

SEISMIC DESIGN MOTIONS
FOR
CAMANCHE AND PARDEE POWER PLANTS

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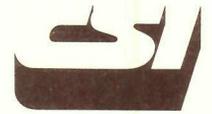
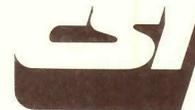


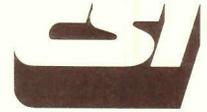
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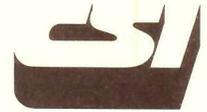
SUMMARY OF PREVIOUS STUDIES

The proposed Camanche and Pardee Power Plants sites lie along the Mokelumne River in the foothills of the Sierra Nevada, near Valley Spring, California. Camanche Dam is located about 15 km downstream from Pardee Dam.

Professor Bruce Bolt has previously evaluated the seismicity of the Camanche and Pardee dams for the East Bay Municipal Utility District (1). Bolt's conclusions and recommendations were updated by Civil Systems Inc. (CSI) as subcontractors to Wahler Associates, during studies currently performed to re-evaluate the seismic stability of Camanche Dike No. 2 (2). Kleinfelder and Associates (3) have investigated the geotechnical conditions at the two power plant sites.

Professor Bolt and CSI both concluded that the southern portion of the Sierra Foothills fault system controls the extreme seismic loading conditions that must be considered in the re-analysis of the Camanche and Pardee dams. The two members of this system that are the closest to the dams are the Bear Mountain and the Melones Faults. The locations of the two proposed power plants with respect to the Sierra Foothills fault system are shown on Figure 1.

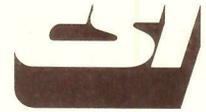
Bolt's and CSI's studies agreed well with respect to general seismic design considerations. They proposed different interpretations, however, for the mechanics of the



Southern portion of the Sierra Foothills fault system. Professor Bolt inferred a dominantly normal down-to-the west faulting mechanism, similar to that existing along the northern portion, as indicated by the 1975 Oroville Earthquake sequence. CSI studies suggested that the southern segment differs from the northern segment and may rather exhibit upthrust (reverse) faulting with secondary subsidence along the monoclinial crest or simply be a deeply buried right-lateral strike-slip fault inducing secondary subsidence and oblique movement. Both studies recommended a maximum credible Richter magnitude of $6\frac{1}{2}$ for the southern portion of the Sierra Foothills fault system. In view of design, a conservative magnitude of $6\frac{1}{2}$ was agreed upon between the State Division of Safety of Dams, the District and CSI to define extreme seismic loading conditions at the proposed power plant sites.

DUAL LEVEL CONCEPT FOR SEISMIC DESIGN

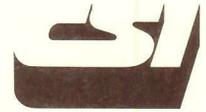
Most major dams are critical with respect to safety because of the high downstream damage potential that could accompany any accidental release of the water they impound. For that reason, their seismic design is essentially deterministic: dams are required to perform satisfactorily when subjected to extreme seismic motions that are postulated to occur at the damsite, based on applicable interpretations of the local seismo-tectonics and geology. The degree of risk associated with the "Design Earthquake", for a dam, is usually not stated explicitly, although Professor Bolt indicated that a nominal mean annual probability of occurrence of 10^{-4} was associated with his recommended design motions for Pardee and Camanche dams.



Another approach, that represents a more refined balance of probabilities of occurrence, design conditions and levels of risk, is often used for the design of major industrial or commercial structures for which the consequences of failure or collapse remain essentially confined to the immediate vicinity of the buildings. This alternative involves the concept of dual level earthquakes or motions and has evolved over the last fifteen years as the state-of-the-art in earthquake-resistant design, despite the inevitable differences of opinion that still persist among specialists regarding earthquake levels and acceptable degrees of risk. The lower of the two levels of motion, which is often associated with about a 50 percent probability of occurrence within the project life, is used for the basic design of the structure in accordance with normal linear elastic design and analysis procedures. The upper level of motion, associated perhaps with a 10 percent probability of occurrence within the project life, is used to check that the structure would not collapse under a more extreme loading, although some repairable damage might be expected.

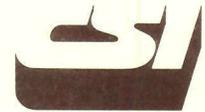
For the Camanche and Pardee Power Plants we recommend that an approach which is intermediate to the above two methods be followed. In this approach two levels of motion are specified as follows:

- The "Level I Earthquake" is equivalent to the lower of the two earthquakes or levels of motion that are normally included in a dual level approach. It does not, in fact, describe a single earthquake or earthquake source mechanism but rather is a label that is used to describe the motion at the site that might be generated from one or more sources during the life of the project. This motion is



nominally associated with a probability of occurrence of 40 percent in 100 years but it should be understood that it is not possible to compute such probabilities of occurrence for the Camanche and Pardee sites with great precision. It is recommended that the power plants be designed to remain elastic under the forces associated with this level of motion. With good seismic design practice this would normally ensure adequate behavior under more extreme levels of motion also, but with the expectation of some undefined, repairable damage.

- The "Level II Earthquake" is a specific extreme earthquake and level of motion that, in this case, corresponds to the "Design Earthquake" for the seismic analysis of Camanche Dike No. 2, and can be used for checking the performance under extreme loadings of elements of the power plants which have either a safety related function, such as emergency outlet works, or, as agreed by Sverdrup & Parcel and the district, have significant economic value. The exact criteria to be used in assessing the performance of these elements is beyond the scope of this report but in general we should note that even critical structures or equipment should not be expected to remain elastic under this extreme level of motion and that either the recommended elastic response spectra should be reduced by appropriate ductility ratios or some form of nonlinear analysis should be performed. This "Level II Earthquake" is, of course, a more extreme event than would be used as the upper level

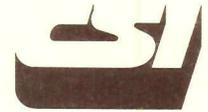


event in conventional dual level seismic design criteria, since it was determined deterministically and is controlled by a close-to-site fault that has indeed exhibited no seismic activity during historical times. The return period of the "Level II Earthquake", although not computed, would significantly exceed return periods commonly associated with the upper level of motion of the conventional dual level approach.

LEVEL I EARTHQUAKE HORIZONTAL DESIGN RESPONSE SPECTRA

The definition proposed for the Level I Earthquake implies a statistical analysis or its equivalent. The historical seismic activity within a 100 km radius circular area centered between Camanche and Pardee dams appears fairly scarce and insufficient to form a meaningful data base in view of its statistical evaluation. However, recently proposed provisions for the development of seismic regulations for buildings (4), prepared jointly by the Applied Technology Council (ATC) and the Structural Engineers Association of California (SEAOC) provide a satisfactory alternative to the statistical analysis in view of the definition of the Level I Earthquake.

