NON-PROPRIETARY CALCULATIONS

Book 8 of 8

Attachments to PG&E Letter DIL-01-004
Dated December 21, 2001

NUCLEAR POWER GENERATION
CF3.ID4
ATTACHMENT 7.2

Index No. 402
Binder No.

TITLE: CALCULATION COVER SHEET

Unit(s): 1 & 2

File No.: 52.27

Responsible Group: Civil

Calculation No.: 52.27.100.735

No. of Pages 3 pages + Index (4 pages) + 1 Attachment (51 pages)

Design Calculation YES [x] NO [ ]

System No. 42C

Quality Classification Q (Safety-Related)

Structure, System or Component: Independent Spent Fuel Storage Facility

Subject: Determination of Seismic Coefficient Time Histories for Potential Sliding Masses Along Cut Slope Behind ISFSI Pad (GEO.DCPP.01.25, Rev. 1)

Electronic calculation YES [ ] NO [x]

Computer Model	Computer ID	Program Location	Date of Last Change

Registered Engineer Stamp: Complete A or B

A. Insert PE Stamp or Seal Below	B. Insert stamp directing to the PE stamp or seal
Expiration Date:	***REGISTERED ENGINEERS' STAMPS AND EXPIRATION DATES ARE SHOWN ON DWG 063618***

NOTE 1: Update DCI promptly after approval.
NOTE 2: Forward electronic calculation file to CCTG for uploading to EDMS.

TITLE: CALCULATION COVER SHEET

CALC No. 52.27.100.735, R0

RECORD OF REVISIONS

Rev No.	Status	Reason for Revision Remarks	Prepared By: Initials/ LAN ID/ Date	LBIE Screen Yes/ No/ NA	LBIE Yes/ No/ NA	Check Method*	LBIE Approval PSRC Mtg. No.	 PSRC Mtg. Date	Checked Initials/ LAN ID/ Date	Supervisor Initials/ LAN ID/ Date	Registered Engineer Signature/ LAN ID/ Date
0	F	Acceptance of Geosciences Calc. No. GEO.DCPP.01.25, Rev. 1. Calc. supports current edition of 10CFR72 DCPP License Application to be reviewed by NRC prior to implementation. Prepared per CF3.ID17.	AFT2 AT 12/15/01	[ ] Yes [ ] No [x] NA	[ ] Yes [ ] No [x] NA	[ ] A [ ] B [x] C	N/A	N/A	N/A	[signature] 12/17/01 LJS2	[signature] 12/17/01 LJS2
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					

*Check Method: A: Detailed Check, B: Alternate Method (note added pages), C: Critical Point Check

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1- This table cross references between Geosciences calculation numbers and DCPP (Civil Group's) calculation numbers. This section is For Information Only.

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(For Information Only)

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1	GEO.DCPP.01.01	Development of Young's Modulus and Poisson's Ratios for DCPP ISFSI Based on Field Data	52.27.100.711	
2	GEO.DCPP.01.02	Determination of Probabilistically Reduced Peak Bedrock Accelerations for DCPP ISFSI Transporter Analyses	52.27.100.712	
3	GEO.DCPP.01.03	Development of Allowable Bearing Capacity for DCPP ISFSI Pad and CTF Stability Analyses	52.27.100.713	
4	GEO.DCPP.01.04	Methodology for Determining Sliding Resistance Along Base of DCPP ISFSI Pads	52.27.100.714	
5	GEO.DCPP.01.05	Determination of Pseudostatic Acceleration Coefficient for Use in DCPP ISFSI Cutslope Stability Analyses	52.27.100.715	
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7	GEO.DCPP.01.07	Development of Coefficient of Subgrade Reaction for DCPP ISFSI Pad Stability Checks	52.27.100.717	
8	GEO.DCPP.01.08	Determination of Rock Anchor Design Parameters for DCPP ISFSI Cutslope	52.27.100.718	
9	GEO.DCPP.01.09	Determination of Applicability of Rock Elastic	52.27.100.719	Calculation to be replaced by letter

