y2.GT.YT)).OR.
     -        ((Y1.LT.YB).AND.(Y2.LT.YB)))) THEN
          SLOPE=(ALOG10(Y2)-ALOG10(Y1))/(ALOG10(XR)-ALOG10(XL))
          YINT=ALOG10(Y1)-SLOPE*ALOG10(XL)
          CALL ENDPTS(SLOPE,YINT,ALOG10(XL),ALOG10(XR),
     -       ALOG10(YB),ALOG10(YT),XX1,YY1,XX2,YY2)
          XX1=10.0**XX1
```

```
            XX2=10.0**XX2
            YY1=10.0**YY1
            YY2=10.0**YY2
            CALL RLVEC(XX1,YY1,XX2,YY2,0000)
         ENDIF
30       CONTINUE

*****
*        PRINT ACCELERATION LABELS
*****

         INDXACC = INT(ALOG10(YB)) + L + 5
         IF((INDXACC.GE.1).AND.(INDXACC.LE.8).AND.
     -       (Y2.GT.YB).AND.(Y2.LT.YT))  THEN
             CALL ANGLE(45)
             CALL HEIGHT(0.1)
             CALL RLMESS(%REF(AUNITS(INDXACC)),8,1.2*XX2,YY2)
             CALL RESET('ANGLE')
             CALL RESET('HEIGHT')
         ENDIF

40       CONTINUE

         CALL RESET('DOT')

*****
*        CONSTRUCT FREQUENCY AXIS
*****

         CALL RLVEC(XL,YT*1.1,XR,YT*1.1,0600)
         START = XR * 10.0
         CALL HEIGHT(0.1)

         DO 60 I=1,3
         START = START / 10.0
         ANUM = 1.0 / START
         CALL RLREAL(ANUM,103,START*0.8,YT*1.3)

         DO 50 J=1,9
         X = START/FLOAT(J)
         CALL RLVEC(X,YT*1.1,X,YT*1.2,0600)
50       CONTINUE

60       CONTINUE

         START = START / 10.0
         ANUM = 1.0 / START
         CALL RLREAL(ANUM,103,START*0.8,YT*1.3)
         CALL RLVEC(START,YT*1.1,START,YT*1.2,0600)
```

```
      CALL RESET('HEIGHT')

*****
*     CONSTRUCT LABELS
*****

      MESS1=STATNUM//'  '//GAUGEOR//'  '//EVNTNAM//'  '//ROTANG
      MESS1A=STATNUM//'  '//GAUGEOR//'  '//'  '//ROTANG
      MESS2='AMP X  '//AMPFAC//'  '//TRACK//'  '//FREQUEN
      WRITE(BTIMOUT,'(F5.2)')BEGTIME
      WRITE(ETIMOUT,'(F5.2)')ENDTIME
      WRITE(95,1279) MESS1A,MESS2,DAMPFC
 1279 FORMAT(1X,A29,1X,A39,1X,F8.3)
      WRITE(95,1280) STAMED(II)
 1280 FORMAT(1X,A10)
      WRITE(95,1281) EVNTNUM,STARNG(II)
 1281 FORMAT(I5,E13.6)
      II = II+1
      MESS3='TIME '//BTIMOUT//' TO '//ETIMOUT//' SECONDS'
      CALL RLMESS(%REF(MESS1),40,XL*2.0,YT*2.5)
      CALL RLMESS(%REF(MESS2),39,XL*2.0,YT*2.0)
      CALL ANGLE(90)
      CALL RLMESS(%REF(MESS3),29,XL/3.0,YB*10.0)
      CALL TIME(TIM)
      STRING(1:8) = TIM
      CALL DATE(DAT)
      STRING(9:18) = DAT
      MSTRING = '   '//STRING(1:8)//'    '//STRING(9:18)
      CALL RLMESS(%REF(MSTRING),25,XL/2.2,YB*10.5)
      CALL RESET('ANGLE')
      CALL HEIGHT(0.1)
      CALL RLMESS('FREQUENCY - HZ',14,10.5*XL,YT*1.6)
      CALL RLMESS('DAMPING=',8,0.3*XR,YT*1.6)
      CALL RLREAL(DAMPFC,103,0.9*XR,YT*1.6)
      CALL RESET('HEIGHT')

      RETURN
      END
```

```
      SUBROUTINE ENDPTS(SLOPE,YINT,XLEFT,XRIGHT,YBOT,YTOP,
     -                  XX1,YY1,XX2,YY2)

***   ENDPTS - DETERMINE ENDPOINTS FOR THE AXIES.
*     D. L. DOWNS.      08/08/83.
*     M. L. SANDERS.    09/22/86. NOS/VE VERSION.

*****
*     THIS ROUTINE RETURNS THE ENDPOINTS OF A GRAPH WITH X-SCALE
*     FROM "XLEFT" TO "XRIGHT" AND Y-SCALE FROM "YBOT" TO "YTOP".
*     USER MUST SUPPLY THE FOLLOWING ARGUMENTS ON INPUT
*
*         SLOPE = SLOPE OF THE LINE SEGMENT
*         YINT  = Y-INTERCEPT OF THE LINE SEGMENT
*         XLEFT = LEFT-MOST X-COORDINATE
*         XRIGHT = RIGHT-MOST X-COORDINATE
*         YBOT  = BOTTOM-MOST Y-COORDINATE
*         YTOP  = TOP-MOST Y-COORDINATE
*
*     THE ROUTINE RETURNS THE FOLLOWING
*
*         XX1 = X-COORDINATE OF LEFT ENDPOINT
*         YY1 = Y-COORDINATE OF LEFT ENDPOINT
*         XX2 = X-COORDINATE OF RIGHT ENDPOINT
*         XX3 = Y-COORDINATE OF RIGHT ENDPOINT
*
*****

      YY=SLOPE*XLEFT + YINT
      IF(YY.LT.YBOT) THEN
          XX1=(YBOT-YINT)/SLOPE
          YY1=YBOT
      ELSE
          IF(YY.GT.YTOP) THEN
              XX1=(YTOP-YINT)/SLOPE
              YY1=YTOP
          ELSE
              XX1=XLEFT
              YY1=YY
          ENDIF
      ENDIF

      YY=SLOPE*XRIGHT + YINT
      IF(YY.LT.YBOT) THEN
          XX2=(YBOT-YINT)/SLOPE
          YY2=YBOT
      ELSE
          IF(YY.GT.YTOP) THEN
              XX2=(YTOP-YINT)/SLOPE
```

```
        YY2=YTOP
    ELSE
        XX2=XRIGHT
        YY2=YY
    ENDIF
ENDIF

RETURN
END
```

```
      SUBROUTINE READID(LUI,IDBUF,IEOI)

***   READID - READ CHANNEL ID BLOCK.
*     T. L. P. BUTLER.  12/16/83.

***       READID READS A CHANNEL ID BLOCK FROM A GIVEN INPUT
*     UNIT.  READID PERFORMS A FORMATTED READ.
*
*     PARAMETERS
*
*         LUI   - INPUT LOGICAL UNIT
*         IDBUF - CHANNEL ID BUFFER
*         IEOI  - END OF INFORMATION FLAG
*                 0, NORMAL RETURN
*                 1, END OF FILE ENCOUNTERED
*
*     ENTRY       INPUT UNIT GIVEN, UNIT MUST BE OPEN AND
*                 CORRECTLY POSITIONED ON ENTRY.
*
*     EXIT        CHANNEL ID BLOCK RETURNED IN ID BUFFER.
*                 IF END OF FILE ENCOUNTERED END OF INFORMATION
*                 FLAG IS SET, AND ID BUFFER CONTENTS ARE UNDEFINED.
*
*     ERRORS
*
*         FILE I/O ERROR
*
*     CALLS NONE.
      CHARACTER*8 IDBUF(100)

      IEOI = 0

      READ(LUI,'(10A8)',ERR=20,IOSTAT=IOERR,END=10) IDBUF

      RETURN

*         END OF INFORMATION

   10 IEOI = 1
      RETURN

*         ERROR ON FILE READ

   20 WRITE(6,100) IOERR
      CALL EXIT
  100 FORMAT(/,2X,'ERROR ',I5,' ON INPUT FILE READ IN READID.')

      END
```

```
      SUBROUTINE READDT(LUI,IVAL,NDVAL,IEOI)

***   READDT - READ CHANNEL DATA.
*     T. L. P. BUTLER.  12/16/83.

***       READDT READS THE COMPRESSED DATA VECTOR FOR A
*     CHANNEL FROM A GIVEN INPUT UNIT.  READDT PERFORMS
*     A FORMATTED READ.
*
*     PARAMETERS
*
*         LUI   - INPUT LOGICAL UNIT
*         IVAL  - CHANNEL DATA VECTOR
*         NDVAL - CHANNEL DATA VECTOR LENGTH
*         IEOI  - END OF INFORMATION FLAG
*                 0, NORMAL RETURN
*                 1, END OF FILE ENCOUNTERED
*
*     ENTRY      INPUT UNIT AND VECTOR LENGTH GIVEN, UNIT MUST
*                BE OPEN AND CORRECTLY POSITIONED ON ENTRY.
*
*     EXIT       CHANNEL DATA VECTOR RETURNED.  IF END OF FILE
*                ENCOUNTERED, END OF INFORMATION FLAG IS SET
*                AND CONTENTS OF DATA VECTOR ARE UNDEFINED.
*
*     ERRORS
*
*         FILE I/O ERROR
*
*     CALLS NONE.
*

      DIMENSION IVAL(NDVAL)

      IEOI = 0

*         DETERMINE NUMBER OF RECORDS TO READ FROM FILE

      NREC = NDVAL/16
      NLFT = MOD(NDVAL,16)
      INX = 1

*         READ INTEGRAL RECORDS

      IF(NREC.GT.0) THEN

          DO 10 I=1,NREC

          READ(LUI,'(16I5)',END=15)
```

```
     -         (IVAL(J),J=INX,INX+15)
            INX = INX+16

   10       CONTINUE

         ENDIF

         IF(NLFT.GT.0) THEN
            READ(LUI,'(16I5)',END=15)
     -         (IVAL(J),J=INX,INX+NLFT-1)
         ENDIF

         RETURN

*           END OF FILE ENCOUNTERED

   15    IEOI = 1
         RETURN

*           ERROR ON READ

   20    WRITE(6,100) IOERR
         CALL EXIT

  100    FORMAT(/,2X,'ERROR ',I5,' ON INPUT FILE READ IN READDT.')

         END
```

```
      SUBROUTINE GRMNX(IDBUF,DMIN,DMAX,CCONST)

***   GRMNX - DECODE DATA MINIMUM, MAXIMUM, AND COMPRESSION CONSTANT.
*     T. L. P. BUTLER.  12/16/83.

***       GRMNX DECODES THE DATA MINIMUM, DATA MAXIMUM, AND THE
*     COMPRESSION CONSTANT FROM THE ID BLOCK OF A GIVEN CHANNEL.
*
*     PARAMETERS
*
*         IDBUF  - CHANNEL ID BLOCK
*                  CHAR*8
*         DMIN   - DATA MINIMUM
*         DMAX   - DATA MAXIMUM
*         CCONST - CHANNEL COMPRESSION CONSTANT
*
*     ENTRY       ID BLOCK GIVEN.
*
*     EXIT        DECODED DATA MINIMUM, MAXIMUM, AND COMPRESSION
*                 CONSTANT RETURNED.
*
*     ERRORS NONE.
*
*     CALLS  NONE.
*

      CHARACTER*8 IDBUF(100)
      CHARACTER*10 CDMIN,CDMAX,ICON

*         EXTRACT MINIMUM, MAXIMUM, AND CONSTANT FROM ID

      CDMIN = IDBUF(12)(1:8)//IDBUF(13)(1:2)
      CDMAX = IDBUF(14)(1:8)//IDBUF(15)(1:2)
      ICON  = IDBUF(16)(1:8)//IDBUF(17)(1:2)

*         CONVERT FROM CHARACTER TO REAL

      READ(CDMIN,'(E10.4)') DMIN
      READ(CDMAX,'(E10.4)') DMAX
      READ(ICON,'(E10.4)') CCONST

      RETURN
      END
```

```
      SUBROUTINE EXPAND(DMIN,IVAL,DVAL,NSIZ,CCONST)

***   EXPAND - EXPAND COMPRESSED DATA VALUES.
*     T. L. P. BUTLER.  08/02/83.

***      EXPAND PERFORMS A REVERSE TRANSFORM ON DATA THAT
*     HAS BEEN COMPRESSED USING *COMPRESS*.  EXPAND WILL
*     PROCESS A BLOCK OF ANY GIVEN SIZE WITHIN THE MEMORY
*     CONSTRAINTS OF THE MACHINE.  THE REAL RESULTS ARE
*     RETURNED IN DVAL.
*
*     THE REVERSE TRANSFORM IS AS FOLLOWS -
*
*         DVAL = (IVAL*COMPRESSION CONSTANT) + DMIN
*
*     PARAMETERS
*
*         DMIN   - DATA SET MINIMUM VALUE
*         IVAL   - INPUT VECTOR OF INTEGER VALUES
*         DVAL   - OUTPUT VECTOR OF REAL VALUES
*         NSIZ   - INPUT VECTOR LENGTH
*         CCONST - COMPRESSION CONSTANT
*
*     ENTRY       DATA MINIMUM, DATA VECTOR, VECTOR LENGTH, AND
*                 COMPRESSION CONSTANT GIVEN.
*
*     EXIT        EXPANDED REAL VALUES RETURNED.
*
*     ERRORS  NONE.
*
*     CALLS   NONE.
*

      DIMENSION DVAL(NSIZ),IVAL(NSIZ)

*         EXPAND DATA BLOCK

      DO 10 I=1,NSIZ

      DVAL(I) = REAL(IVAL(I))*CCONST+DMIN

   10 CONTINUE

      RETURN
      END
```

"FIT - MULTIPLE EVENT VERSION"

```
C
C    THIS PROGRAM IS USED TO DO MULTIPLE LINEAR REGRESSIONS
C    ON THE PSRV DATA CALCULATED FROM THE PSRV CODE AND PROCESSED
C    THE PREPRO CODE.  THE PROGRAM USES ROUTINES FROM THE IMSL
C    MATH LIBRARY.
C
C    THE INPUT DATA IS ON TAPE 96 REGRESSION PARAMETERS ARE OUTPUT
C    ON 'FITOUT'.  THE DATA ARE PLOTTED USING DISSPLA ROUTINES.
C
      INTEGER EVNTNUM(80,1500)
      DIMENSION WEVENT(80,1500),STARNG(80,1500),AMP(80,1500),
     & NBR(6),TEMP(3),XM(3),X(1500,3),Y(1500,3),A(6),
     & ANOVA(14),B(3,7),VARB(3),X1(1500),X2(1500),RS(1500),
     & PV(1500),FP(80)
      CHARACTER*10 FREQ(80)
      CHARACTER*5 SITE
      CHARACTER*8 GAGEOR
C
       OPEN(UNIT=96,FILE='TAPE96',STATUS='OLD')
       OPEN(UNIT=6,FILE='FITOUT',STATUS='NEW')
       OPEN(UNIT=98,FILE='FITCOEF',STATUS='NEW')
       CALL VSTART(0.0,0)
C
C      READ INPUT
C
       READ(96,100) NTOT,SITE,GAGEOR
C
       WRITE(6,800) NTOT,SITE,GAGEOR
C
C      SET UP THE NBR ARRAY FOR THE BECOVM ARRAY
C
       NBR(1) = 3
       NBR(2) = NTOT
       NBR(3) = NTOT
       NBR(4) = 1
       NBR(5) = 1
       NBR(6) = 1
C
C    SET UP FREQUENCY ARRAY FOR SORTING
       FP(1) = 0.1
       DO 1234 I=2,73
       FP(I) = FP(I-1) * 1.1
 1234 CONTINUE