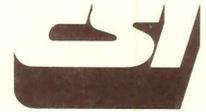
The ATC zoning defines two design parameters, the Effective Peak Acceleration (EPA) and the Effective Peak Velocity (EPV). These parameters are related to the peak ground acceleration and the peak ground velocity but without being directly proportional to these quantities. The EPA and EPV are defined county-by-county and are intended to replace the unprecise seismic zoning of the current Uniform Building Code. The coefficient A_a , directly adapted from the probabilistic seismic hazard mapping presented by Algermissen



and Perkins for the continental United States (5), represents the EPA. The Algermissen-Perkins map provides peak horizontal acceleration contours with a 90 percent probability of not being exceeded in a 50-year period. This level of risk is intended to be associated with inelastic design practice and for the Level I Earthquake a 40 percent probability of exceedance during a 100-year assumed design life seems a more appropriate value. Modified values of EPA and EPV corresponding to different risk levels can be derived from the ATC provided A_a and A_v coefficients by using simple statistical procedures (4).

Applying these procedures and averaging the values for San Joaquin and Amador/Calaveras Counties (since Camanche Dam lies at the eastern end of San Joaquin County and Pardee Dam straddles the border of Amador and Calaveras Counties) a value for A_a of 0.14g is obtained. This modified EPA can be used to scale design response spectra that are provided in reference (4) for different site conditions. The ATC response spectrum for site profile type S1 (rock of stiff soil conditions) can thus be scaled to a peak acceleration of 0.14g to provide the proposed Level I Earthquake Horizontal Design Response Spectrum for Camanche and Pardee Power Plants.

This spectrum is presented on Figure 2 for 2 and 5 percent of critical damping. The 5 percent spectrum matches the ATC response spectrum for site profile type S1, and the 2 percent damping response spectrum was directly derived from the 5 percent damping response spectrum by using the procedure recommended by ATC (4). Figure 3 presents these response spectra in tripartite form.

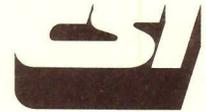


LEVEL II EARTHQUAKE HORIZONTAL DESIGN RESPONSE SPECTRA

The Level II Earthquake definition calls for a more deterministic approach than does the Level I Earthquake. It is proposed that the Design Earthquake developed for the seismic re-evaluation of Camanche Dike No. 2 be used directly as the Level II Earthquake for the Camanche Power Plant. The peak acceleration of this earthquake is 0.30g and the corresponding acceleration time-history is shown on Figure 4. The normalized response spectrum computed for the Camanche Design Earthquake is presented on Figure 5 for 5 and 10 percent of critical damping. It should be noted that the peak acceleration value of 0.30g represents a reasonable mean value, used to scale a conservative response spectrum, intended to closely match an 84 percentile response spectrum (2).

The Design Earthquake developed for Camanche Dike No. 2 assumed an event of Richter magnitude $6\frac{1}{2}$ occurring along the Bear Mountain fault at its point closest to the dike. Because of the short distance between Pardee Dam and the Bear Mountain fault (see Figure 1), this earthquake would generate ground motion with significantly higher intensity at Pardee Dam. The motion at Pardee can, however, be represented by the same acceleration time-history as that presented on Figure 4, but scaled to a different peak ground acceleration taking into account the applicable distance between Pardee and the Bear Mountain fault.

The attenuation relationships used to develop the peak horizontal acceleration for Camanche Dike No. 2 Design Earthquake provide the following values, at the Pardee site, for a magnitude $6\frac{1}{2}$ earthquake along the Bear Mountain fault:



Schnabel - Seed (1972):	0.65g
Donovan - Bornstein (1977):	0.31g
McGuire (1978):	0.66g
Idriss - Power (1978):	0.54g
Joyner <u>et al.</u> (1978):	Not applicable

The values listed above reflect a considerable scatter due to the fact that all currently used attenuation relationships, including those referenced above, were developed using data bases that were complete only in the range of 10 to 150 km and did not really apply to short distances such as the 2 km that separate Pardee Dam from the Bear Mountain fault.

CSI is currently preparing a review of near field (less than 10 km) strong ground motion. This review includes information developed during the most recent Californian earthquakes, such as the 1978 Santa Barbara, 1978 Coyote Lake, and the 1979 Imperial County earthquake. Figures 6 and 7 present peak horizontal acceleration values plotted as a function of Richter magnitude and distance that are currently available for distances equal to or less than 10 km. Since horizontal peak ground acceleration has little dependence on distance for near field motions, either Figure 6 or Figure 7 can be used to estimate a reasonable average horizontal peak ground acceleration for Pardee corresponding to a magnitude $6\frac{1}{2}$ event. An average value of 0.45g was selected to represent the peak acceleration of the Level II Earthquake for Pardee Power Plant. As can be seen on Figure 6, near fault peak horizontal accelerations have little dependence on magnitude, and the selected value of 0.45g applies either to the $6\frac{1}{4}$ magnitude recommended by Professor Bolt or to the $6\frac{1}{2}$ magnitude presently selected for design.



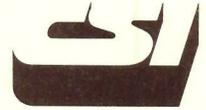
The corresponding Level II acceleration time-history can be directly obtained by scaling the accelerogram presented on Figure 4 to a peak acceleration of 0.45g. The normalized response spectrum shown on Figure 5 is applicable to Pardee Level II Earthquake.

CSI will provide digitized accelerograms representing Camanche and Pardee Level II Earthquakes to Sverdrup & Parcel upon request. The irregularly shaped response spectra that correspond exactly to the acceleration histories are not, however, entirely suitable for a response spectrum type of analysis. Therefore, smoothed spectra are presented as absolute acceleration and tripartite response spectra on Figures 8 and 9 for the Camanche Power Plant and on Figures 10 and 11 for Pardee Power Plant, for 5 and 10 percent of critical damping, in each case.

It must be emphasized that the response spectra presented on Figures 8 through 11 are elastic design response spectra and should be appropriately modified to represent any inelastic response of structures and equipment to the Level II Earthquake.

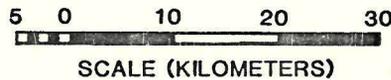
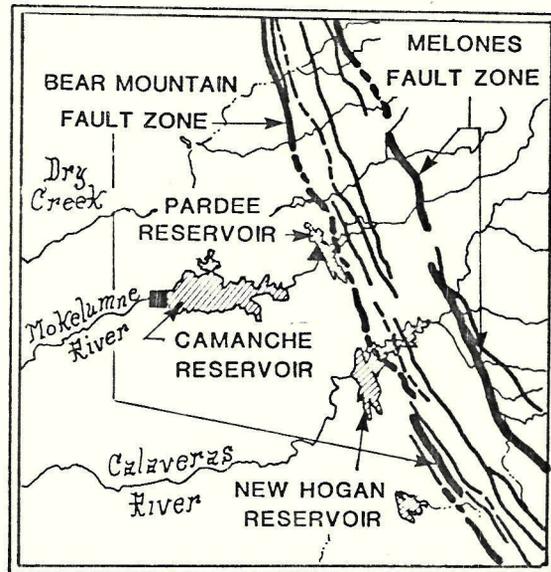
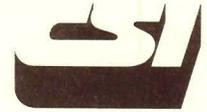
LEVEL I AND LEVEL II VERTICAL DESIGN RESPONSE SPECTRA

Vertical elastic design response spectra for the Level I and Level II Earthquakes can be obtained by scaling the response spectra presented on Figures 2 and 3 and 8 through 11 to a peak acceleration equal to two-thirds of the peak horizontal accelerations.



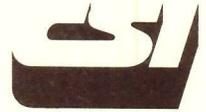
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2. Wahler Associates (----) "Seismic Re-evaluation of Camanche Dike No. 2". Chapter 3, "Regional and Geology and Seismicity" and Chapter 4, "Development of Design Earthquake". (In press)
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4. Applied Technology Council (1978) "Tentative Provisions for the Development of Seismic Regulations for Buildings", ATC Publication ATC 3-06, NSG Special Publication 510, NSF Publication 78-8, June 1978.
5. Algermissen, S. T.; Pérkins, D. M. (1976) "A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States", USGS open file Report 76-416.

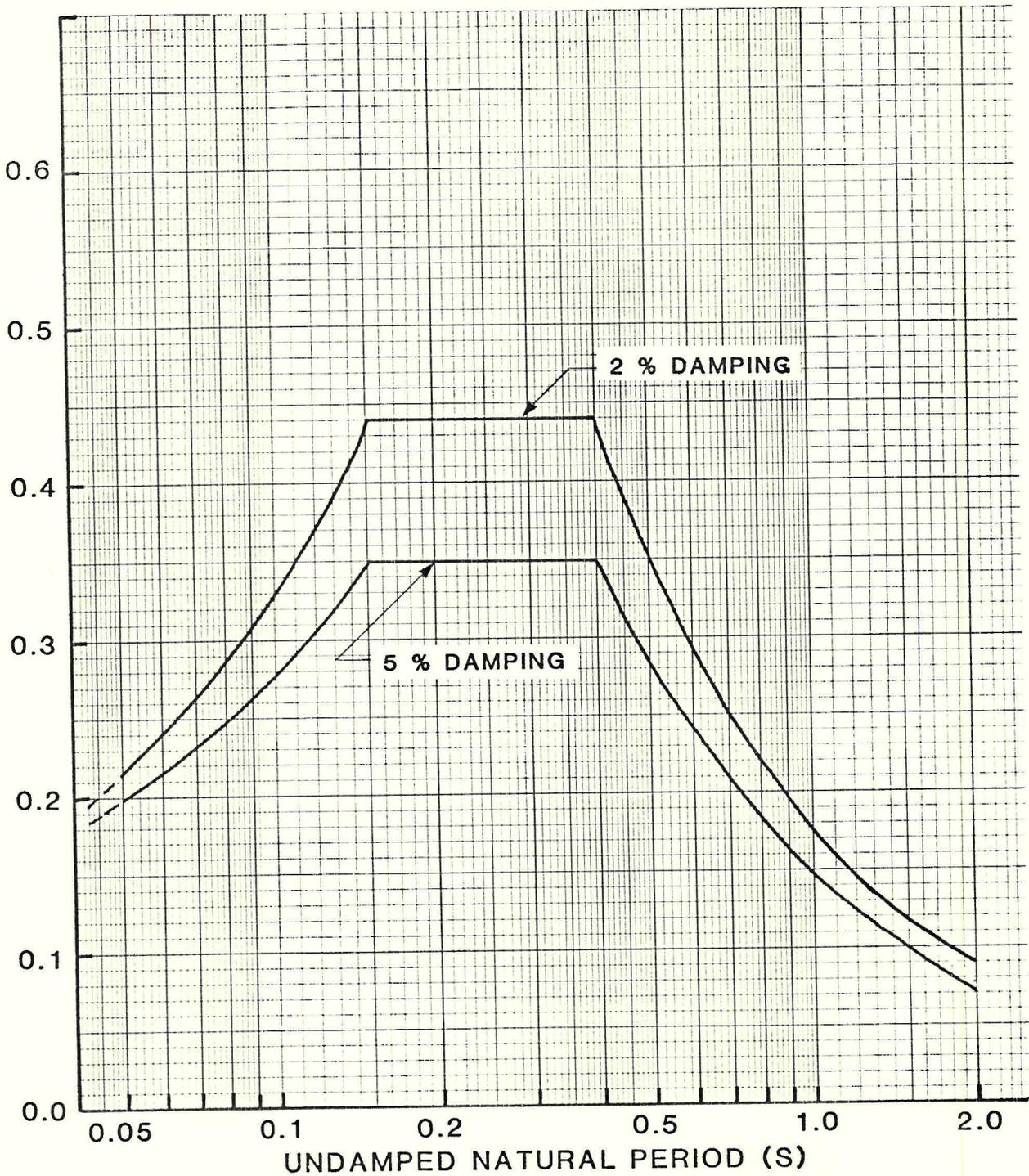


- CAMANCHE POWERHOUSE
- ▲ PARDEE POWERHOUSE

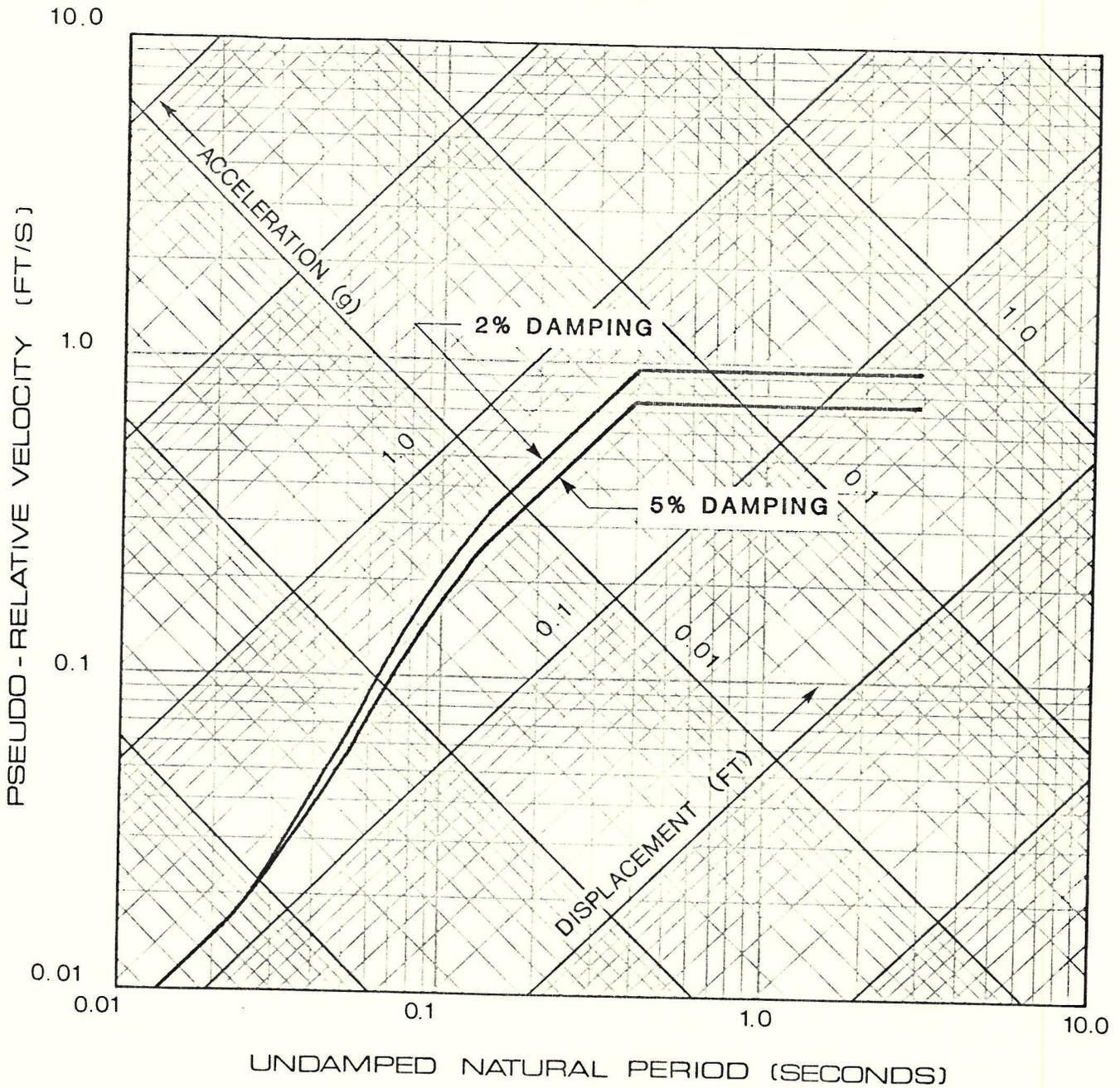
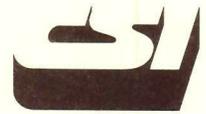
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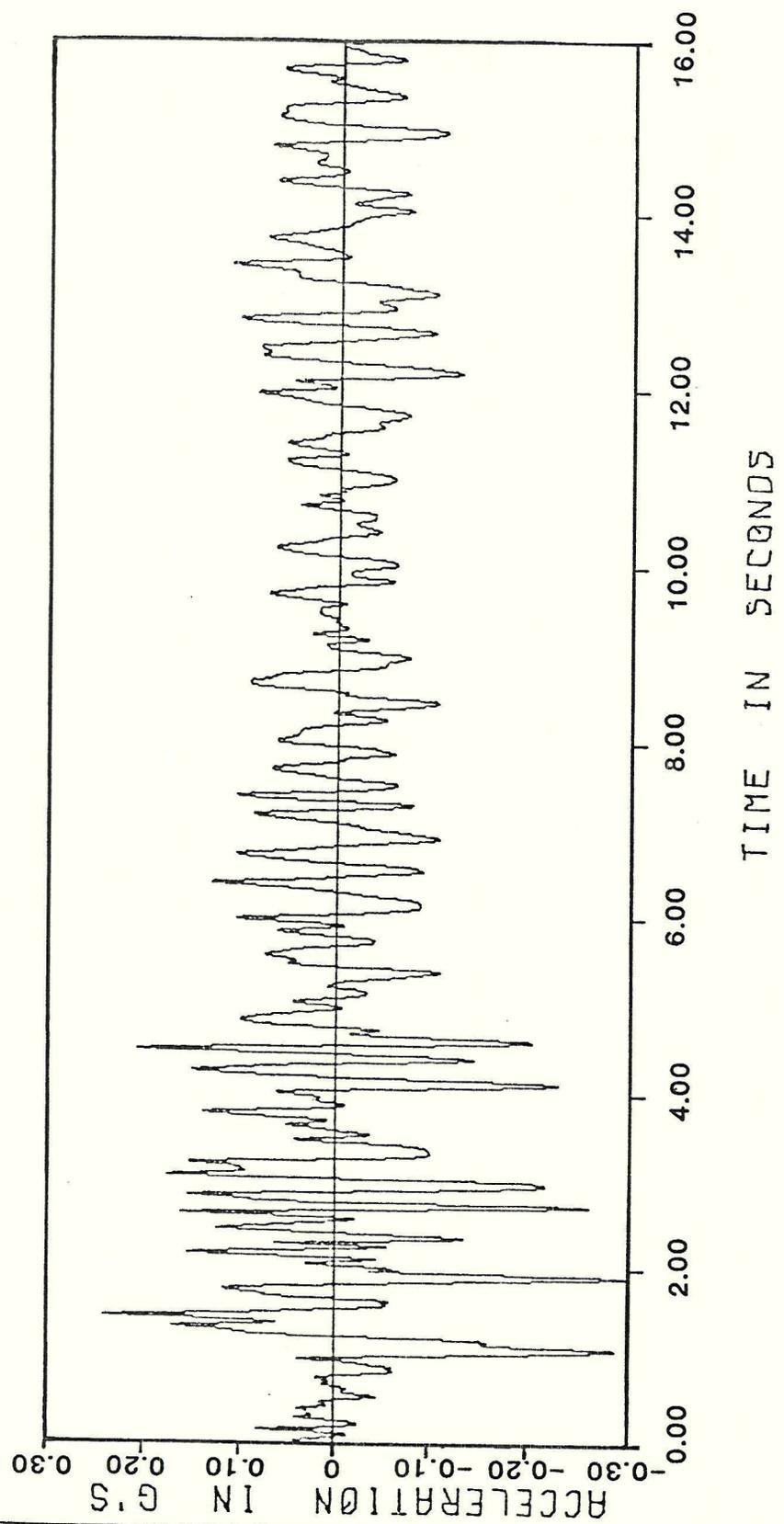
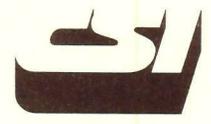
ABSOLUTE ACCELERATION (g)



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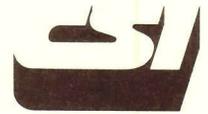