       DO 1000 I=1,73
       READ(96,200) FREQ(I)
       READ(96,300) (EVNTNUM(I,J),WEVENT(I,J),STARNG(I,J),AMP(I,J),
     &             J=1,NTOT)
```

```
       READ(96,300) NDE,DW,DR,DA
 1000 CONTINUE
C
      WRITE(98,3246) SITE
 3246 FORMAT(2X,'SITE IS ',A5)
C
C     FILL THE X ARRAY FOR INPUT INTO BECOVM
C
      DO 2000 I=1,73
      IF(FP(I) .LT. 0.3 .OR. FP(I) .GT. 30.) GO TO 2000

C   SORT OUT FILTERED FREQUENCIES

       DO 2001 M=1,NTOT
       X(M,1) = WEVENT(I,M)
       X(M,2) = STARNG(I,M)
       X(M,3) = AMP(I,M)
 2001 CONTINUE
C      WRITE(6,200) FREQ(I)
C      WRITE(6,400)((X(K,M),K=1,NTOT),M=1,3)
C
C
C     TRANSFORM DATA INTO LOG-LOG SPACE
C
      CALL TOLOG(X,Y,NTOT)
C
C     WRITE (6,400)((Y(K,M),K=1,NTOT),M=1,3)
C     SET UP THE MATRIX OF CORRECTED SUMS OF SQUARES AND
C     CROSS PRODUCTS OF THE INDEPENDENT AND DEPENDENT VARIABLES
C
      CALL BECOVM(Y,1500,NBR,TEMP,XM,A,IERR)
      IF(IERR .NE. 0) GO TO 9998
C      WRITE(6,200) ((A(M),M=1,6))
C
C     DO THE REGRESSION FOR DATA FROM A SINGLE FREQUENCY
C     AT THE 95% CONFIDENCE LEVEL
C
      CALL RLMUL(A,XM,NTOT,2,0.05,ANOVA,B,3,VARB,IER)
C      IF(IER .NE. 0) GO TO 9999
C
C     TRANSFORM REGRESSION COEFFICIENTS TO ARITHMETIC VALUES
C
      CALL FROMLOG(B,ANOVA)
C
C     WRITE REGRESSION INFORMATION FOR THIS FREQUENCY
C     ON THE OUTPUT FILE
C
      CALL OUT(B,ANOVA,FREQ(I))
C
```

```
C     SET UP DATA FOR PLOTTING AND PLOT RESULTS FOR THIS FREQUENCY
C
      CALL SETPLOT(X,B,NTOT,FREQ(I),SITE,GAGEOR)
C      IF(I .EQ. 1) GO TO 999
 2000 CONTINUE
      GO TO 999
 9998 WRITE(6,600) IERR
      GO TO 999
 9999 WRITE(6,700) IER
      GO TO 999

  100  FORMAT(1X,I5,1X,A5,1X,A8)
  200  FORMAT(A10)
  300  FORMAT(I4,3E12.6)
  400  FORMAT(3(3E12.6))
  600  FORMAT(//,2X,'ERROR IN BECOVM',I10)
  700  FORMAT(//,2X,'ERROR IN RLMUL',I10)
  800  FORMAT(2X,'TOTAL NUMBER OF DATA POINTS ANALYZED IN THIS
      &RUN = ',I5,//,2X,'RECORDING SITE GEOLOGY IS ',A5,//,2X,
      &'GAGE ORIENTATION OF THESE DATA IS ',A8,//)
  999  CALL DONEPL
       END
```

```
      SUBROUTINE TOLOG(X,Y,NTOT)
C
C     THIS SUBROUTINE CONVERTS THE INCOMING DATA INTO LOG SPACE
C
      DIMENSION X(1500,3),Y(1500,3)
C
      DO 1000 K=1,NTOT
      Y(K,1) = ALOG10(X(K,1))
      Y(K,2) = ALOG10(X(K,2))
      Y(K,3) = ALOG10(X(K,3))
C      WRITE(6,1243) Y(K,1),Y(K,2),Y(K,3)
C 1243 FORMAT(3(1X,E12.6))
 1000 CONTINUE
      RETURN
      END

      SUBROUTINE FROMLOG(B,ANOVA,VARB)
C
C     THIS SUBROUTINE CONVERTS THE REGRESSION COEFFICIENTS TO ARITHMETIC
C     VALUES
C
      DIMENSION B(3,7),ANOVA(14)

C      DO 1000 I=1,14
C      ANOVA(I) = 10.**(ANOVA(I))
C 1000 CONTINUE
       DO 2001 J=1,7
       B(3,J) = 10.**(B(3,J))
 2001 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE OUT(B,ANOVA,FREQ)
C
C     THIS SUBROUTINE WRITES THE CALCULATED REGRESSION COEFFICIENTS
C     IN A READABLE FORMAT ON THE OUTPUT FILE
C
      DIMENSION B(3,7),ANOVA(14)
      CHARACTER*10 FREQ
      WRITE(6,100) FREQ
      WRITE(6,200)
      WRITE(6,300) (B(I,1),I=1,3)
      EXPO = ABS(B(2,2)*B(1,1)/B(2,1))
      EXPO1 = ABS(B(2,3)*B(1,1)/B(2,1))
      WRITE(98,1100) (B(I,1),I=1,3),EXPO,(B(J,2),J=2,3),
     &                 EXPO1,(B(K,3),K=2,3)
      WRITE(6,400) (B(I,2),I=1,3)
      WRITE(6,500) (B(I,3),I=1,3)
      WRITE(6,600) (B(I,4),I=1,3)
      WRITE(6,700) (B(I,5),I=1,3)
      WRITE(6,800) (B(I,6),I=1,3)
      WRITE(6,900) (B(I,7),I=1,3)
      WRITE(6,1000) (ANOVA(I),I=1,14)

 100  FORMAT(///,2X,'FREQUENCY IS ',2X,A10)
 200  FORMAT(//,2X,'REGRESSION COEFFICIENTS CALCULATED FOR THIS
     & FREQUENCY',//)
 300  FORMAT(2X,'YIELD COEFFICIENT = ',E13.6,//,2X,'RANGE
     &COEFFICIENT = ',E13.6,//,
     &2X,'INTERCEPT = ',E13.6,//)
 400  FORMAT(2X,'LOWER CONFIDENCE LIMITS FOR:',//,2X,
     &'YIELD = ',E13.6,2X,'RANGE = ',E13.6
     &,2X,'INTERCEPT = ',E13.6)
 500  FORMAT(//,2X,'UPPER CONFIDENCE LIMITS FOR:',//,2X
     &,'YIELD = ',E13.6,2X,'RANGE = ',E13.6,2X,
     &'INTERCEPT = ',E13.6)
 600  FORMAT(//,2X,'STANDARD ERROR FOR:',//,2X,
     &'YIELD = ',E13.6,2X,'RANGE = ',E13.6,2X,
     &'INTERCEPT = ',E13.6)
 700  FORMAT(//,2X,'ADJUSTED SUMS OF SQUARES FOR:',//,2X,
     &'YIELD = ',E16.6,2X,'RANGE = ',E13.6,2X,
     &'INTERCEPT = ',E13.6)
 800  FORMAT(//,2X,'PARTIAL F-TEST VALUES FOR:',//,2X,
     &'YIELD = ',E13.6,2X,'RANGE = ',E13.6,2X,
     &'INTERCEPT = ',E13.6)
 900  FORMAT(//,2X,'P(EXCEEDING F UNDER HO)',//,2X,
     &'YIELD = ',E13.6,2X,'RANGE = ',E13.6,
     &2X,'INTERCEPT = ',E13.6)
1000  FORMAT(//,2X,'ANALYSIS OF VARIANCE',//,2X,
     &'DEGREES OF FREEDOM',//2X,'REGRESSION = ',E13.6,2X,
```

```
    &'RESIDUAL = ',E13.6,'CORRECTED TOTAL = ',
    &E13.6,//,'SUMS OF SQUARES',//,2X,
    &'REGRESSION = ',E13.6,2X,'RESIDUAL = '
    &,E13.6,2X,'CORRECTED TOTAL = ',E13.6,//,
    &'MEAN SQUARES',//,2X,'REGRESSION = ',E13.6,2X,
    &'RESIDUAL = ',E13.6,//,'F-VALUE',//,2X,
    &'REGRESSION = ',E13.6,//,'P(EXCEEDING F UNDER HO)',
    &//,2X,'REGRESSION = ',E13.6,//,2X,
    &'PERCENTAGE VARIATION EXPLAINED BY THE ESTIMATED MODEL IS '
    &,E13.6,//,2X,'STANDARD DEVIATION OF THE RESIDUALS
    &IS ',E13.6,//,2X,
    &'RESIDUAL STANDARD DEVIATION AS A % OF THE RESPONSE
    &MEAN IS ',E13.6,//,2X,'NUMBER OF DECIMAL DIGITS
    &OF ACCURACY IN THE
    &REGRESSION COEFFICIENTS IS ',E13.6)
1100 FORMAT(1X,9E13.6)
     RETURN
     END
```

```
      SUBROUTINE SETPLOT(X,B,NTOT,FREQ,SITE,GAGEOR)
C
C     THIS SUBROUTINE SETS UP THE DATA AND REGRESSION INFORMATION
C     FOR PLOTTING
C
      CHARACTER*10 FREQ
      CHARACTER*8 GAGEOR
      DIMENSION X(1500,3),B(3,7),X1(1500),X2(1500),
     & RS(1500),PV(1500),
     & XP(3),YP(3),XL(3),YL(3),XU(3),YU(3)
      DO 2000 K=1,NTOT
      EXPO = ABS(B(1,1)/B(2,1))
      X1(K) = X(K,1)**EXPO
      X2(K) = X(K,2)
      RS(K) = X2(K)/X1(K)
      PV(K) = X(K,3)
 2000 CONTINUE
C      WRITE(6,100) (RS(I),PV(I),I=1,NTOT)
 100  FORMAT(4(2X,F10.5))
C     FIND MAX AND MINS
      XMX = RS(1)
      XMN = RS(1)
      YMX = PV(1)
      YMN = PV(1)
      DO 3000 I=1,NTOT
      XMX = AMAX1(RS(I),XMX)
      YMX = AMAX1(PV(I),YMX)
      XMN = AMIN1(RS(I),XMN)
      YMN = AMIN1(PV(I),YMN)
 3000 CONTINUE
      CALL PREDICT(B,XP,YP,XL,YL,XU,YU)
      CALL PLT(FREQ,RS,PV,XP,YP,XL,YL,XU,YU,NTOT,SITE,
     & XMX,XMN,YMX,YMN,GAGEOR)
      RETURN
      END
```

```
      SUBROUTINE PREDICT(B,XP,YP,XL,YL,XU,YU)
C
C     THIS SUBROUTINE USES THE REGRESSION EQUATION TO PRODUCE THE
C     BEST FIR LINE AND THE UPPER AND LOWER BOUNDS FOR THE PLOT]
C
      DIMENSION B(3,7),XP(3),YP(3),XL(3),YL(3),XU(3),YU(3),R(3)
      R(1) = 10.
      R(2) = 1.0
      R(3) = 100.0
      W =150.
      EXPO1 = ABS(B(1,1)/B(2,1))
      EXPO2 = ABS(B(1,2)/B(2,2))
      EXPO3 = ABS(B(1,3)/B(2,3))
      DO 1000 I=1,3
      XP(I) = R(I) / W**EXPO1
      IF(B(2,2) .EQ. 0.0 .OR. B(2,3) .EQ. 0.0) GO TO 1234
      XL(I) = R(I) * (W**EXPO2 / (W**EXPO1) / (W**EXPO2))
      XU(I) = R(I) * (W**EXPO3 / W**EXPO1 / W**EXPO3)
      YL(I) =  B(3,2) * (XL(I)**B(2,2))
      YU(I) =  B(3,3) * (XU(I)**B(2,3))
 1234 YP(I) =  B(3,1) * (XP(I)**B(2,1))
 1000 CONTINUE

      RETURN
      END
```

```
      SUBROUTINE PLT(FREQ,RS,PV,XP,YP,XL,YL,XU,YU,NTOT
     &,SITE,XMX,XMN,YMX,YMN,GAGEOR)
C
C     THIS SUBROUTINE PLOTS THE DATA AND THE BEST FIT LINE
C     WITH THE UPPER AND LOWER BOUNDS
C
      CHARACTER*8 GAGEOR
      CHARACTER*10 FREQ
      CHARACTER*5 SITE
      CHARACTER*60 MESS
      DATA XSIZE/8.0/
      DATA YSIZE/8.0/
      CALL RESET('ALL')
      CALL NOBRDR
      CALL PAGE(11.0,11.0)
      CALL AREA2D(XSIZE,YSIZE)
      XR = 10.0 ** INT(ALOG10(XMX) +1)
      XLP = 10.0 ** INT(ALOG10(XMN) -1)
      YT = 10.0 ** INT(ALOG10(YMX) +1)
      YB = 10.0 ** INT(ALOG10(YMN) -1)
      XCYCLE = XSIZE / (ALOG10(XR) - ALOG10(XLP))
      YCYCLE = YSIZE / (ALOG10(YT) - ALOG10(YB))
C     WRITE(6,1247)XR,XLP,YT,YB,XCYCLE,YCYCLE
C 1247 FORMAT(//,6(2XF10.5))
      CALL YNAME('PSEUDO RELATIVE VELOCITY - CM/S$',31)
      CALL XNAME('SCALED RANGE - KM&KT UNITS$',26)
      CALL HEADIN(%REF(FREQ),10,1.0,3)
      CALL HEADIN(%REF(SITE),5,1.0,3)
      CALL HEADIN(%REF(GAGEOR),8,1.0,3)
      CALL LOGLOG(XLP,XCYCLE,YB,YCYCLE)
      CALL GRID(1,1)
      CALL CURVE(RS,PV,NTOT,-1)
      CALL CURVE(XP,YP,3,0)
      CALL DASH
      CALL CURVE(XL,YL,3,0)
      CALL CURVE(XU,YU,3,0)
      CALL ENDPL(0)

      RETURN
      END
```

"FIT - SINGLE EVENT VERSION

```
C
C     THIS PROGRAM IS USED TO DO MULTIPLE LINEAR REGRESSIONS
C     ON THE PSRV DATA CALCULATED FROM THE PSRV CODE AND PROCESSED
C     THE PREPRO CODE.  THE PROGRAM USES ROUTINES FROM THE IMSL
C     MATH LIBRARY.  This version is for a single event.
C
C     THE INPUT DATA IS ON TAPE 96 REGRESSION PARAMETERS ARE OUTPUT
C     ON 'FITOUT'.  THE DATA ARE PLOTTED USING DISSPLA ROUTINES.
C
C       INTEGER EVNTNUM(80,1500)
       DIMENSION WEVENT(80,1500),STARNG(80,1500),AMP(80,1500),
     & NBR(6),TEMP(2),XM(2),X(1500,2),Y(1500,2),A(6),
     & ANOVA(14),B(2,7),VARB(3),X1(1500),X2(1500),RS(1500),
     & PV(1500)
       CHARACTER*10 FREQ(80)
       CHARACTER*5 SITE,EVNTNUM(80,1500),ENO
       CHARACTER*8 GAGEOR
C
        OPEN(UNIT=96,FILE='TAPE96',STATUS='OLD')
        OPEN(UNIT=6,FILE='FITOUT',STATUS='NEW')
        OPEN(UNIT=98,FILE='FITCOEF',STATUS='NEW')
        CALL VSTART(0.0,0)
C
C       READ INPUT
C
        READ(96,100) NTOT,SITE,GAGEOR
C
        WRITE(6,800) NTOT,SITE,GAGEOR
C
C       SET UP THE NBR ARRAY FOR THE BECOVM ARRAY
C
        NBR(1) = 2
        NBR(2) = NTOT
        NBR(3) = NTOT
        NBR(4) = 1
        NBR(5) = 1
        NBR(6) = 1
C
        DO 1000 I=1,73
        READ(96,200) FREQ(I)
        READ(96,300) (EVNTNUM(I,J),WEVENT(I,J),STARNG(I,J),AMP(I,J),
     &            J=1,NTOT)
        READ(96,300) NDE,DW,DR,DA
 1000  CONTINUE