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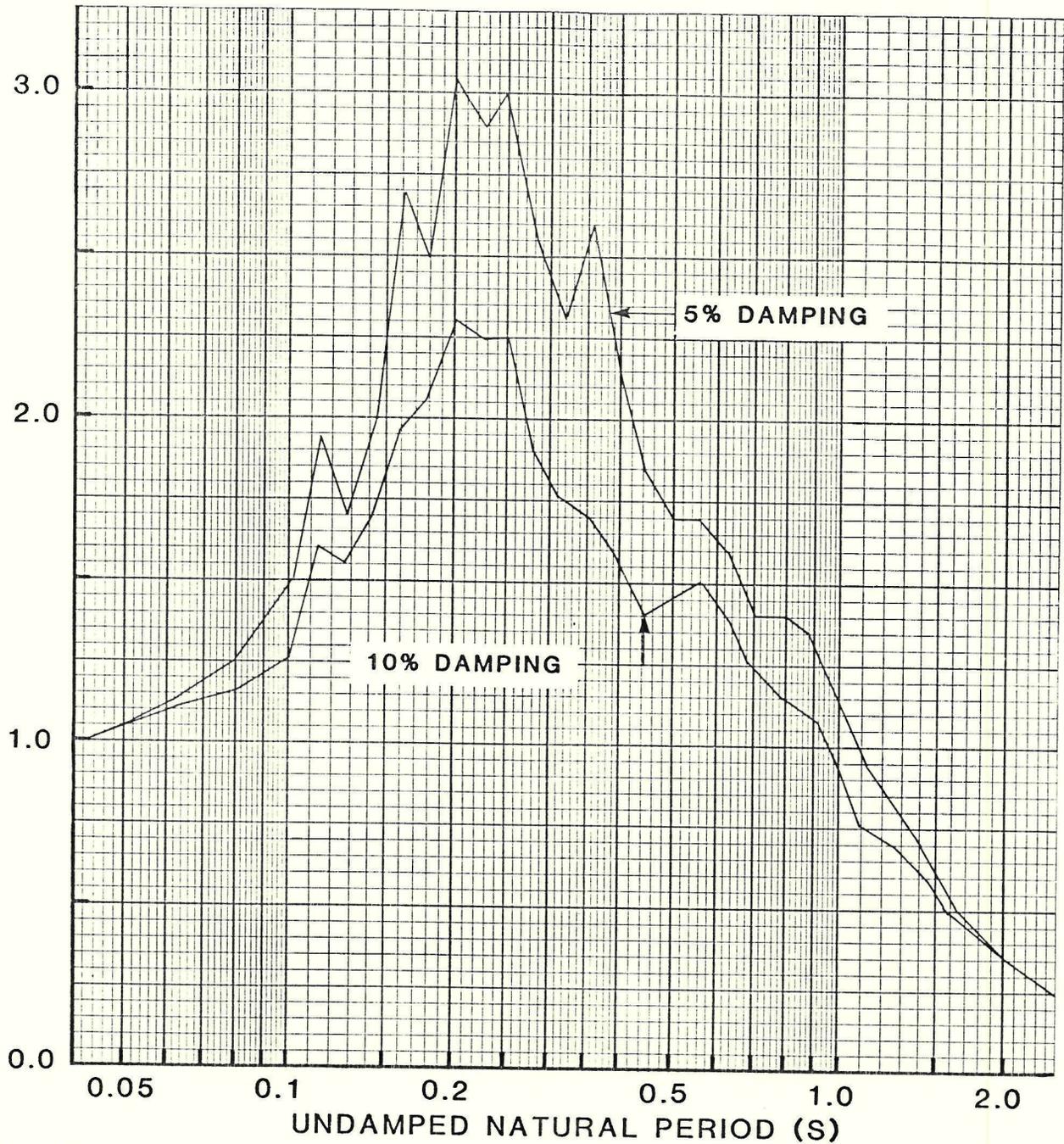