       WRITE(98,3245)EVNTNUM(1,1)
```

```
      WRITE(98,3246) SITE
      WRITE(98,3247) GAGEOR
 3247 FORMAT(2X,'GAGE ORIENTATION IS ',A8)
 3246 FORMAT(2X,'SITE IS ',A5)
C
C     FILL THE X ARRAY FOR INPUT INTO BECOVM
C
      DO 2000 I=1,73
       DO 2001 M=1,NTOT
c       X(M,1) = WEVENT(I,M)
       X(M,1) = STARNG(I,M)
       X(M,2) = AMP(I,M)
 2001 CONTINUE
C      WRITE(6,200) FREQ(I)
C       WRITE(6,400)((X(K,M),K=1,NTOT),M=1,3)
C
C
C     TRANSFORM DATA INTO LOG-LOG SPACE
C
      CALL TOLOG(X,Y,NTOT)
C
C     WRITE (6,400)((Y(K,M),K=1,NTOT),M=1,3)
C     SET UP THE MATRIX OF CORRECTED SUMS OF SQUARES AND
C     CROSS PRODUCTS OF THE INDEPENDENT AND DEPENDENT VARIABLES
C
      CALL BECOVM(Y,1500,NBR,TEMP,XM,A,IERR)
      IF(IERR .NE. 0) GO TO 9998
C      WRITE(6,200) ((A(M),M=1,6))
C
C     DO THE REGRESSION FOR DATA FROM A SINGLE FREQUENCY
C
      CALL RLMUL(A,XM,NTOT,1,0.1,ANOVA,B,2,VARB,IER)
C      IF(IER .NE. 0) GO TO 9999
C
C     TRANSFORM REGRESION COEFFICIENTS TO ARITHMETIC VALUES
C
      CALL FROMLOG(B,ANOVA)
C
      WRITE(6,3245) EVNTNUM(1,1)
 3245 FORMAT(//,2X,'EVENT ANLYZED IN THIS RUN IS  ',A4)
C     WRITE REGRESSION INFORMATION FOR THIS FREQUENCY
C     ON THE OUTPUT FILE
C
      CALL OUT(B,ANOVA,FREQ(I))
C
C     SET UP DATA FOR PLOTTING AND PLOT RESULTS FOR THIS FREQUENCY
C
      ENO = EVNTNUM(1,1)
      CALL SETPLOT(X,B,NTOT,FREQ(I),SITE,ENO,GAGEOR)
```

```
C       IF(I .EQ. 1) GO TO 999
 2000 CONTINUE
      GO TO 999
 9998 WRITE(6,600) IERR
      GO TO 999
 9999 WRITE(6,700) IER
      GO TO 999

 100  FORMAT(1X,I5,1X,A5,1X,A8)
 200  FORMAT(A10)
 300  FORMAT(A4,3E12.6)
 400  FORMAT(3(3E12.6))
 600  FORMAT(//,2X,'ERROR IN BECOVM',I10)
 700  FORMAT(//,2X,'ERROR IN RLMUL',I10)
 800  FORMAT(2X,'TOTAL NUMBER OF DATA POINTS ANALYZED IN THIS
     &RUN = ',I5,//,2X,'RECORDING SITE GEOLOGY IS ',A5,//,2X,
     &'GAGE ORIENTATION OF THESE DATA IS ',A8,//)
 999  CALL DONEPL
      END
```

```
      SUBROUTINE TOLOG(X,Y,NTOT)
C
C     THIS SUBROUTINE CONVERTS THE INCOMING DATA INTO LOG SPACE
C
      DIMENSION X(1500,2),Y(1500,2)
C
      DO 1000 K=1,NTOT
      Y(K,1) = ALOG10(X(K,1))
      Y(K,2) = ALOG10(X(K,2))
C      Y(K,3) = ALOG10(X(K,3))
C      WRITE(6,1243) Y(K,1),Y(K,2),Y(K,3)
C 1243 FORMAT(3(1X,E12.6))
 1000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FROMLOG(B,ANOVA,VARB)
C
C     THIS SUBROUTINE CONVERTS THE REGRESSION COEFFICIENTS TO ARITHMETIC
C     VALUES
C
      DIMENSION B(2,7),ANOVA(14)

C      DO 1000 I=1,14
C      ANOVA(I) = 10.**(ANOVA(I))
C 1000 CONTINUE
       DO 2001 J=1,7
       B(2,J) = 10.**(B(2,J))
 2001 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE OUT(B,ANOVA,FREQ)
C
C     THIS SUBROUTINE WRITES THE CALCULATED REGRESSION COEFFICIENTS
C     IN A READABLE FORMAT ON THE OUTPUT FILE
C
      DIMENSION B(2,7),ANOVA(14)
      CHARACTER*10 FREQ
      WRITE(6,100) FREQ
      WRITE(6,200)
      WRITE(6,300) (B(I,1),I=1,2)
      WRITE(98,1100) (B(I,1),I=1,2)
      WRITE(6,400) (B(I,2),I=1,2)
      WRITE(6,500) (B(I,3),I=1,2)
      WRITE(6,600) (B(I,4),I=1,2)
      WRITE(6,700) (B(I,5),I=1,2)
      WRITE(6,800) (B(I,6),I=1,2)
      WRITE(6,900) (B(I,7),I=1,2)
      WRITE(6,1000) (ANOVA(I),I=1,14)

 100  FORMAT(///,2X,'FREQUENCY IS ',2X,A10)
 200  FORMAT(//,2X,'REGRESSION COEFFICIENTS CALCULATED FOR THIS
     & FREQUENCY',//)
 300  FORMAT(2X,'RANGE
     &COEFFICIENT = ',E13.6,//,
     &2X,'INTERCEPT = ',E13.6,//)
 400  FORMAT(2X,'LOWER CONFIDENCE LIMITS FOR:',//,2X,
     &'RANGE = ',E13.6
     &,2X,'INTERCEPT = ',E13.6)
 500  FORMAT(//,2X,'UPPER CONFIDENCE LIMITS FOR:',//,2X
     &,'RANGE = ',E13.6,2X,
     &'INTERCEPT = ',E13.6)
 600  FORMAT(//,2X,'STANDARD ERROR FOR:',//,2X,
     &'RANGE = ',E13.6,2X,
     &'INTERCEPT = ',E13.6)
 700  FORMAT(//,2X,'ADJUSTED SUMS OF SQUARES FOR:',//,2X,
     &'RANGE = ',E13.6,2X,
     &'INTERCEPT = ',E13.6)
 800  FORMAT(//,2X,'PARTIAL F-TEST VALUES FOR:',//,2X,
     &'RANGE = ',E13.6,2X,
     &'INTERCEPT = ',E13.6)
 900  FORMAT(//,2X,'P(EXCEEDING F UNDER HO)',//,2X,
     &'RANGE = ',E13.6,
     &2X,'INTERCEPT = ',E13.6)
1000  FORMAT(//,2X,'ANALYSIS OF VARIANCE',//,2X,
     &'DEGREES OF FREEDOM',//2X,'REGRESSION = ',E13.6,2X,
     &'RESIDUAL = ',E13.6,'CORRECTED TOTAL = ',
     &E13.6,//,'SUMS OF SQUARES',//,2X,
     &'REGRESSION = ',E13.6,2X,'RESIDUAL = '
     &,E13.6,2X,'CORRECTED TOTAL = ',E13.6,//,
```

```
     &'MEAN SQUARES',//,2X,'REGRESSION = ',E13.6,2X,
     &'RESIDUAL = ',E13.6,//,'F-VALUE',//,2X,
     &'REGRESSION = ',E13.6,//,'P(EXCEEDING F UNDER HO)',
     &//,2X,'REGRESSION = ',E13.6,//,2X,
     &'PERCENTAGE VARIATION EXPLAINED BY THE ESTIMATED MODEL IS '
     &,E13.6,//,2X,'STANDARD DEVIATION OF THE RESIDUALS
     &IS ',E13.6,//,2X,
     &'RESIDUAL STANDARD DEVIATION AS A % OF THE RESPONSE
     &MEAN IS ',E13.6,//,2X,'NUMBER OF DECIMAL DIGITS
     &OF ACCURACY IN THE
     &REGRESSION COEFFICIENTS IS ',E13.6)
1100 FORMAT(1X,2E13.6)
      RETURN
      END
```

```
      SUBROUTINE SETPLOT(X,B,NTOT,FREQ,SITE,ENO,GAGEOR)
C
C     THIS SUBROUTINE SETS UP THE DATA AND REGRESSION INFORMATION
C     FOR PLOTTING
C
      CHARACTER*8 GAGEOR
      CHARACTER*10 FREQ
      CHARACTER*5 ENO
      DIMENSION X(1500,2),B(2,7),X1(1500),X2(1500),
     & RS(1500),PV(1500),
     & XP(3),YP(3),XL(3),YL(3),XU(3),YU(3)
      DO 2000 K=1,NTOT
      RS(K) = X(K,1)
      PV(K) = X(K,2)
 2000 CONTINUE
C      WRITE(6,100) (RS(I),PV(I),I=1,NTOT)
 100  FORMAT(4(2X,F10.5))
C     FIND MAX AND MINS
      XMX = RS(1)
      XMN = RS(1)
      YMX = PV(1)
      YMN = PV(1)
      DO 3000 I=1,NTOT
      XMX = AMAX1(RS(I),XMX)
      YMX = AMAX1(PV(I),YMX)
      XMN = AMIN1(RS(I),XMN)
      YMN = AMIN1(PV(I),YMN)
 3000 CONTINUE
      CALL PREDICT(B,XP,YP)
      CALL PLT(FREQ,RS,PV,XP,YP,NTOT,SITE,
     & XMX,XMN,YMX,YMN,ENO,GAGEOR)
      RETURN
      END
```

```
      SUBROUTINE PREDICT(B,XP,YP)
C
C     THIS SUBROUTINE USES THE REGRESSION EQUATION TO PRODUCE THE
C     BEST FIR LINE AND THE UPPER AND LOWER BOUNDS FOR THE PLOT]
C
      DIMENSION B(2,7),XP(3),YP(3),XL(3),YL(3),XU(3),YU(3),R(3)
      R(1) = 10.0
      R(2) = 20.0
      R(3) = 100.0
      W =150.
      DO 1000 I=1,3
      XL(I) = R(I)
      XU(I) = R(I)
      XP(I) = R(I)
      YL(I) = B(2,2) * (R(I)**B(1,2))
      YU(I) = B(2,3) * (R(I)**B(1,3))
 1234 YP(I) = B(2,1) * (R(I)**B(1,1))
 1000 CONTINUE

      RETURN
      END
```

```
      SUBROUTINE PLT(FREQ,RS,PV,XP,YP,NTOT
     &,SITE,XMX,XMN,YMX,YMN,ENO,GAGEOR)
C
C     THIS SUBROUTINE PLOTS THE DATA AND THE BEST FIT LINE
C     WITH THE UPPER AND LOWER BOUNDS
C
      CHARACTER*10 FREQ
      CHARACTER*8 GAGEOR
      CHARACTER*5 SITE,ENO
      CHARACTER*60 MESS
      DATA XSIZE/8.0/
      DATA YSIZE/8.0/
      CALL RESET('ALL')
      CALL NOBRDR
      CALL PAGE(11.0,11.0)
      CALL AREA2D(XSIZE,YSIZE)
      XR = 10.0 ** INT(ALOG10(XMX) +1)
      XLP = 10.0 ** INT(ALOG10(XMN) -1)
      YT = 10.0 ** INT(ALOG10(YMX) +1)
      YB = 10.0 ** INT(ALOG10(YMN) -1)
      XCYCLE = XSIZE / (ALOG10(XR) - ALOG10(XLP))
      YCYCLE = YSIZE / (ALOG10(YT) - ALOG10(YB))
C     WRITE(6,1247)XR,XLP,YT,YB,XCYCLE,YCYCLE
C 1247 FORMAT(//,6(2XF10.5))
      CALL YNAME('PSEUDO RELATIVE VELOCITY - CM/S$',31)
      CALL XNAME('RANGE - km$',10)
      CALL HEADIN(%REF(FREQ),10,1.0,4)
      CALL HEADIN(%REF(SITE),5,1.0,4)
      CALL HEADIN(%REF(ENO),5,1.0,4)
      CALL HEADIN(%REF(GAGEOR),8,1.0,4)
      CALL LOGLOG(XLP,XCYCLE,YB,YCYCLE)
      CALL GRID(1,1)

      CALL CURVE(RS,PV,NTOT,-1)
      CALL CURVE(XP,YP,3,0)
      CALL ENDPL(0)

      RETURN
      END
```

"SORT CODE"

```
C   THIS SORTS THROUGH THE PSRV DATA FILES PRIOR TO
C   USE OF THE 'PREPRO' PROGRAM


      CHARACTER*10 STAMED
      CHARACTER*8 STANUM(70),STATNUM,GAGEOR,ROTANG
      CHARACTER*39 MESS2
      DIMENSION AMP(80)
      INTEGER EVNTNUM

      PRINT*,'ENTER TOTAL NUMBER OF EVENTS'
      READ*, NEVENT
      PRINT*,'DO YOU WISH TO SORT ON STATION MEDIUM? (1=YES)'
      READ*, NA
      IF(NA .EQ. 1) GO TO 100
      PRINT*,'DO YOU WISH TO ELIMINATE SOME STATIONS? (1=YES)'
      READ*, NB
      IF(NB .EQ. 1) GO TO 200
      GO TO 999

 100  OPEN(UNIT=95,FILE='TAPE95',STATUS='OLD')
      OPEN(UNIT=96,FILE='ROCK',STATUS='NEW')
      OPEN(UNIT=97,FILE='ALLU',STATUS='NEW')

      DO 1000 I=1,NEVENT
 30   READ(95,300,END=999) STATNUM,GAGEOR,ROTANG,MESS2
      READ(95,400) STAMED
      READ(95,500) EVNTNUM,STARNG
      IF(EVNTNUM .GT. NEVENT) GO TO 999
      READ(95,600) (AMP(J),J=1,73)
      IF(STAMED .EQ. 'ROCK') GO TO 10
      IF(STAMED .EQ. 'ALLU') GO TO 20
  10  WRITE(96,300) STATNUM,GAGEOR,ROTANG,MESS2
      WRITE(96,400) STAMED
      WRITE(96,500) EVNTNUM,STARNG
      WRITE(96,600) (AMP(J),J=1,73)
      IF(I .EQ. EVNTNUM) GO TO 30
      GO TO 1000
  20  WRITE(97,300) STATNUM,GAGEOR,ROTANG,MESS2
      WRITE(97,400) STAMED
      WRITE(97,500) EVNTNUM,STARNG
      WRITE(97,600) (AMP(J),J=1,73)
      IF(I .EQ. EVNTNUM) GO TO 30
 1000 CONTINUE
      GO TO 999
```

```
200   PRINT*,'HOW MANY STATIONS WILL BE ELIMINATED?'
      READ*,N
      PRINT*,'WHICH STATIONS WILL BE ELIMINATED? (USE APOSTRAPHES)
     & INCLUDE FULL NAME'
      READ*,(STANUM(I),I=1,N)
      OPEN(UNIT=95,FILE='TAPE95',STATUS='OLD')
      OPEN(UNIT=98,FILE='STASORT',STATUS='NEW')

      DO 2000 I=1,NEVENT
40    READ(95,300,END=999)STATNUM,GAGEOR,ROTANG,MESS2
      READ(95,400) STAMED
      READ(95,500) EVNTNUM,STARNG
      IF(EVNTNUM .GT. NEVENT) GO TO 999
      READ(95,600) (AMP(K),K=1,73)
       DO 2001 J=1,N
       IF(STANUM(J) .EQ. STATNUM) GO TO 40
2001   CONTINUE
      WRITE(98,300) STATNUM,GAGEOR,ROTANG,MESS2
      WRITE(98,400) STAMED
      WRITE(98,500) EVNTNUM,STARNG
      WRITE(98,600) (AMP(K),K=1,73)
      IF(I .EQ. EVNTNUM) GO TO 40
2000  CONTINUE
300   FORMAT(1X,A8,2X,A8,2X,A8,1X,A39)
400   FORMAT(1X,A10)
500   FORMAT(I5,E13.6)
600   FORMAT(1X,10E13.6)

999   END
```

"PREPRO CODE"

PREPRO

```
C
C     THIS PROGRAM PREPROCESSES THE OUTPUT FILE FROM PSRV
C     (TAPE95.DAT) FOR INPUT INTO THE REGRESSION CODE.
C     THE INPUT FILE "PPIN" CONTAINS 2 CARDS:
C          CARD 1 HAS THE TOTAL NUMBER OF EVENTS (I5)
C          CARD 2 HAS THE YIELDS OF THE EVENTS (F10.5)

      CHARACTER*5 SITE
      CHARACTER*8 STATNUM,GAGEOR,ROTANG
      CHARACTER*39 MESS2
      DIMENSION WEVENT(50),W(3000),EVNTNUM(3000),STARNG(3000),
     &   AMP(80,3000)
      INTEGER EVNTNUM

      OPEN(UNIT=5,FILE='PPIN',STATUS='OLD')
      OPEN(UNIT=95,FILE='TAPE95',STATUS='OLD')
      OPEN(UNIT=96,FILE='TAPE96',STATUS='NEW')

      READ(5,100) NEVENT,SITE
      READ(5,200) (WEVENT(I),I=1,NEVENT)


      N = 1
      DO 1000 J=1,NEVENT
 10   READ(95,300,END=20)(STATNUM,GAGEOR,ROTANG,MESS2)
      READ(95,400) STAMED
      READ(95,500) EVNTNUM(N),STARNG(N)
      READ(95,600) (AMP(I,N),I=1,73)
      W(N) = WEVENT(J)
      IF(EVNTNUM(N) .EQ. J+1) W(N) = WEVENT(J+1)
      IF(EVNTNUM(N) .EQ. J+2) W(N) = WEVENT(J+2)
      N = N  + 1
      IF(EVNTNUM(N-1) .EQ. J) GO TO 10
 1000 CONTINUE

  20  FREQ = 0.1

        NMO = N-1
        WRITE(96,900) NMO,SITE,GAGEOR

       DO 2000 I=1,73
        WRITE(96,700) FREQ

         DO 3000 J=1,N
         WRITE(96,800) EVNTNUM(J),W(J),STARNG(J),AMP(I,J)
 3000    CONTINUE

        FREQ = 1.1 * FREQ
```

```
2000 CONTINUE

100   FORMAT(I5,1X,A5)
200   FORMAT(5E10.5)
300   FORMAT(1X,A8,2X,A8,2X,A8,1X,A39)
400   FORMAT(1X,A10)
500   FORMAT(I5,E13.6)
600   FORMAT(1X,10E13.6)
700   FORMAT(F10.5)
800   FORMAT(3(I4,3E12.6))
900   FORMAT(1X,I5,1X,A5,1X,A8)
      END
```

"PROGRAM COMPARE"

Program COMPARE

```
C
C  THIS PROGRAM COMPARES PREDICTED AND MEASURED PSRV
C  FROM A SINGLE EVENT.
C
      CHARACTER*10 EVNTNUM
      CHARACTER*10 SITE
      CHARACTER*10 STAMED(50)
      CHARACTER*8 STATNUM(50),GAGEOR,ROTANG,STA(50),STATNO
      CHARACTER*50 MESS2,MESS1,MESS4
      CHARACTER*39 MESS3
      DIMENSION RC(80),R(50),CON(80),AMP(80),PER(80)
     & ,DAT(50,80),STARNG(50),DAMP(80)

      OPEN(UNIT=5,FILE='FITCOEF',STATUS='OLD')
      OPEN(UNIT=7,FILE='DATA',STATUS='OLD')

      CALL VSTART(0.0,0)
      CALL VDESCP(900,0,0)

      READ(5,100)MESS1
      READ(5,100) MESS2
      READ(5,100)MESS4
      READ(5,300) (RC(I),CON(I), I=1,73)
      I = 1
 20   READ(7,400,END=10) STATNUM(I),GAGEOR,ROTANG,MESS3
      READ(7,500) STAMED(I)
      READ(7,600) EVNTNUM,STARNG(I)
      READ(7,700) (DAT(I,J),J=1,73)
      I = I+1
      GO TO 20
 10   NN = I-1
      PRINT*,'THE STATIONS IN THE DATA FILE ARE'
      PRINT*,(STATNUM(I),I=1,NN)
      PRINT*,'HOW MANY RANGES DO YOU WANT TO PREDICT?'
      READ*,N
      PRINT*, 'ENTER RANGES IN km'
      READ*,(R(I), I=1,N)
      PRINT*,'ENTER STATION NAMES IN SAME ORDER AS RANGES'
      READ*,(STA(I),I=1,N)

      DO 1000 J=1,N
      F = 0.1
       DO 2000 I=1,73
       PER(I) = 1. / F
       AMP(I) =  (CON(I) * (R(J)**RC(I)))
       F = F * 1.1
 2000  CONTINUE
```

```
      DO 3000 K=1,NN
      IF(STATNUM(K) .NE. STA(J)) GO TO 3000
       DO 4000 L=1,73
       DAMP(L) =  DAT(K,L)
4000   CONTINUE
3000   CONTINUE
     CALL SCALE(73,PER,AMP,DAMP,.01,10.,YB,YT)
     SITE = STAMED(J)
     STRNG = R(J)
     STATNO = STATNUM(J)
     CALL LGLGLG(DAMPFC,EVNTNUM,GAGEOR,STATNO,0.01,10.,
    &            YB,YT,SITE,STRNG)

     CALL DRWCUR(73,PER,AMP,1)
     CALL DRWCUR(73,PER,DAMP,2)

     CALL ENDPL(-1)

1000 CONTINUE

     CALL DONEPL
     CLOSE(UNIT=5)
     CLOSE(UNIT=7)

100  FORMAT(1X,A50)
300  FORMAT(1X,2E13.6)
400  FORMAT(1X,A8,2X,A8,2X,A8,1X,A39)
500  FORMAT(1X,A10)
600  FORMAT(A5,E13.6)
700  FORMAT(1X,10E13.6)
     END
```

```
      SUBROUTINE SCALE(INDXPER,PERIOD,PSRVAL,DPSRVAL
     &                   ,XL,XR,YB,YT)

***   SCALE - SCALE Y AXIS FOR PLOT.
*     D. L. DOWNS.      08/08/83.

***
*     THIS ROUTINE FINDS THE MAXIMUM PSRV VALUE AND COMPUTES
*     AN APPROPRIATE SCALE FOR THE Y-AXIS.  THE USER SHOULD
*     SUPPLY THE FOLLOWING ARGUMENTS
*
*         INDXPER= NUMBER OF PERIOD-PSRV COORDINATES
*         PERIOD = A 200 ELEMENT ARRAY OF COMPUTED PERIODS
*         PSRVAL = A 200 ELEMENT ARRAY OF PREDICTED PSRV VALUES
*         DPSRVAL = ARRAY OF CALCULATED PSRVs FROM DATA
*         XL      = LEFT-MOST X-COORDINATE
*         XR      = RIGHT-MOST X-COORDINATE
*
*     THE ROUTINE RETURNS THE FOLLOWING
*
*         YB = BOTTOM-MOST Y-COORDINATE
*         YT = TOP-MOST Y-COORDINATE
*
*     X-COORDINATES REPRESENT PERIOD AND Y-COORDINATES REPRESENT
*     PSRV.
*
*

      DIMENSION PERIOD(80),PSRVAL(80),DPSRVAL(80)

*****
*     FIND MAXIMUM PERIOD
*****

      PSRVMX = PSRVAL(1)
      DPSRVMX = DPSRVAL(1)

      DO 10 I=2,INDXPER
      PSRVMX = AMAX1(PSRVAL(I),PSRVMX)
      DPSRVMX = AMAX1(DPSRVAL(I),DPSRVMX)
10    CONTINUE
      PSRVMX = AMAX1(PSRVMX,DPSRVMX)

*****
*     COMPUTE ENDPOINTS
*****

      IF(ALOG10(PSRVMX).GT.0.0) THEN
          YT = 10.0**INT(ALOG10(PSRVMX) + 1)
```

```
ELSE
    YT = 10.0**INT(ALOG10(PSRVMX))
ENDIF
YB = YT / 10000.0

RETURN
END
```

```
      SUBROUTINE DRWCUR(INDXPER,PERIOD,PSRVAL,II)

***   DRWCUR - PLOTS THE CURVE.
*     D. L. DOWNS.      08/08/83.

*****
*     THIS DRAWS THE PSRV CURVE.  USER SHOULD SUPPLY THE
*     COMPUTED PERIOD-PSRV COORDINATES STORED IN THE
*     200 ELEMENT ARRAYS PERIOD AND PSRV, AND THE NUMBER
*     OF COORDINATE PAIRS STORED IN INDXPER.
*****

      DIMENSION PERIOD(80),PSRVAL(80)
      IF(II .EQ. 2) CALL DASH
      IF(II .EQ. 1) CALL RESET('DASH')
      CALL THKCRV(0.02)
      CALL CURVE(PERIOD,PSRVAL,INDXPER,0)
      CALL RESET('THKCUR')

      RETURN
      END
```

```
      SUBROUTINE LGLGLG(DAMPFC,EVNTNAM,
     -                  GAUGEOR,STATNO,
     -                  XL,XR,YB,YT,SITE,STRNG)

***   LGLGLG - CONSTRUCTS A GRID.
*     D. L. DOWNS.      08/08/83.
*     M. L. SANDERS.    09/22/86. NOS/VE VERSION.
*                       REPLACE 'DATE(DAY)' WITH 'DATE()'.

***
*     THIS ROUTINE CONSTRUCTS A LOG-LOG-LOG GRID.  THE USER SHOULD
*     SUPPLY THE FOLLOWING ARGUMENTS
*
*          AMPFAC  = AMPLIFICATION FACTOR STRING
*          DAMPFC  = DAMPING FACTOR
*          BEGTIME = BEGINNING TIME FOR COMPUTATIONS
*          ENDTIME = END TIME FOR COMPUTATIONS
*          EVNTNAM = EVENT NAME STRING
*          FREQUEN = FREQUENCY STRING
*          GAUGEOR = GAUGE ORIENTATION STRING
*          ROTANG  = ROTATION ANGLE STRING
*          STATNUM = STATION NUMBER STRING
*          TRACK   = TRACK STRING
*          XL      = LEFT-MOST X-COORDINATE
*          XR      = RIGHT-MOST X-COORDINATE
*          YB      = BOTTOM-MOST Y-COORDINATE
*          YT      = TOP-MOST Y-COORDINATE
*

      CHARACTER*4 EVNTNUM
      CHARACTER*8 RANGE
      CHARACTER*6 BTIMOUT,ETIMOUT
      CHARACTER*8 AUNITS(8),DUNITS(8)
      CHARACTER*8 AMPFAC,GAUGEOR,ROTANG,STATNO,TIM
      CHARACTER*8 SITE
      CHARACTER*10 EVNTNAM,FREQUEN,TRACK,DAT
      CHARACTER*12 LXNAME
      CHARACTER*25 STRING,MSTRING
      CHARACTER*29 MESS3
      CHARACTER*48 MESS2
      CHARACTER*40 MESS1,MESS1A
      CHARACTER*42 LYNAME


      DATA DUNITS/'.0001CM ','.001CM  ','.01CM   ','.1CM    ',
     -            '1CM     ','10CM    ','100CM   ','1000CM  '/

      LATA AUNITS/'1.E-8G  ','1.E-7G  ','1.E-6G  ','1.E-5G  ',
     -            '1.E-4G  ','1.E-3G  ','1.E-2G  ','1.E-2G  '/
```

```
      DATA LXNAME/'PERIOD - SEC'/,IXNAME/12/,IYNAME/42/

      DATA LYNAME/'PSEUDO RELATIVE RESPONSE VELOCITY - CM/SEC'/

*****
*     XSIZE AND YSIZE GIVE THE SIZE OF THE PLOT REGION IN
*     INCHES.  XSIZE AND YSIZE SHOULD NORMALLY BE IN A RATIO
*     OF 3:4.
*****

      DATA XSIZE/6.0/
      DATA YSIZE/8.0/

*****
*     COMPUTE CYCLE LENGTH
*****

      CYCLE = XSIZE/(ALOG10(XR) - ALOG10(XL))

*****
*     THIS SEGMENT CONSTRUCTS THE BORDER AND THE HORIZONTAL
*     AND VERTICAL GRID LINES.
*****

      CALL PAGE(11,11)
      CALL NOBRDR
      CALL AREA2D(XSIZE,YSIZE)
      CALL XNAME(%REF(LXNAME),IXNAME)
      CALL YNAME(%REF(LYNAME),IYNAME)
      CALL LOGLOG(XL,CYCLE,YB,CYCLE)
      CALL GRID(1,1)

*****
*     THIS SEGMENT CONSTRUCTS THE LEFT DIAGONAL GRID LINES
*     REPRESENTING DISPLACEMENT.
*****

      TWOPI = ATAN(1.0) * 8.0
      CALL DASH

      DO 20 L=1,10

      DO 10 M=1,9
      DISP = YB * FLOAT(M+1) * 10.0 ** (L-4)
      Y1=TWOPI * DISP /XL
      Y2=TWOPI * DISP /XR
      IF(.NOT.(((Y1.GT.YT).AND.(Y2.GT.YT)).OR.
     -         ((Y1.LT.YB).AND.(Y2.LT.YB)))) THEN
```

```
               SLOPE=(ALOG10(Y2)-ALOG10(Y1))/(ALOG10(XR)-ALOG10(XL))
               YINT=ALOG10(Y1)-SLOPE*ALOG10(XL)
               CALL ENDPTS(SLOPE,YINT,ALOG10(XL),ALOG10(XR),
     -            ALOG10(YB),ALOG10(YT),XX1,YY1,XX2,YY2)
               XX1=10.0**XX1
               XX2=10.0**XX2
               YY1=10.0**YY1
               YY2=10.0**YY2
               CALL RLVEC(XX1,YY1,XX2,YY2,0000)
           ENDIF
10         CONTINUE

*****
*          PRINT DISPLACEMENT LABELS
*****

           INDXDIS = INT(ALOG10(YB)) + L + 2
           IF((INDXDIS.GE.1).AND.(INDXDIS.LE.8).AND.
     -        (Y2.GT.YB).AND.(Y2.LT.YT))  THEN
               CALL ANGLE(315)
               CALL HEIGHT(0.1)
               CALL RLMESS(%REF(DUNITS(INDXDIS)),8,1.2*XX2,YY2)
               CALL RESET('ANGLE')
               CALL RESET('HEIGHT')
           ENDIF

20         CONTINUE

           CALL RESET('DASH')

*****
*          THIS SEGMENT CONSTRUCTS THE RIGHT DIAGONAL GRID LINES
*           REPRESENTING ACCELERATION.
*****

           CALL DOT

           DO 40 L=1,10

           DO 30 M=1,9
           ACCEL = YB * FLOAT(M+1) * 980.2368 * 10.0 ** (L-5)
           Y1=ACCEL * XL /TWOPI
           Y2=ACCEL * XR /TWOPI
           IF(.NOT.(((Y1.GT.YT).AND.(Y2.GT.YT)).OR.
     -              ((Y1.LT.YB).AND.(Y2.LT.YB)))) THEN
               SLOPE=(ALOG10(Y2)-ALOG10(Y1))/(ALOG10(XR)-ALOG10(XL))
               YINT=ALOG10(Y1)-SLOPE*ALOG10(XL)
               CALL ENDPTS(SLOPE,YINT,ALOG10(XL),ALOG10(XR),
     -            ALOG10(YB),ALOG10(YT),XX1,YY1,XX2,YY2)
```