CAMANCHE DIKE NO2 - DESIGN EQ

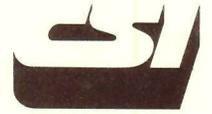
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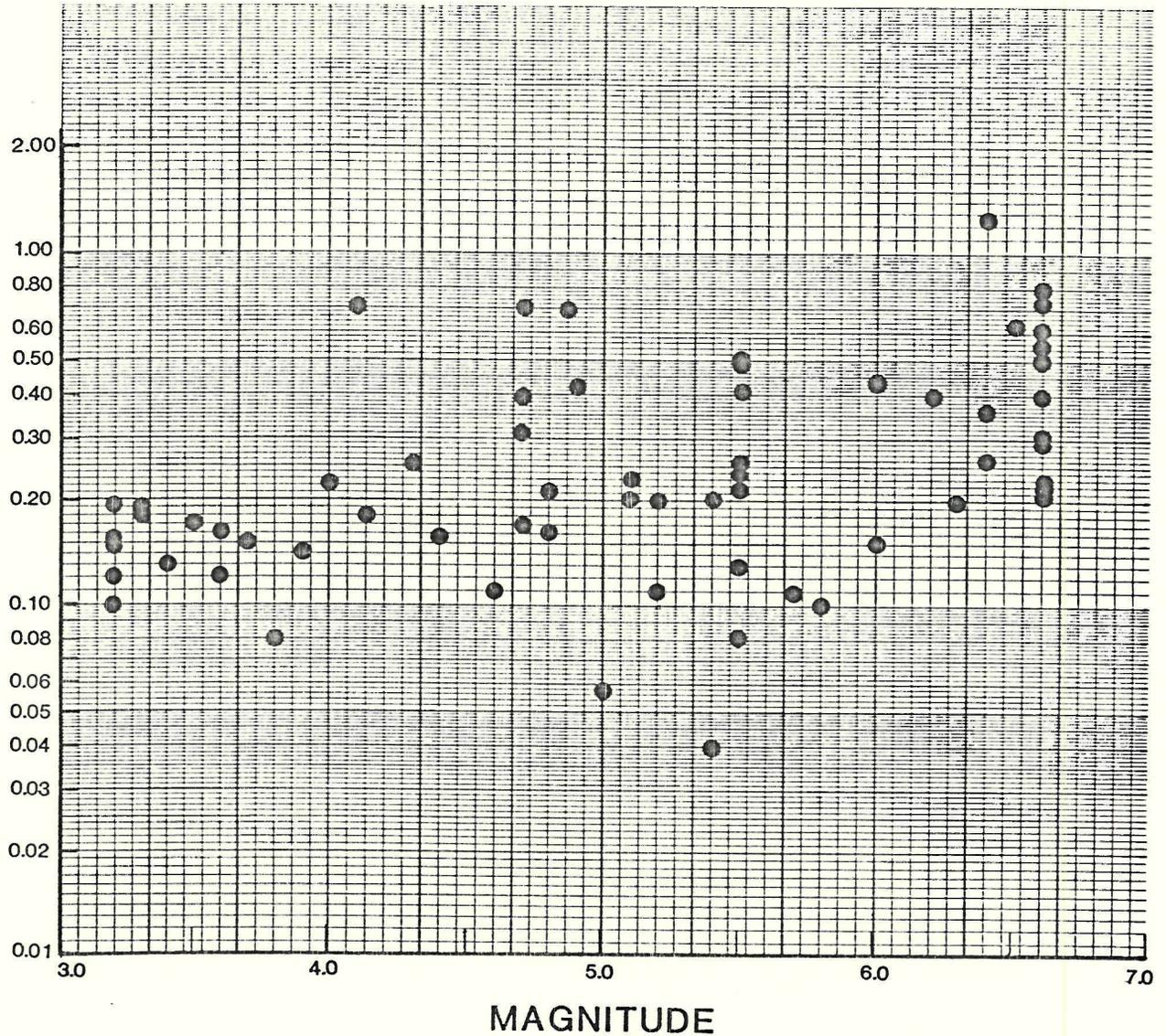
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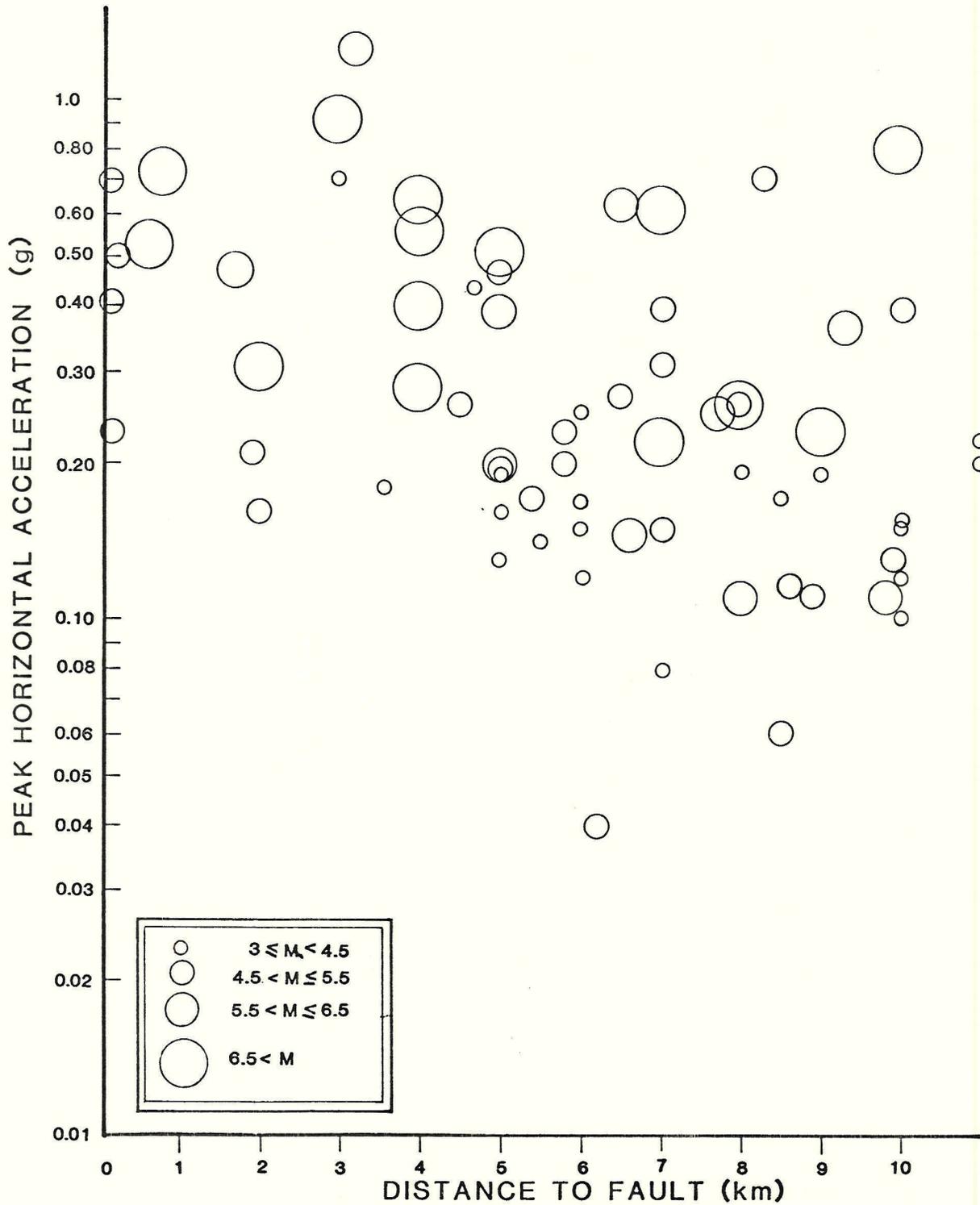
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PEAK HORIZONTAL ACCELERATION (g)



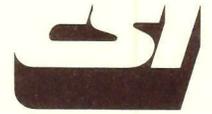
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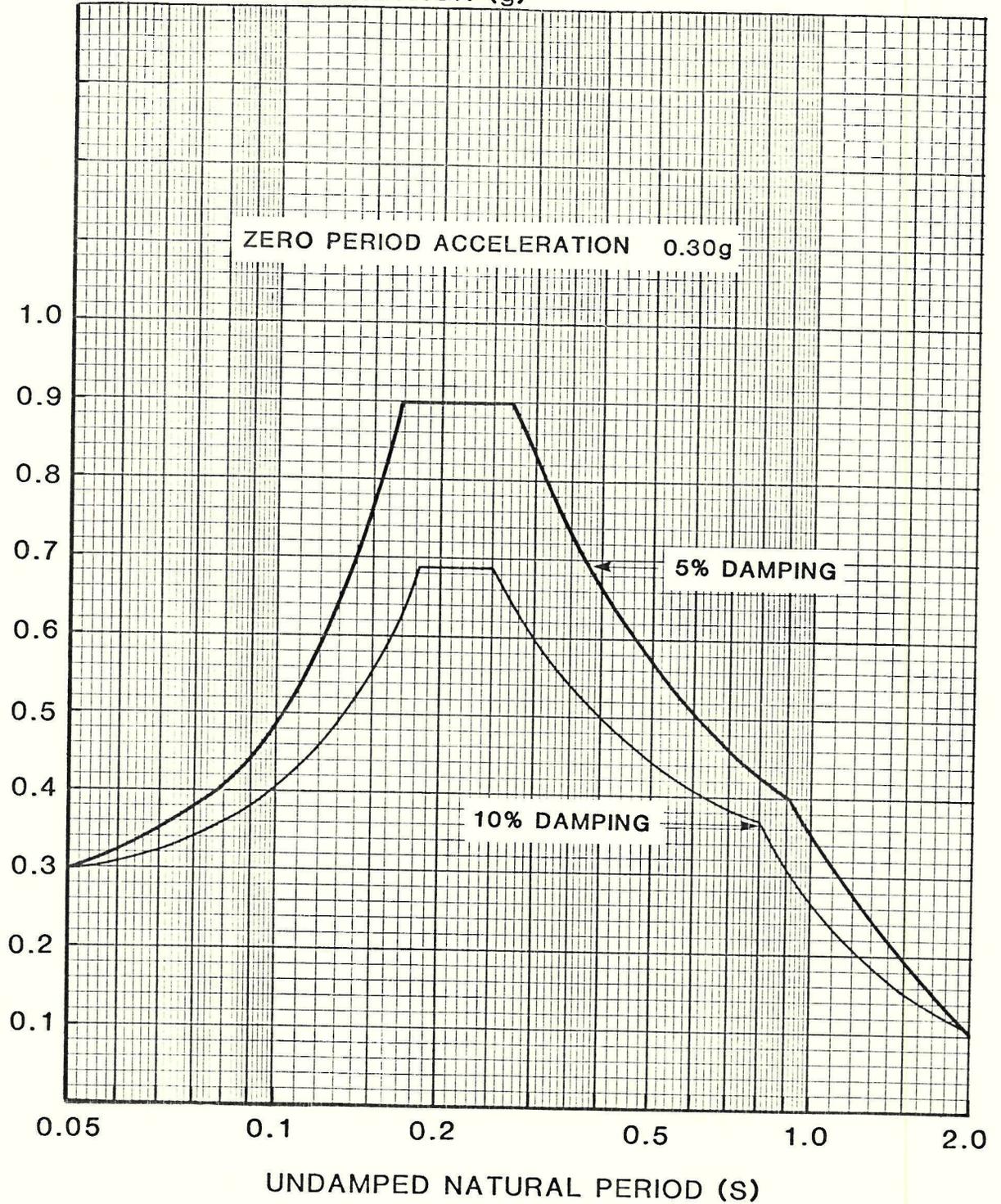
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CAMANCHE AND PARDEE POWERHOUSES
NEAR FAULT STRONG GROUND MOTION

FIGURE NO.
7



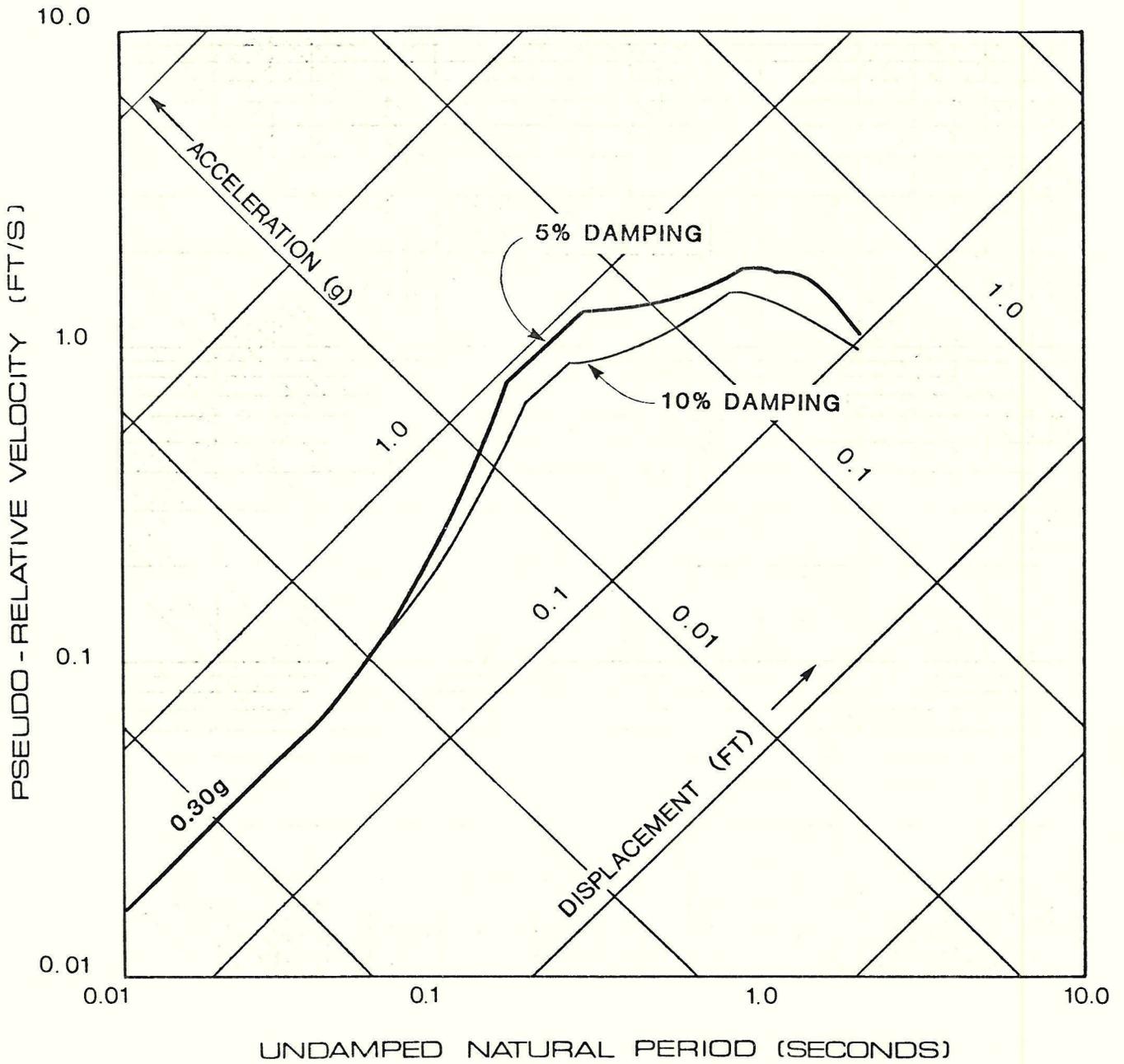
ABSOLUTE ACCELERATION (g)