```
          XX1=10.0**XX1
          XX2=10.0**XX2
          YY1=10.0**YY1
          YY2=10.0**YY2
          CALL RLVEC(XX1,YY1,XX2,YY2,0000)
      ENDIF
30    CONTINUE

*****
*     PRINT ACCELERATION LABELS
*****

      INDXACC = INT(ALOG10(YB)) + L + 5
      IF((INDXACC.GE.1).AND.(INDXACC.LE.8).AND.
     -   (Y2.GT.YB).AND.(Y2.LT.YT))  THEN
          CALL ANGLE(45)
          CALL HEIGHT(0.1)
          CALL RLMESS(%REF(AUNITS(INDXACC)),8,1.2*XX2,YY2)
          CALL RESET('ANGLE')
          CALL RESET('HEIGHT')
      ENDIF

40    CONTINUE

      CALL RESET('DOT')

*****
*     CONSTRUCT FREQUENCY AXIS
*****

      CALL RLVEC(XL,YT*1.1,XR,YT*1.1,0600)
      START = XR * 10.0
      CALL HEIGHT(0.1)

      DO 60 I=1,3
      START = START / 10.0
      ANUM = 1.0 / START
      CALL RLREAL(ANUM,103,START*0.8,YT*1.3)

      DO 50 J=1,9
      X = START/FLOAT(J)
      CALL RLVEC(X,YT*1.1,X,YT*1.2,0600)
50    CONTINUE

60    CONTINUE

      START = START / 10.0
      ANUM = 1.0 / START
      CALL RLREAL(ANUM,103,START*0.8,YT*1.3)
```

```
      CALL RLVEC(START,YT*1.1,START,YT*1.2,0600)
      CALL RESET('HEIGHT')

*****
*     CONSTRUCT LABELS
*****

      WRITE(RANGE,'(F6.3)')STRNG

      MESS1 = STATNO//'  '//GAUGEOR//'  '//EVNTNAM//'  '//SITE
      MESS2='R = '//RANGE//'PREDICTION (SOLID CURVE)'

      CALL RLMESS(%REF(MESS1),40,XL*2.0,YT*2.5)
      CALL RLMESS(%REF(MESS2),40,XL*2.0,YT*2.0)

      CALL HEIGHT(0.1)
      CALL RLMESS('FREQUENCY - HZ',14,10.5*XL,YT*1.6)
      CALL RLMESS('DAMPING=',8,0.3*XR,YT*1.6)
      CALL RLREAL(DAMPFC,103,0.9*XR,YT*1.6)
      CALL RESET('HEIGHT')

      RETURN
      END
```

```
      SUBROUTINE ENDPTS(SLOPE,YINT,XLEFT,XRIGHT,YBOT,YTOP,
     -                  XX1,YY1,XX2,YY2)

***   ENDPTS - DETERMINE ENDPOINTS FOR THE AXIES.
*     D. L. DOWNS.       08/08/83.
*     M. L. SANDERS.     09/22/86. NOS/VE VERSION.

*****
*     THIS ROUTINE RETURNS THE ENDPOINTS OF A GRAPH WITH X-SCALE
*     FROM "XLEFT" TO "XRIGHT" AND Y-SCALE FROM "YBOT" TO "YTOP".
*     USER MUST SUPPLY THE FOLLOWING ARGUMENTS ON INPUT
*
*         SLOPE = SLOPE OF THE LINE SEGMENT
*         YINT  = Y-INTERCEPT OF THE LINE SEGMENT
*         XLEFT = LEFT-MOST X-COORDINATE
*         XRIGHT = RIGHT-MOST X-COORDINATE
*         YBOT  = BOTTOM-MOST Y-COORDINATE
*         YTOP  = TOP-MOST Y-COORDINATE
*
*     THE ROUTINE RETURNS THE FOLLOWING
*
*         XX1 = X-COORDINATE OF LEFT ENDPOINT
*         YY1 = Y-COORDINATE OF LEFT ENDPOINT
*         XX2 = X-COORDINATE OF RIGHT ENDPOINT
*         XX3 = Y-COORDINATE OF RIGHT ENDPOINT
*
*****

      YY=SLOPE*XLEFT + YINT
      IF(YY.LT.YBOT) THEN
          XX1=(YBOT-YINT)/SLOPE
          YY1=YBOT
      ELSE
          IF(YY.GT.YTOP) THEN
              XX1=(YTOP-YINT)/SLOPE
              YY1=YTOP
          ELSE
              XX1=XLEFT
              YY1=YY
          ENDIF
      ENDIF

      YY=SLOPE*XRIGHT + YINT
      IF(YY.LT.YBOT) THEN
          XX2=(YBOT-YINT)/SLOPE
          YY2=YBOT
      ELSE
          IF(YY.GT.YTOP) THEN
              XX2=(YTOP-YINT)/SLOPE
```

```
          YY2=YTOP
      ELSE
          XX2=XRIGHT
          YY2=YY
      ENDIF
  ENDIF

  RETURN
  END
```

REFERENCES FOR APPENDIX A

Environmental Research Corporation, 1984, Prediction of Ground Motion Characteristics of Underground Nuclear Detonations, NVO-1163-239 (NNA.870406.0100)

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International Mathematical and Statistical Libraries, Inc., 1984, IMSL Library, FORTRAN Subroutines for Mathematics and Statistics, Edition 9.2., Houston, TX (NNA.901127.0196)

Sanders, M. L., 1987, Description of Ground Motion Data Processing Codes, SAND87-1176, Vol. I, Sandia National Laboratories, Albuquerque, NM (NNA.890713.0182)

APPENDIX B: PREDICTION PROCEDURE FOR PSRVs

This appendix contains a description of the automated version of the prediction procedure developed in this study. This description includes a discussion of the logic, information on the individual subroutines used, and instructions for use of the program. Also included is the source code listing. This code is written in FORTRAN 5 and uses Dissplay plot routines (Integrated Software Systems Corp., 1984). The equations used to predict the PSRVs were derived with the following units; distance is in km, yield is in kt, pseudo velocity is in cm/s, acceleration in gs and displacement in cm.

Program PREDICT will perform predictions of surface PSRVs at any location and downhole PSRVs at stations W12/30, W25, W28 or W29. In addition, the prediction may be compared to observed data or to the prediction procedure developed by Lynch (Environmental Research Corporation, 1984 and Lynch, 1969), main body of the report). An overview of the structure of PREDICT is shown in Figure B-1. External files required for the operation of the code are the equation coefficient files (a total of 6) and a data file (if one exists). The coefficient file contains a header and the coefficients in the formats shown. The numerical coefficients in these files were given in Tables 4-1 through 4-6. The data file consists of three lines of header information and the numerical values in the formats shown. The numerical values in this file are pseudo velocity amplitudes only. The associated frequencies are matched to these amplitudes in the logic of the PREDICT code. The final product of a prediction is the PSRV plot.

The major components of the code and a description of their function are listed in Table B-1. Problem setup and calculations are done in the main program. Plotting is set up and done in subroutines SCALE, LGLGLG, DRWCUR and ENDPTS (these routines were taken from the PSRV code). Coefficients and logic necessary to predict the downhole PSRVs are located in subroutine DWNHOLE. The Lynch prediction procedure is implemented in subroutine ERCSPEC.

The logic of the input sequence of the program is shown in Figure B-2. The program runs in an interactive mode. The user is prompted with questions which set up a particular run. Numerical values are input in free format (i.e., no specific format, multiple values separated by commas). Character values are input enclosed in single quotation marks ('). There are two primary options in this code. The first option is prediction. The second option is the comparison of predicted values to observed values. Both options require the same initial definition of site geology and gage orientation. After this information is input, the code asks slightly different questions of the user. These will be summarized below.

```
                                 _______
                                |       |
                                | USER  |
                                |_______|
                                    |
                                    |
                                    |   Interactive Problem
                                    |   Set up and execution
                                    |
 ____________________________   _______   __________________________________________
|                            | |       | |                                          |
|EXTERNAL COEFFICIENT FILES* |_|PREDICT|_|            EXTERNAL DATA FILES           |
|                            | |_______| |               "DATA FILE"                |
|  "VROCK PRED"              |     ↑     | (Line 1 format 1X,A8,2X,A9,2X,A9,1X,A30) |
|  "VALLU PRED"              |     |     | (Line 2 format 1X,A10                  ) |
|  "RROCK PRED"              |     |     | (Line 3 format A5,E13.6                ) |
|  "RALLU PRED"              |     |     |__________________________________________|
|  "TROCK PRED"              |     |
|  "TALLU ROCK"              |     |
| (Line 1 format A50)        |     |
| (Data format 1X,9E13.6)    |     |
|____________________________|     |
                                   |
                                   |
                                   ↓
                                 _______
                                |       |
                                | PSRV  |
                                | PLOT  |
                                |_______|
```

*Coefficient files defined as follows:
    OSSSS PRED
O=ORIENTATION, VERTICAL, RADIAL, TRANSVERSE
SSSS=SITE GEOLOGY, ROCK, ALLUVIUM

Figure B-1. Block Diagram Showing Overall Structure of PREDICT Code

TABLE B.1 Description of the Major Components of the PSRV Prediction Code.

COMPONENT	DESCRIPTION	FUNCTION
PREDICT	MAIN PROGRAM	SETS UP PROBLEM CALCULATES PREDICTED PSRV CALLS ROUTINES FOR LYNCH PROCEDURE & DOWNHOLE FACTORS SETS UP ARRAYS FOR PLOTTING
SCALE	SUBROUTINE	SETS UP SCALES FOR PLOT (from PSRV code)
LGLGLG	SUBROUTINE	SETS UP THE TRIPARTITE PLOT OF PSRV (from PSRV code)
DRWCUR	SUBROUTINE	DRAWS PSRV CURVE ON TRIPARTITE PLOT
ERCSPEC	SUBROUTINE	CONTAINS COEFFICIENTS FOR LYNCH PREDICTION PROCEDURE
DWNHOLE	SUBROUTINE	CONTAINS FACTORS FOR PREDICTION OF DOWNHOLE PSRVs
ENDPTS	SUBROUTINE	DETERMINES ENDPOINTS FOR AXES IN TRIPARTITE PLOT

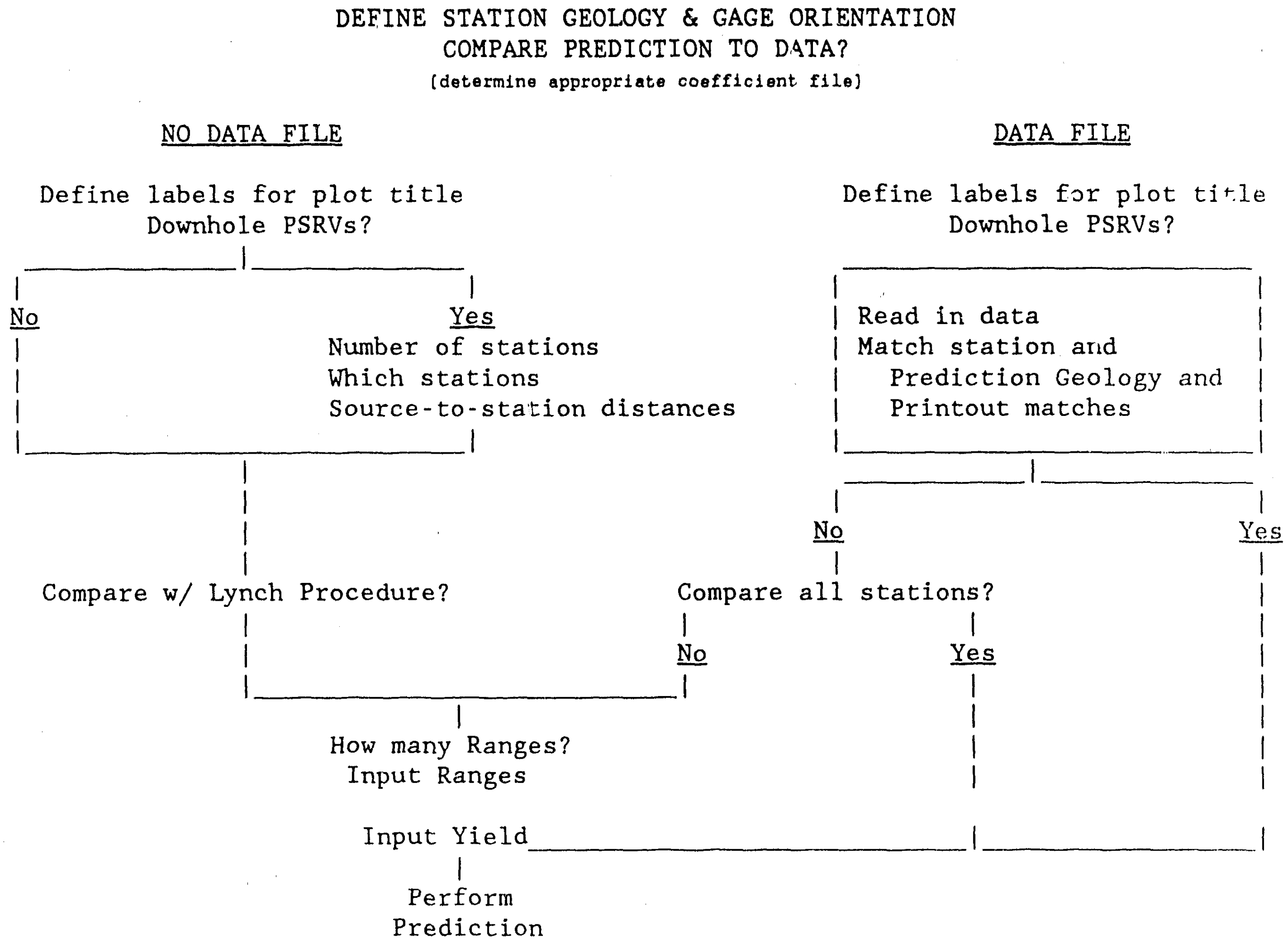

Figure B.2. Input sequence for PSRV prediction code

> Option 1 Prediction: After site geology and gage orientation are selected the user is queried about performing downhole predictions. If downhole predictions are desired, the user must supply the number of downhole stations (4 max.), the station name (W25 BOT, W28 BOT, W29 BOT or W30 BOT) and the source-to-station distance (range in km). The user is given the option to compare the predicted results of this procedure with that of Lynch (ERC). (Note that the Lynch procedure is for surface stations only.) The next parameters the user must specify are the number and the values of range and the yield. If no downhole PSRVs are requested the user is given the option of comparing the current prediction with the Lynch prediction and then must supply the number and value of ranges and the yield.
>
> Option 2 Prediction and Comparison: After site geology and gage orientation are selected the program will search all records in the data file to match the site geology of the station with that specified in the initial setup. The user is then queried about performing downhole predictions. If downhole predictions are desired, the program will ask for the yield (kt) and predict and compare all stations included in the data file. For the prediction of surface PSRVs, the user may compare all data in the file or selected stations. For all stations the user only specifies the yield. For the selected station option, the user must specify the number and value of the ranges and the yield.

The basic instructions for use of this code are summarized above, in the documentation of the source code and through the interactive input sequence. Additional "rules" are summarized here.

- Only one site type and gage orientation is allowed per run.
- Site geology must be specified in this code and in a data file used for comparison as either ROCK or ALLU.
- Gage orientation must be specified as VERT, RAD, or TRANS.
- Pseudo velocities in the data file are assumed to be at the same frequencies as the prediction procedure.
- Downhole predictions can only be made for four stations: W25 BOT, W28 BOT, W29 BOT and W30 BOT. When option 1 is used companion surface PSRVs will also be calculated. For option 2, all data will be compared.

The listing of the source code is given below.