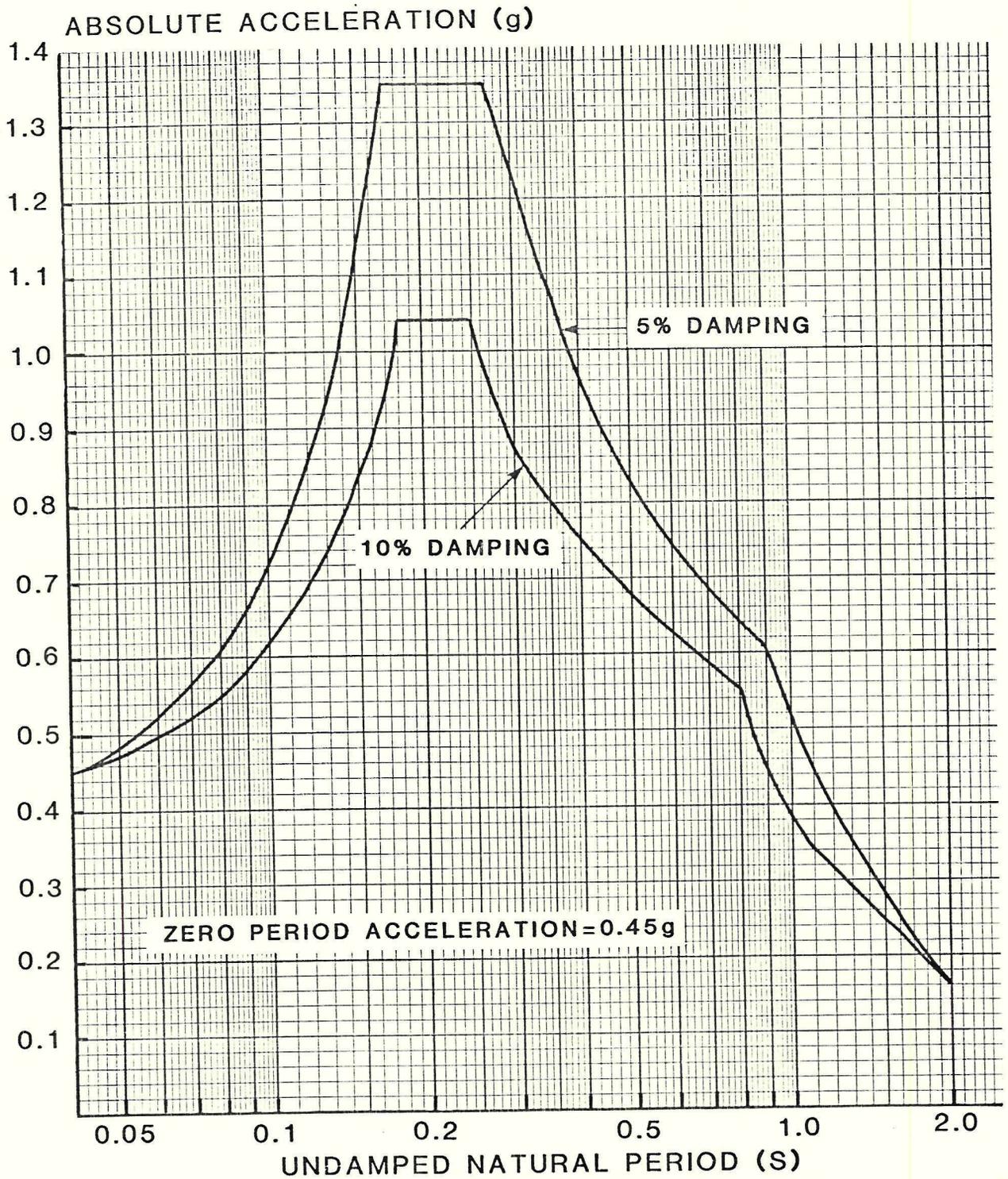
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CAMANCHE AND PARDEE POWERHOUSES
LEVEL II EARTHQUAKE - CAMANCHE

FIGURE NO.
8



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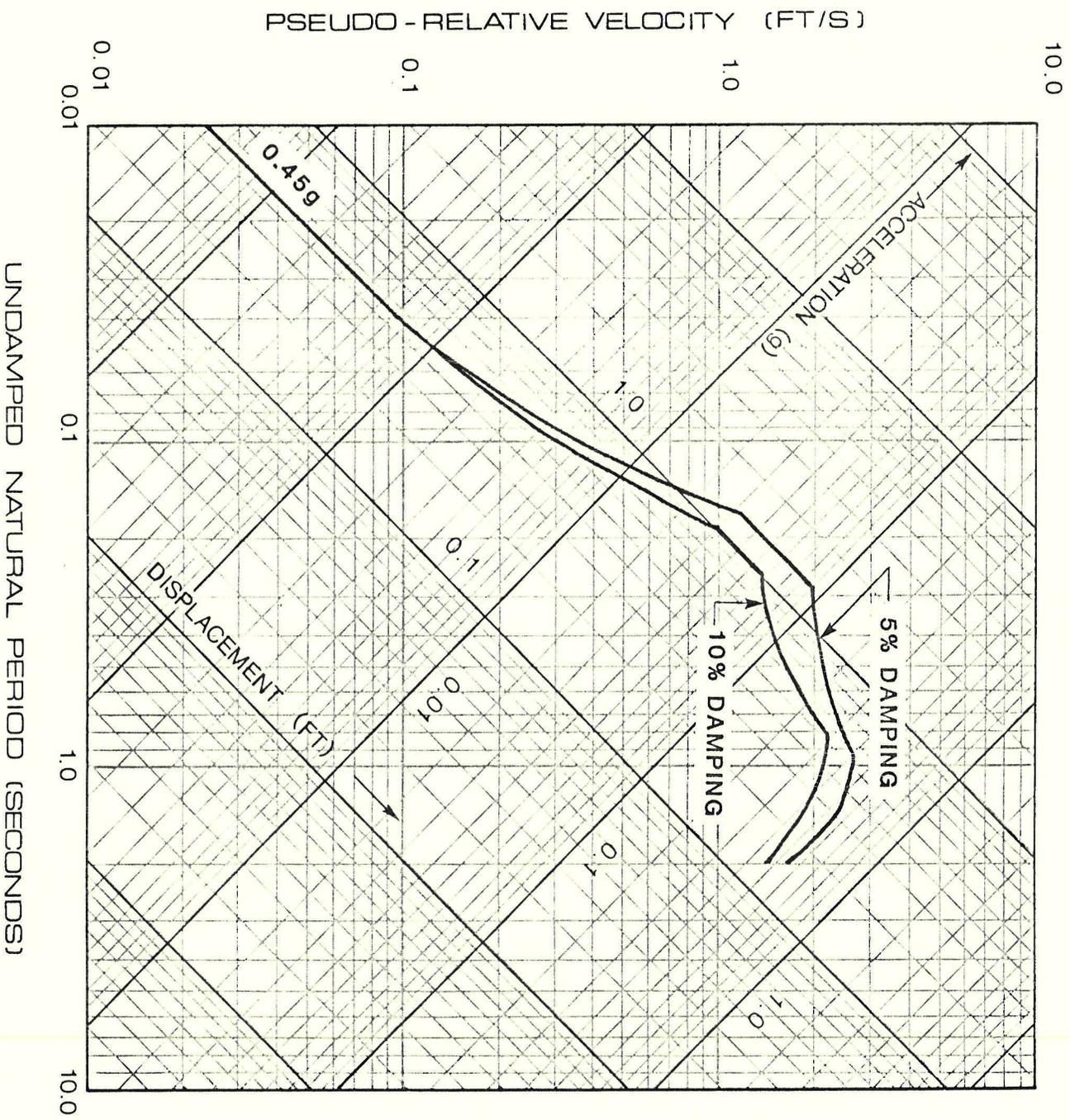
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CAMANCHE AND PARDEE POWERHOUSES

LEVEL II EARTHQUAKE - PARDEE

FIGURE NO.

10



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		LEVEL II EARTHQUAKE - PARDEE	11