```
      PROGRAM PREDICT
C
C  THIS PROGRAM PROVIDES MEAN AND THE UPPER AND LOWER 95% CONFIDENCE
C  INTERVALS FOR PREDICTED PSRV.
C
      CHARACTER*10 EVNTNUM
      CHARACTER*10 SITE,MESS4
      CHARACTER*10 STAMED(50)
      CHARACTER*8 STATNUM(50),GAGEOR,ROTANG,STA(50),STATNO
     &           ,GAGEORD,SLABEL,DSTA(4),BSTA
      CHARACTER*50 MESS2,MESS1
      CHARACTER*39 MESS3
      DIMENSION RC1(80),R(50),CON1(80),AMP1(80),PER(80),
     &          AMP2(80),AMP3(80),RC2(80),RC3(80),WC1(80)
     &          ,WC2(80),WC3(80),CON2(80),CON3(80),A(80),
     &          AMP4(80),STARNG(20),DAT(20,80),P(40),PSRV(80)
     &          ,ATTEN(50),FD(80),RD(5),RR(50)


      CALL VSTART(0.0,0)
      CALL VDESCP(900,0,0)

      PRINT*, 'IS THE SITE "ROCK" OR "ALLU"?'
      READ*, SITE
      PRINT*, 'IS THIS VERT, RAD OR  TRANS?'
      READ*, GAGEOR

      IF(SITE .EQ. 'ROCK' .AND. GAGEOR .EQ. 'VERT')
     & OPEN(UNIT=5,FILE='VROCKPRED',STATUS='OLD')
      IF(SITE .EQ. 'ALLU' .AND. GAGEOR .EQ. 'VERT')
     & OPEN(UNIT=5,FILE='VALLUPRED',STATUS='OLD')
      IF(SITE .EQ. 'ROCK' .AND. GAGEOR .EQ. 'RAD')
     & OPEN(UNIT=5,FILE='RROCKPRED',STATUS='OLD')
      IF(SITE .EQ. 'ALLU' .AND. GAGEOR .EQ. 'RAD')
     & OPEN(UNIT=5,FILE='RALLUPRED',STATUS='OLD')
      IF(SITE .EQ. 'ROCK' .AND. GAGEOR .EQ. 'TRANS')
     & OPEN(UNIT=5,FILE='TROCKPRED',STATUS='OLD')
      IF(SITE .EQ. 'ALLU' .AND. GAGEOR .EQ. 'TRANS')
     & OPEN(UNIT=5,FILE='TALLUPRED',STATUS='OLD')
C
C   READ IN PREDICTION COEFFICIENTS
C

      READ(5,100) MESS1
      READ(5,300) (WC1(I),RC1(I),CON1(I),WC2(I),RC2(I),CON2(I)
     &             ,WC3(I),RC3(I),CON3(I), I=1,48)

C
      PRINT*, 'IS THERE A DATA FILE TO COMPARE WITH? (YES=1)'
```

```
      READ*, K
      IF(K .NE. 1) THEN
      PRINT*, 'ENTER EVENT - 10 CHAR'
      READ*, MESS4
      PRINT*, 'SECOND PLOT LABEL - 8 CHAR'
      READ*,SLABEL
       PRINT*, 'DO YOU WANT TO PREDICT DOWNHOLE PSRVs? (YES=1)'
       READ*, LJ
        IF(LJ .EQ. 1) THEN
        PRINT*, 'HOW MANY? (4 MAX)'
        READ*, NLJ
        PRINT*,'WHICH STATION(S)? (W25 BOT,W28 BOT,W29 BOT,W30 BOT)'
        READ*,(DSTA(I), I=1,NLJ)
        IR = 1
        DO 3 I=1,NLJ
        STA(IR) = DSTA(I)
        IF(DSTA(I) .EQ. 'W25 BOT') STA(IR+1) = 'W25 TOP'
        IF(DSTA(I) .EQ. 'W28 BOT') STA(IR+1) = 'W28 TOP'
        IF(DSTA(I) .EQ. 'W29 BOT') STA(IR+1) = 'W29 TOP'
        IF(DSTA(I) .EQ. 'W30 BOT') STA(IR+1) = 'W30 TOP'
        IR = IR +1
 3      CONTINUE

        PRINT*,'ENTER RANGES FOR DOWNHOLE STATIONS - km'
        READ*,(RD(I),I=1,NLJ)
        ENDIF
      PRINT*, 'DO YOU WANT TO COMPARE THIS PREDICTION WITH
     & THE ERC PREDICTION (YES=1)'
      READ*,MM
      GO TO 1234
      ENDIF
      PRINT*, 'ENTER DATA TITLE FOR PLOT - 10 CHAR MAX'
      READ*,MESS4
      PRINT*, 'DO YOU WANT TO COMPARE DOWNHOLE PSRVS? (YES=1)'
      PRINT*, 'IF THIS IS A DOWNHOLE RUN ALL STATIONS IN THE
     & DATA FILE WILL BE COMPARED'
      READ*, LJ
C
C   READ IN DATA
C
      I = 1
      OPEN(UNIT=7,FILE='DATAFILE',STATUS='OLD')
 20   READ(7,400,END=10) STATNUM(I),GAGEORD,ROTANG,MESS3
      READ(7,500) STAMED(I)
      READ(7,600)EVNTNUM,STARNG(I)
      READ(7,700) (DAT(I,J),J=1,73)
      I=I+1
      GO TO 20
 10   NN = I-1
```

```
C     SORT THROUGH DATA TO FIND THE MATCHES ON MEDIUM (ROCK OR ALLU)

      JJ = 1
      FD(1) = 0.1
      DO 2222 JJKK=2,73
      FD(JJKK) = 1.1*FD(JJKK-1)
 2222 CONTINUE
      DO 1100 J=1,NN
      IF(STAMED(J) .NE. SITE) GO TO 1100
      STAMED(JJ) = STAMED(J)
      STATNUM(JJ) = STATNUM(J)
      STARNG(JJ) = STARNG(J)
       DO 1200 JK=1,73
       DAT(JJ,JK) = DAT(J,JK)
 1200  CONTINUE
      JJ = JJ + 1
 1100 CONTINUE
      JJJ = JJ -1

      PRINT*, 'THE STATIONS THAT MATCH THE SITE TYPE
     & IN THE DATA FILE ARE...'
      PRINT*,(STATNUM(I),I=1,JJJ)
      PRINT*, 'THE STATION RANGES ARE....'
      PRINT*,(STARNG(I),I=1,JJJ)
      PRINT*, 'DO YOU WANT PREDICTIONS FOR ALL STATIONS (YES=1)'
      READ*,KK
      IF(KK .NE. 1) GO TO 1234
      DO 1111 I=1,JJJ
      STA(I) = STATNUM(I)
 1111 CONTINUE
      GO TO 1235
 1234 IF(LJ .EQ. 1) THEN
      PRINT*,'THIS IS A DOWNHOLE RUN'
      ELSE
      PRINT*,'HOW MANY SURFACE RANGES DO YOU WANT TO PREDICT?'
      READ*,N
      IF(N .EQ. 0) GO TO 1235
      PRINT*, 'ENTER RANGES IN km'
      READ*,(R(I), I=1,N)
      ENDIF
      IF(K .NE. 1) GO TO 1235
      PRINT*,'INPUT STATIONS AS LISTED ABOVE'
      READ*,(STA(I), I=1,N)
 1235 PRINT*, 'WHAT IS THE YIELD (kt)?'
      READ*, W

      IF(KK .EQ. 1) N = JJJ
```

```
      IF(LJ .EQ. 1 .AND. KK .NE. 1) THEN
       N = NLJ*2
       LT = 1
       DO 1 IT=1,NLJ
       R(IT) = RD(LT)
       R(IT+1) = RD(LT)
       LT = LT + 1
 1     CONTINUE
      PRINT*, 'DOWNHOLE STATIONS ARE CALCULATED FIRST'
      PRINT*, 'N = ',N
      PRINT*, (R(I), I=1,N)
      PRINT*,(STA(I),I=1,N)
      ENDIF

      DO 1000 J=1,N
      F = 0.31384

       DO 2000 I=1,48
       IF(KK .EQ. 1) R(J) = STARNG(J)
       PER(I) = 1. / F
       AMP1(I) =  (CON1(I) * (W** WC1(I)) * (R(J)**RC1(I)))
       AMP2(I) =  (CON2(I) * (W** WC2(I)) * (R(J)**RC2(I)))
       AMP3(I) =  (CON3(I) * (W** WC3(I)) * (R(J)**RC3(I)))
       AMP4(I) = 0.0
       F = F * 1.1
2000   CONTINUE

      IF(LJ .EQ. 1 .AND. STA(J) .EQ. 'W25 BOT' .OR.
     &  LJ .EQ. 1 .AND. STA(J) .EQ. 'W28 BOT' .OR.
     &  LJ .EQ. 1 .AND. STA(J) .EQ. 'W29 BOT' .OR.
     &  LJ .EQ. 1 .AND. STA(J) .EQ. 'W30 BOT' .OR.
     &  LJ .EQ. 1 .AND. STA(J) .EQ. 'W12 BOT') THEN
       BSTA = STA(J)
       CALL DWNHOLE(BSTA,ATTEN,GAGEOR)
       PRINT*,(ATTEN(I),I=1,48)
       DO 2001 II=1,48
       AMP1(II) = AMP1(II) * ATTEN(II)
       AMP2(II) = AMP2(II) * ATTEN(II)
       AMP3(II) = AMP3(II) * ATTEN(II)
2001   CONTINUE
      ENDIF

      IF(K .NE. 1) GO TO 1236
      DO 3000 JJ=1,JJJ
      IF(STATNUM(JJ) .NE. STA(J)) GO TO 3000
       IJKL = 1
       DO 4000 L=1,73
       IF(FD(L) .LT. 0.3 .OR. FD(L) .GT. 30.) GO TO 4000
       AMP4(IJKL) = DAT(JJ,L)
```

```
      IJKL = IJKL+1
4000  CONTINUE
3000 CONTINUE
C
C
1236 CALL SCALE(48,PER,AMP1,AMP2,AMP3,AMP4,.01,10.,YB,YT)
     SITE = STAMED(J)
     STRNG = R(J)
     IF(KK .EQ. 1) THEN
      STATNO = STATNUM(J)
     ELSE
      STATNO = STA(J)
     ENDIF
     IF(K .NE. 1) STATNO = SLABEL
     IF(LJ .EQ.1) STATNO = STA(J)
     CALL LGLGLG(DAMPFC,EVNTNUM,GAGEOR,STATNO,0.01,10.,
    &            YB,YT,SITE,STRNG,MESS4)

     CALL DRWCUR(48,PER,AMP1,1)
     CALL DRWCUR(48,PER,AMP2,2)
     CALL DRWCUR(48,PER,AMP3,3)
     IF(MM .EQ. 1) THEN
     R1 = R(J)
     CALL ERCSPC(R1,W)
     ELSE
     CALL DRWCUR(48,PER,AMP4,4)
     ENDIF

     CALL ENDPL(-1)

1000 CONTINUE

     CALL DONEPL
     CLOSE(UNIT=5)
     CLOSE(UNIT=7)

100  FORMAT(1X,A50)
300  FORMAT(1X,9E13.6)
400  FORMAT(1X,A8,2X,A8,2X,A8,1X,A39)
500  FORMAT(1X,A10)
600  FORMAT(A5,E13.6)
700  FORMAT(1X,10E13.6)
     END
```

```
      SUBROUTINE SCALE(INDXPER,PERIOD,PSRVAL1,PSRVAL2
     &                 ,PSRVAL3,PSRVAL4,XL,XR,YB,YT)

***   SCALE - SCALE Y AXIS FOR PLOT.
*     D. L. DOWNS.      08/08/83.

***
*     THIS ROUTINE FINDS THE MAXIMUM PSRV VALUE AND COMPUTES
*     AN APPROPRIATE SCALE FOR THE Y-AXIS.  THE USER SHOULD
*     SUPPLY THE FOLLOWING ARGUMENTS
*
*         INDXPER= NUMBER OF PERIOD-PSRV COORDINATES
*         PERIOD = A 200 ELEMENT ARRAY OF COMPUTED PERIODS
*         PSRVAL = A 200 ELEMENT ARRAY OF PREDICTED PSRV VALUES
*         DPSRVAL = ARRAY OF CALCULATED PSRVs FROM DATA
*         XL      = LEFT-MOST X-COORDINATE
*         XR      = RIGHT-MOST X-COORDINATE
*
*     THE ROUTINE RETURNS THE FOLLOWING
*
*         YB = BOTTOM-MOST Y-COORDINATE
*         YT = TOP-MOST Y-COORDINATE
*
*     X-COORDINATES REPRESENT PERIOD AND Y-COORDINATES REPRESENT
*     PSRV.
*
*

      DIMENSION PERIOD(80),PSRVAL1(80),PSRVAL2(80),PSRVAL3(80),
     & PSRVAL4(80)

*****
*     FIND MAXIMUM PERIOD
*****

      PSRVMX1 = PSRVAL1(1)
      PSRVMX2 = PSRVAL2(1)
      PSRVMX3 = PSRVAL3(I)
      PSRVMX4 = PSRVAL4(I)

      DO 10 I=2,INDXPER
      PSRVMX1 = AMAX1(PSRVAL1(I),PSRVMX1)
      PSRVMX2 = AMAX1(PSRVAL2(I),PSRVMX2)
      PSRVMX3 = AMAX1(PSRVAL3(I),PSRVMX3)
      PSRVMX4 = AMAX1(PSRVAL4(I),PSRVMX4)
 10   CONTINUE
      PSRVMX = AMAX1(PSRVMX1,PSRVMX2)
      PSRVMX = AMAX1(PSRVMX3,PSRVMX)
      PSRVMX = AMAX1(PSRVMX4,PSRVMX)
```

```
*****
*     COMPUTE ENDPOINTS
*****

      IF(ALOG10(PSRVMX).GT.0.0) THEN
          YT = 10.0**INT(ALOG10(PSRVMX) + 1)
      ELSE
          YT = 10.0**INT(ALOG10(PSRVMX))
      ENDIF
      YB = YT / 10000.0

      RETURN
      END
```

```
      SUBROUTINE DRWCUR(INDXPER,PERIOD,PSRVAL,II)

***   DRWCUR - PLOTS THE CURVE.
*     D. L. DOWNS.      08/08/83.

*****
*     THIS DRAWS THE PSRV CURVE.  USER SHOULD SUPPLY THE
*     COMPUTED PERIOD-PSRV COORDINATES STORED IN THE
*     200 ELEMENT ARRAYS PERIOD AND PSRV, AND THE NUMBER
*     OF COORDINATE PAIRS STORED IN INDXPER.
*****

      DIMENSION PERIOD(80),PSRVAL(80)
      IF(II .EQ. 4) CALL CHNDSH
      IF(II .EQ. 3) CALL DASH
      IF(II .EQ. 2) CALL DASH
      IF(II .EQ. 1) CALL RESET('CHNDSH')
      CALL THKCRV(0.02)
      CALL CURVE(PERIOD,PSRVAL,INDXPER,0)
      CALL RESET('THKCUR')

      RETURN
      END
```

```
      SUBROUTINE LGLGLG(DAMPFC,EVNTNAM,
     -                  GAUGEOR,STATNO,
     -                  XL,XR,YB,YT,SITE,STRNG,MESS4)

***   LGLGLG - CONSTRUCTS A GRID.
*     D. L. DOWNS.      08/08/83.
*     M. L. SANDERS.    09/22/86. NOS/VE VERSION.
*                       REPLACE 'DATE(DAY)' WITH 'DATE()'.

***
*     THIS ROUTINE CONSTRUCTS A LOG-LOG-LOG GRID.  THE USER SHOULD
*     SUPPLY THE FOLLOWING ARGUMENTS
*
*          AMPFAC  = AMPLIFICATION FACTOR STRING
*          DAMPFC  = DAMPING FACTOR
*          BEGTIME = BEGINNING TIME FOR COMPUTATIONS
*          ENDTIME = END TIME FOR COMPUTATIONS
*          EVNTNAM = EVENT NAME STRING
*          FREQUEN = FREQUENCY STRING
*          GAUGEOR = GAUGE ORIENTATION STRING
*          ROTANG  = ROTATION ANGLE STRING
*          STATNUM = STATION NUMBER STRING
*          TRACK   = TRACK STRING
*          XL      = LEFT-MOST X-COORDINATE
*          XR      = RIGHT-MOST X-COORDINATE
*          YB      = BOTTOM-MOST Y-COORDINATE
*          YT      = TOP-MOST Y-COORDINATE
*

      CHARACTER*4 EVNTNUM
      CHARACTER*8 RANGE
      CHARACTER*6 BTIMOUT,ETIMOUT
      CHARACTER*8 AUNITS(8),DUNITS(8)
      CHARACTER*8 AMPFAC,GAUGEOR,ROTANG,STATNO,TIM
      CHARACTER*8 SITE
      CHARACTER*10 EVNTNAM,FREQUEN,TRACK,DAT,MESS4
      CHARACTER*12 LXNAME
      CHARACTER*25 STRING,MSTRING
      CHARACTER*29 MESS3
      CHARACTER*50 MESS2
      CHARACTER*49 MESS1,MESS1A
      CHARACTER*42 LYNAME


      DATA DUNITS/'.0001CM ','.001CM  ','.01CM   ','.1CM    ',
     -            '1CM     ','10CM    ','100CM   ','1000CM  '/

      DATA AUNITS/'1.E-8G  ','1.E-7G  ','1.E-6G  ','1.E-5G  ',
     -            '1.E-4G  ','1.E-3G  ','1.E-2G  ','1.E-2G  '/
```

```
      DATA LXNAME/'PERIOD - SEC'/,IXNAME/12/,IYNAME/42/

      DATA LYNAME/'PSEUDO RELATIVE RESPONSE VELOCITY - CM/SEC'/

*****
*     XSIZE AND YSIZE GIVE THE SIZE OF THE PLOT REGION IN
*     INCHES.  XSIZE AND YSIZE SHOULD NORMALLY BE IN A RATIO
*     OF 3:4.
*****

      DATA XSIZE/6.0/
      DATA YSIZE/8.0/

*****
*     COMPUTE CYCLE LENGTH
*****

      CYCLE = XSIZE/(ALOG10(XR) - ALOG10(XL))

*****
*     THIS SEGMENT CONSTRUCTS THE BORDER AND THE HORIZONTAL
*     AND VERTICAL GRID LINES.
*****

      CALL PAGE(11,11)
      CALL NOBRDR
      CALL AREA2D(XSIZE,YSIZE)
      CALL XNAME(%REF(LXNAME),IXNAME)
      CALL YNAME(%REF(LYNAME),IYNAME)
      CALL LOGLOG(XL,CYCLE,YB,CYCLE)
      CALL GRID(1,1)

*****
*     THIS SEGMENT CONSTRUCTS THE LEFT DIAGONAL GRID LINES
*     REPRESENTING DISPLACEMENT.
*****

      TWOPI = ATAN(1.0) * 8.0
      CALL DASH

      DO 20 L=1,10

      DO 10 M=1,9
      DISP = YB * FLOAT(M+1) * 10.0 ** (L-4)
      Y1=TWOPI * DISP /XL
      Y2=TWOPI * DISP /XR
      IF(.NOT.(((Y1.GT.YT).AND.(Y2.GT.YT)).OR.
     -         ((Y1.LT.YB).AND.(Y2.LT.YB)))) THEN
```

```
             SLOPE=(ALOG10(Y2)-ALOG10(Y1))/(ALOG10(XR)-ALOG10(XL))
             YINT=ALOG10(Y1)-SLOPE*ALOG10(XL)
             CALL ENDPTS(SLOPE,YINT,ALOG10(XL),ALOG10(XR),
     -          ALOG10(YB),ALOG10(YT),XX1,YY1,XX2,YY2)
             XX1=10.0**XX1
             XX2=10.0**XX2
             YY1=10.0**YY1
             YY2=10.0**YY2
             CALL RLVEC(XX1,YY1,XX2,YY2,0000)
       ENDIF
10     CONTINUE

*****
*      PRINT DISPLACEMENT LABELS
*****

       INDXDIS = INT(ALOG10(YB)) + L + 2
       IF((INDXDIS.GE.1).AND.(INDXDIS.LE.8).AND.
     -    (Y2.GT.YB).AND.(Y2.LT.YT))  THEN
             CALL ANGLE(315)
             CALL HEIGHT(0.1)
             CALL RLMESS(%REF(DUNITS(INDXDIS)),8,1.2*XX2,YY2)
             CALL RESET('ANGLE')
             CALL RESET('HEIGHT')
       ENDIF

20     CONTINUE

       CALL RESET('DASH')

*****
*      THIS SEGMENT CONSTRUCTS THE RIGHT DIAGONAL GRID LINES
*       REPRESENTING ACCELERATION.
*****

       CALL DOT

       DO 40 L=1,10

       DO 30 M=1,9
       ACCEL = YB * FLOAT(M+1) * 980.2368 * 10.0 ** (L-5)
       Y1=ACCEL * XL /TWOPI
       Y2=ACCEL * XR /TWOPI
       IF(.NOT.(((Y1.GT.YT).AND.(Y2.GT.YT)).OR.
     -          ((Y1.LT.YB).AND.(Y2.LT.YB)))) THEN
             SLOPE=(ALOG10(Y2)-ALOG10(Y1))/(ALOG10(XR)-ALOG10(XL))
             YINT=ALOG10(Y1)-SLOPE*ALOG10(XL)
             CALL ENDPTS(SLOPE,YINT,ALOG10(XL),ALOG10(XR),
     -          ALOG10(YB),ALOG10(YT),XX1,YY1,XX2,YY2)
```

```
         XX1=10.0**XX1
         XX2=10.0**XX2
         YY1=10.0**YY1
         YY2=10.0**YY2
         CALL RLVEC(XX1,YY1,XX2,YY2,0000)
      ENDIF
30    CONTINUE

*****
*     PRINT ACCELERATION LABELS
*****

      INDXACC = INT(ALOG10(YB)) + L + 5
      IF((INDXACC.GE.1).AND.(INDXACC.LE.8).AND.
     -   (Y2.GT.YB).AND.(Y2.LT.YT))  THEN
         CALL ANGLE(45)
         CALL HEIGHT(0.1)
         CALL RLMESS(%REF(AUNITS(INDXACC)),8,1.2*XX2,YY2)
         CALL RESET('ANGLE')
         CALL RESET('HEIGHT')
      ENDIF

40    CONTINUE

      CALL RESET('DOT')

*****
*     CONSTRUCT FREQUENCY AXIS
*****

      CALL RLVEC(XL,YT*1.1,XR,YT*1.1,0600)
      START = XR * 10.0
      CALL HEIGHT(0.1)

      DO 60 I=1,3
      START = START / 10.0
      ANUM = 1.0 / START
      CALL RLREAL(ANUM,103,START*0.8,YT*1.3)

      DO 50 J=1,9
      X = START/FLOAT(J)
      CALL RLVEC(X,YT*1.1,X,YT*1.2,0600)
50    CONTINUE

60    CONTINUE

      START = START / 10.0
      ANUM = 1.0 / START
      CALL RLREAL(ANUM,103,START*0.8,YT*1.3)
```

```
      CALL RLVEC(START,YT*1.1,START,YT*1.2,0600)
      CALL RESET('HEIGHT')

*****
*     CONSTRUCT LABELS
*****

      WRITE(RANGE,'(F6.3)')STRNG

      MESS1 ='PREDICTED MEAN & 95% BOUNDS'//' '//GAUGEOR
     &//' '//'R = '//RANGE
      MESS2=STATNO//' '//MESS4//' '//'DATA=CHNDSH PRED=SOLID'

      CALL RLMESS(%REF(MESS1),49,XL*2.0,YT*2.5)
      CALL RLMESS(%REF(MESS2),49,XL*2.0,YT*2.0)

      DAMPFC = 0.05

      CALL HEIGHT(0.1)
      CALL RLMESS('FREQUENCY - HZ',14,10.5*XL,YT*1.6)
      CALL RLMESS('DAMPING=',8,0.3*XR,YT*1.6)
      CALL RLREAL(DAMPFC,103,0.9*XR,YT*1.6)
      CALL RESET('HEIGHT')

      RETURN
      END
```

```
      SUBROUTINE ENDPTS(SLOPE,YINT,XLEFT,XRIGHT,YBOT,YTOP,
     -                  XX1,YY1,XX2,YY2)

***   ENDPTS - DETERMINE ENDPOINTS FOR THE AXIES.
*     D. L. DOWNS.       08/08/83.
*     M. L. SANDERS.     09/22/86. NOS/VE VERSION.

*****
*     THIS ROUTINE RETURNS THE ENDPOINTS OF A GRAPH WITH X-SCALE
*     FROM "XLEFT" TO "XRIGHT" AND Y-SCALE FROM "YBOT" TO "YTOP".
*     USER MUST SUPPLY THE FOLLOWING ARGUMENTS ON INPUT
*
*         SLOPE = SLOPE OF THE LINE SEGMENT
*         YINT  = Y-INTERCEPT OF THE LINE SEGMENT
*         XLEFT = LEFT-MOST X-COORDINATE
*         XRIGHT = RIGHT-MOST X-COORDINATE
*         YBOT  = BOTTOM-MOST Y-COORDINATE
*         YTOP  = TOP-MOST Y-COORDINATE
*
*     THE ROUTINE RETURNS THE FOLLOWING
*
*         XX1 = X-COORDINATE OF LEFT ENDPOINT
*         YY1 = Y-COORDINATE OF LEFT ENDPOINT
*         XX2 = X-COORDINATE OF RIGHT ENDPOINT
*         XX3 = Y-COORDINATE OF RIGHT ENDPOINT
*
*****

      YY=SLOPE*XLEFT + YINT
      IF(YY.LT.YBOT) THEN
          XX1=(YBOT-YINT)/SLOPE
          YY1=YBOT
      ELSE
          IF(YY.GT.YTOP) THEN
              XX1=(YTOP-YINT)/SLOPE
              YY1=YTOP
          ELSE
              XX1=XLEFT
              YY1=YY
          ENDIF
      ENDIF

      YY=SLOPE*XRIGHT + YINT
      IF(YY.LT.YBOT) THEN
          XX2=(YBOT-YINT)/SLOPE
          YY2=YBOT
      ELSE
          IF(YY.GT.YTOP) THEN
              XX2=(YTOP-YINT)/SLOPE
```

```
            YY2=YTOP
        ELSE
            XX2=XRIGHT
            YY2=YY
        ENDIF
    ENDIF

    RETURN
    END
```

```
      SUBROUTINE ERCSPC(R,W)
      DIMENSION PSRV(40),F(40),A(40),B1(40),B2(40),PSRV2(40)
     & ,PS1(40),PS2(40),P(40)
      DATA (P(I),I=1,40) /2.469,2.234,2.022,1.829,1.655, 1.498,1.355,
     &             1.226,1.110,1.004,.908,.822,.744,.673,.609,
     &             .551,.499,.451,.408,.369,.334,.302,.274,.248,
     &             .224,.203,.183,.166,.150,.136,.123,.111,.101,
     &             .091,.082,.075,.067,.061,.055,.05/
      DATA (A(I),I=1,40) /2.4,2.37,2.35,1.96,1.59,1.61,1.66,1.56,1.83,
     &             2.08,1.72,1.59,2.02,2.76,2.93,2.96,3.63,6.4,
     &             7.15,6.82,8.65,11.3,11.0,12.1,12.1,16.7,20.1,
     &             20.6,24.8,21.8,18.9,15.3,12.9,11.8,10.8,8.87,
     &             6.76,5.0,3.69,2.69/
      DATA (B1(I),I=1,40)
/.699,.701,.719,.732,.749,.753,.775,.771,.748,
     &              .732,.713,.698,.665,.645,.636,.632,
     &              .601,.583,.572,.555,.528,.508,.504,.509,.498,
     &              .480,.479,.478,.466,.468,.480,.480,.475,.468,
     &              .457,.463,.474,.483,.479,.491/
      DATA (B2(I),I=1,40) /1.137,1.165,1.181,1.168,1.143,1.145,1.160,
     &              1.129,1.128,1.133,1.083,1.06,1.085,1.121,
     &              1.134,1.134,1.15,1.255,1.276,1.263,1.303,
     &              1.342,1.354,1.395,1.399,1.469,1.533,1.555,
     &              1.597,1.591,1.6,1.582,1.558,1.546,1.533,1.515,
     &              1.486,1.447,1.395,1.340/

C
      DO 2000 I=1,40
      PSRV(I) = A(I) * (W ** B1(I))/(R ** B2(I))
 2000 CONTINUE
      CALL DRWCUR(40,P,PSRV,4)
      RETURN
      END
```

```
      SUBROUTINE DWNHOLE(BSTA,ATTEN,GAGEOR)
      CHARACTER*7 BSTA
      CHARACTER*8 GAGEOR
      DIMENSION ATTEN(50),W25AV(50),W25AR(50),W25AT(50),
     & W28AV(50),W28AR(50),W28AT(50),W29AV(50),W29AR(50),
     & W29AT(50),W30AV(50),W30AR(50),W30AT(50)
C
      IF(BSTA .EQ. 'W12 BOT') BSTA = 'W30 BOT'
      DATA(W25AV(I),I=1,48)/
     &     0.970567E+00,0.960824E+00,0.945569E+00,0.945425E+00,
     &     0.944986E+00,0.903739E+00,0.887707E+00,0.874417E+00,
     &     0.857737E+00,0.837766E+00,0.710168E+00,0.634193E+00,
     &     0.625966E+00,0.600751E+00,0.545759E+00,0.525724E+00,
     &     0.470580E+00,0.384996E+00,0.349719E+00,0.264270E+00,
     &     0.258319E+00,0.242990E+00,0.318943E+00,0.379295E+00,
     &     0.297380E+00,0.274413E+00,0.252245E+00,0.230439E+00,
     &     0.227730E+00,0.253176E+00,0.265805E+00,0.269940E+00,
     &     0.262102E+00,0.212969E+00,0.239881E+00,0.207327E+00,
     &     0.171684E+00,0.191047E+00,0.197395E+00,0.196530E+00,
     &     0.219242E+00,0.256933E+00,0.260930E+00,0.245302E+00,
     &     0.243563E+00,0.262231E+00,0.264770E+00,0.253581E+00/
C
      DATA(W25AR(I),I=1,48)/
     &     0.578958E+00,0.552678E+00,0.532745E+00,0.501293E+00,
     &     0.523746E+00,0.488556E+00,0.480587E+00,0.443011E+0C,
     &     0.484371E+00,0.465867E+00,0.447501E+00,0.433176E+00,
     &     0.416712E+00,0.405892E+00,0.377199E+00,0.327074E+00,
     &     0.349744E+00,0.365981E+00,0.365435E+00,0.408336E+00,
     &     0.339859E+00,0.237408E+00,0.205437E+00,0.238376E+00,
     &     0.183174E+00,0.190448E+00,0.271784E+00,0.337991E+00,
     &     0.344358E+00,0.274489E+00,0.224670E+00,0.238821E+00,
     &     0.233388E+00,0.258609E+00,0.237790E+00,0.254756E+00,
     &     0.246286E+00,0.225383E+00,0.202474E+00,0.199485E+00,
     &     0.223920E+00,0.266708E+00,0.277060E+00,0.295165E+00,
     &     0.314260E+00,0.277957E+00,0.275779E+00,0.287460E+00/
C
      DATA(W25AT(I),I=1,48)/
     &     0.841200E+00,0.797211E+00,0.709862E+00,0.682900E+00,
     &     0.682307E+00,0.640752E+00,0.617915E+00,0.609621E+00,
     &     0.572745E+00,0.552284E+00,0.461146E+00,0.463189E+00,
     &     0.453180E+00,0.445168E+00,0.366134E+00,0.346819E+00,
     &     0.336124E+00,0.267981E+00,0.234584E+00,0.187535E+00,
     &     0.189875E+00,0.201060E+00,0.207088E+00,0.151977E+00,
     &     0.117969E+00,0.145182E+00,0.149868E+00,0.156480E+00,
     &     0.147538E+00,0.117723E+00,0.141921E+00,0.154823E+00,
     &     0.139773E+00,0.142506E+00,0.129043E+00,0.140466E+00,
     &     0.144874E+00,0.126004E+00,0.133236E+00,0.127862E+00,
     &     0.137864E+00,0.154282E+00,0.144010E+00,0.140415E+00,
     &     0.136960E+00,0.135715E+00,0.147196E+00,0.144700E+00/
```

```
C
      DATA(W28AV(I),I=1,48)/
     &     0.953635E+00,0.979526E+00,0.983161E+00,0.974596E+00,
     &     0.956554E+00,0.929370E+00,0.926742E+00,0.907257E+00,
     &     0.861580E+00,0.836409E+00,0.677089E+00,0.524683E+00,
     &     0.449306E+00,0.408921E+00,0.357179E+00,0.338688E+00,
     &     0.318453E+00,0.330129E+00,0.225081E+00,0.226781E+00,
     &     0.299166E+00,0.367627E+00,0.435495E+00,0.513578E+00,
     &     0.611466E+00,0.526239E+00,0.402578E+00,0.360592E+00,
     &     0.354383E+00,0.403484E+00,0.436239E+00,0.451416E+00,
     &     0.459308E+00,0.485772E+00,0.464921E+00,0.398975E+00,
     &     0.441412E+00,0.473047E+00,0.542267E+00,0.482713E+00,
     &     0.454260E+00,0.397177E+00,0.427011E+00,0.532096E+00,
     &     0.565205E+00,0.573599E+00,0.541258E+00,0.504431E+00/
C
      DATA(W28AR(I),I=1,48)/
     &     0.520294E+00,0.493108E+00,0.493753E+00,0.464274E+00,
     &     0.413465E+00,0.389040E+00,0.375082E+00,0.347076E+00,
     &     0.371629E+00,0.341044E+00,0.341463E+00,0.300372E+00,
     &     0.259999E+00,0.224639E+00,0.212005E+00,0.250512E+00,
     &     0.213939E+00,0.196787E+00,0.205634E+00,0.311474E+00,
     &     0.344947E+00,0.370879E+00,0.380389E+00,0.383036E+00,
     &     0.367204E+00,0.440095E+00,0.515028E+00,0.478338E+00,
     &     0.469065E+00,0.550498E+00,0.642565E+00,0.694572E+00,
     &     0.793217E+00,0.840552E+00,0.855157E+00,0.929928E+00,
     &     0.118723E+01,0.119309E+01,0.926757E+00,0.100847E+01,
     &     0.964298E+00,0.117589E+01,0.129047E+01,0.144589E+01,
     &     0.154224E+01,0.142847E+01,0.132334E+01,0.118989E+01/
C
      DATA(W28AT(I),I=1,48)/
     &     0.711397E+00,0.705380E+00,0.641150E+00,0.633919E+00,
     &     0.612209E+00,0.561351E+00,0.490153E+00,0.442463E+00,
     &     0.396635E+00,0.386022E+00,0.277439E+00,0.281024E+00,
     &     0.319224E+00,0.230946E+00,0.232735E+00,0.359227E+00,
     &     0.327523E+00,0.313307E+00,0.367728E+00,0.403873E+00,
     &     0.473644E+00,0.461424E+00,0.372308E+00,0.471681E+00,
     &     0.436874E+00,0.422887E+00,0.393318E+00,0.408078E+00,
     &     0.417166E+00,0.553674E+00,0.702274E+00,0.670986E+00,
     &     0.703024E+00,0.733563E+00,0.109615E+01,0.152374E+01,
     &     0.175071E+01,0.188512E+01,0.215224E+01,0.192024E+01,
     &     0.191774E+01,0.159596E+01,0.156515E+01,0.137213E+01,
     &     0.128711E+01,0.127989E+01,0.118481E+01,0.121962E+01/
C
      DATA(W29AV(I),I=1,48)/
     &     0.975708E+00,0.975713E+00,0.977065E+00,0.976542E+00,
     &     0.973667E+00,0.972819E+00,0.971512E+00,0.971852E+00,
     &     0.964950E+00,0.950302E+00,0.916410E+00,0.901446E+00,
     &     0.889094E+00,0.891489E+00,0.862972E+00,0.864119E+00,
     &     0.853554E+00,0.847847E+00,0.807703E+00,0.743013E+00,
```

```
     &     0.722925E+00,0.695989E+00,0.645274E+00,0.618070E+00,
     &     0.565571E+00,0.497885E+00,0.449492E+00,0.447024E+00,
     &     0.438475E+00,0.580582E+00,0.594544E+00,0.570746E+00,
     &     0.596985E+00,0.693954E+00,0.671136E+00,0.614244E+00,
     &     0.515101E+00,0.429068E+00,0.496387E+00,0.512047E+00,
     &     0.526410E+00,0.538661E+00,0.584358E+00,0.576124E+00,
     &     0.539566E+00,0.520360E+00,0.536965E+00,0.508113E+00/
C
      DATA(W29AR(I),I=1,48)/
     &     0.569109E+00,0.622223E+00,0.688831E+00,0.787537E+00,
     &     0.831283E+00,0.791687E+00,0.748767E+00,0.772632E+00,
     &     0.786767E+00,0.697187E+00,0.673883E+00,0.698627E+00,
     &     0.719188E+00,0.745758E+00,0.737806E+00,0.717541E+00,
     &     0.683800E+00,0.620734E+00,0.585671E+00,0.623933E+00,
     &     0.521103E+00,0.495367E+00,0.444456E+00,0.377600E+00,
     &     0.381005E+00,0.347815E+00,0.408729E+00,0.462994E+00,
     &     0.410196E+00,0.538749E+00,0.550721E+00,0.537081E+00,
     &     0.592866E+00,0.558007E+00,0.516183E+00,0.489872E+00,
     &     0.489926E+00,0.475001E+00,0.519812E+00,0.445382E+00,
     &     0.450921E+00,0.468590E+00,0.491383E+00,0.529355E+00,
     &     0.583605E+00,0.563129E+00,0.530960E+00,0.520530E+00/
C
```

```
      DATA(W29AR(I),I=1,48)/
     &     0.569109E+00,0.622223E+00,0.688831E+00,0.787537E+00,
     &     0.831283E+00,0.791687E+00,0.748767E+00,0.772632E+00,
     &     0.786767E+00,0.697187E+00,0.673883E+00,0.698627E+00,
     &     0.719188E+00,0.745758E+00,0.737806E+00,0.717541E+00,
     &     0.683800E+00,0.620734E+00,0.585671E+00,0.623933E+00,
     &     0.521103E+00,0.495367E+00,0.444456E+00,0.377600E+00,
     &     0.381005E+00,0.347815E+00,0.408729E+00,0.462994E+00,
     &     0.410196E+00,0.538749E+00,0.550721E+00,0.537081E+00,
     &     0.592866E+00,0.558007E+00,0.516183E+00,0.489872E+00,
     &     0.489926E+00,0.475001E+00,0.519812E+00,0.445382E+00,
     &     0.450921E+00,0.468590E+00,0.491383E+00,0.529355E+00,
     &     0.583605E+00,0.563129E+00,0.530960E+00,0.520530E+00/
```

```
C
      DATA(W29AT(I),I=1,48)/
     &     0.965070E+00,0.965703E+00,0.958076E+00,0.944985E+00,
     &     0.941726E+00,0.943760E+00,0.934476E+00,0.929495E+00,
     &     0.915973E+00,0.886283E+00,0.879470E+00,0.874137E+00,
     &     0.839855E+00,0.814395E+00,0.813425E+00,0.798142E+00,
     &     0.726507E+00,0.652593E+00,0.670539E+00,0.723898E+00,
     &     0.628902E+00,0.586439E+00,0.538510E+00,0.491392E+00,
     &     0.507712E+00,0.505412E+00,0.549321E+00,0.[illegible]7152E+00,
     &     0.663865E+00,0.739065E+00,0.743435E+00,0.734909E+00,
     &     0.701942E+00,0.679371E+00,0.596963E+00,0.597095E+00,
     &     0.627306E+00,0.659317E+00,0.715405E+00,0.659263E+00,
     &     0.705437E+00,0.676360E+00,0.650235E+00,0.629048E+00,
     &     0.566178E+00,0.641429E+00,0.641908E+00,0.645184E+00/
```

```
C
       DATA(W30AV(I),I=1,48)/
      &     0.111762E+01,0.112638E+01,0.113207E+01,0.112807E+01,
      &     0.113047E+01,0.112498E+01,0.112260E+01,0.109491E+01,
      &     0.107558E+01,0.993633E+00,0.844433E+00,0.805705E+00,
      &     0.777126E+00,0.746498E+00,0.716564E+00,0.691687E+00,
      &     0.629604E+00,0.485322E+00,0.463809E+00,0.414819E+00,
      &     0.438953E+00,0.545194E+00,0.530773E+00,0.601272E+00,
      &     0.645164E+00,0.740238E+00,0.902832E+00,0.769824E+00,
      &     0.752549E+00,0.763636E+00,0.663689E+00,0.766461E+00,
      &     0.918749E+00,0.981195E+00,0.878173E+00,0.705556E+00,
      &     0.628545E+00,0.575170E+00,0.542869E+00,0.601239E+00,
      &     0.594752E+00,0.553771E+00,0.582443E+00,0.598299E+00,
      &     0.644848E+00,0.662638E+00,0.677093E+00,0.662057E+00/
C
       DATA(W30AR(I),I=1,48)/
      &     0.653456E+00,0.658319E+00,0.678996E+00,0.714990E+00,
      &     0.709428E+00,0.643330E+00,0.621079E+00,0.697985E+00,
      &     0.760587E+00,0.696880E+00,0.645436E+00,0.642477E+00,
      &     0.668535E+00,0.724780E+00,0.702498E+00,0.500357E+00,
      &     0.420956E+00,0.453428E+00,0.554914E+00,0.645625E+00,
      &     0.605105E+00,0.747893E+00,0.754851E+00,0.704110E+00,
      &     0.845318E+00,0.769991E+00,0.650387E+00,0.740006E+00,
      &     0.737650E+00,0.915945E+00,0.964491E+00,0.872913E+00,
      &     0.769843E+00,0.708719E+00,0.659835E+00,0.613909E+00,
      &     0.561479E+00,0.548805E+00,0.561646E+00,0.596715E+00,
      &     0.584552E+00,0.600693E+00,0.637062E+00,0.611373E+00,
      &     0.690017E+00,0.719500E+00,0.721972E+00,0.743177E+00/
C
       DATA(W30AT(I),I=1,48)/
      &     0.840569E+00,0.796278E+00,0.765898E+00,0.699166E+00,
      &     0.683645E+00,0.740705E+00,0.786191E+00,0.824036E+00,
      &     0.724340E+00,0.626184E+00,0.593016E+00,0.527160E+00,
      &     0.451668E+00,0.439757E+00,0.478294E+00,0.418859E+00,
      &     0.392596E+00,0.395434E+00,0 472265E+00,0.480250E+00,
      &     0.487892E+00,0.489437E+00,0.425324E+00,0.391090E+00,
      &     0.441167E+00,0.480444E+00,0.491186E+00,0.582275E+00,
      &     0.693687E+00,0.644441E+00,0.568182E+00,0.511520E+00,
      &     0.445785E+00,0.373984E+00,0.342569E+00,0.385479E+00,
      &     0.412092E+00,0.388736E+00,0.460750E+00,0.471392E+00,
      &     0.479464E+00,0.445374E+00,0.389539E+00,0.425402E+00,
      &     0.441209E+00,0.435538E+00,0.453044E+00,0.464795E+00/
C

       IF(BSTA .EQ. 'W25 BOT' .AND. GAGEOR .EQ. 'VERT') THEN
        DO 2001 J=1,48
        ATTEN(J) = W25AV(J)
 2001   CONTINUE
       ENDIF
```

```
      IF(BSTA .EQ. 'W25 BOT' .AND. GAGEOR .EQ. 'RAD') THEN
       DO 2002 J=1,48
       ATTEN(J) = W25AR(J)
 2002  CONTINUE
      ENDIF

      IF(BSTA .EQ. 'W25 BOT' .AND. GAGEOR .EQ. 'TRANS') THEN
       DO 2003 J=1,48
       ATTEN(J) = W25AT(J)
 2003  CONTINUE
      ENDIF

      IF(BSTA .EQ. 'W28 BOT' .AND. GAGEOR .EQ. 'VERT') THEN
       DO 2004 J=1,48
       ATTEN(J) =W28AV(J)
 2004  CONTINUE
      ENDIF

      IF(BSTA .EQ. 'W28 BOT' .AND. GAGEOR .EQ. 'RAD') THEN
       DO 2005 J=1,48
       ATTEN(J) = W28AR(J)
 2005  CONTINUE
      ENDIF

      IF(BSTA .EQ. 'W28 BOT' .AND. GAGEOR .EQ. 'TRANS') THEN
       DO 2006 J=1,48
       ATTEN(J) = W28AT(J)
 2006  CONTINUE
      ENDIF

      IF(BSTA .EQ. 'W29 BOT' .AND. GAGEOR .EQ. 'VERT') THEN
       DO 2007 J=1,48
       ATTEN(J) = W29AV(J)
 2007  CONTINUE
      ENDIF

      IF(BSTA .EQ. 'W29 BOT' .AND. GAGEOR .EQ. 'RAD') THEN
       DO 2008 J=1,48
       ATTEN(J) = W29AR(J)
 2008  CONTINUE
      ENDIF

      IF(BSTA .EQ. 'W29 BOT' .AND. GAGEOR .EQ. 'TRANS') THEN
       DO 2009 J=1,48
       ATTEN(J) = W29AT(J)
 2009  CONTINUE
      ENDIF
```

```
      IF(BSTA .EQ. 'W30 BOT' .AND. GAGEOR .EQ. 'VERT') THEN
       DO 2010 J=1,48
       ATTEN(J) = W30AV(J)
 2010  CONTINUE
      ENDIF

      IF(BSTA .EQ. 'W30 BOT' .AND. GAGEOR .EQ. 'RAD') THEN
       DO 2011 J=1,48
       ATTEN(J) = W30AR(J)
 2011  CONTINUE
      ENDIF

      IF(BSTA .EQ. 'W30 BOT' .AND. GAGEOR .EQ. 'TRANS') THEN
       DO 2012 J=1,48
       ATTEN(J) = W30AT(J)
 2012  CONTINUE
      ENDIF

      RETURN
      END
```

REFERENCES FOR APPENDIX B:

CA-DISSPLA User's Manual, Release 11.0, 1989, Computer Associates International, Inc., Garden City, NY (NNA.901128.0164)

Environmental Research Corporation, 1984, Prediction of Ground Motion Characteristics of Underground Nuclear Detonations, NVO-1163-239 (NNA.870406.0100)

Lynch, R. D., 1969, "Response Spectra for Pahute Mesa Events," Bulletin of the Seismological Society of America, Vol. 59 (NNA.890714.0073)

APPENDIX C: SEPDB AND RIB INFORMATIONND

Information from the Reference Information Base Used in this Report

This report contains no information from the Reference Information Base.

Candidate Information for the Reference Information Base

This report contains no candidate information for the Reference Information Base.

Candidate Information for the Site & Engineering Properties Data Base

This report contains no candidate information for the Site and Engineering Properties Data Base.

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