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(For Information Only)

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10	GEO.DCPP.01.10	Determination of SSER 34 Long Period Spectral Values	52.27.100.720	
11	GEO.DCPP.01.11	Development of ISFSI Spectra	52.27.100.721	
12	GEO.DCPP.01.12	Development of Fling Model for Diablo Canyon ISFSI	52.27.100.722	
13	GEO.DCPP.01.13	Development of Spectrum Compatible Time Histories	52.27.100.723	
14	GEO.DCPP.01.14	Development of Time Histories with Fling	52.27.100.724	
15	GEO.DCPP.01.15	Development of Young's Modulus and Poisson's Ratio Values for DCPP ISFSI Based on Laboratory Data	52.27.100.725	
16	GEO.DCPP.01.16	Development of Strength Envelopes for Non-jointed Rock at DCPP ISFSI Based on Laboratory Data	52.27.100.726	
17	GEO.DCPP.01.17	Determination of Mean and Standard Deviation of Unconfined Compression Strengths for Hard Rock at DCPP ISFSI Based on Laboratory Tests	52.27.100.727	
18	GEO.DCPP.01.18	Determination of Basic Friction Angle Along Rock Discontinuities at DCPP ISFSI Based on Laboratory	52.27.100.728	

SUBJECT Determination of Seismic Coefficient Time Histories for Potential Sliding Masses Along Cut Slope Behind ISFSI Pad

MADE BY A. Tafoya KT DATE 12/15/01 CHECKED BY N/A DATE

Cross-Index
(For Information Only)

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21	GEO.DCPP.01.21	Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPP ISFSI Site	52.27.100.731	
22	GEO.DCPP.01.22	Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site	52.27.100.732	
23	GEO.DCPP.01.23	Pseudostatic Wedge Analyses of DCPP ISFSI Cutslopes (SWEDGE Analysis)	52.27.100.733	
24	GEO.DCPP.01.24	Stability and Yield Acceleration Analysis of Cross-Section I-I'	52.27.100.734	
25	GEO.DCPP.01.25	Determination of Seismic Coefficient Time Histories for Potential Siding Masses Along Cut Slope Behind ISFSI Pad	52.27.100.735	
26	GEO.DCPP.01.26	Determination of Earthquake-Induced Displacements of Potential Sliding Masses on ISFSI Slope	52.27.100.736	
27	GEO.DCPP.01.27	Cold Machine Shop Retaining Wall Stability	52.27.100.737	
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SUBJECT Determination of Seismic Coefficient Time Histories for Potential Sliding Masses Along Cut Slope Behind ISFSI Pad

MADE BY A. Tafoya AT DATE 12/15/01 CHECKED BY N/A DATE

Cross-Index
(For Information Only)

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		Retaining Wall Stability		
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31	GEO.DCPP.01.31	Development of Strength Envelopes for Clay Beds at DCPP ISFSI	52.27.100.741	
32	GEO.DCPP.01.32	Verification of Computer Program SPCTLR.EXE	52.27.100.742	
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34	GEO.DCPP.01.34	Verification of Computer Code - QUAD4M	52.27.100.744	
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36	GEO.DCPP.01.36	Reserved	52.27.100.746	
37	GEO.DCPP.01.37	Development of Freefield Ground Motion Storage Cask Spectra and Time Histories for the Used Fuel Storage Project	52.27.100.747	

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number	GEO.DCPP.01.25
Revision	1
Date	12/13/01
Calc Pages:	48
Verification Method:	A
Verification Pages:	1

TITLE: Determination of Seismic Coefficient Time Histories for Potential Sliding Masses along Cut Slope behind ISFSI Pad

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Exp. 12/31/02

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PACIFIC GAS AND ELECTRIC COMPANY
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Exp. 12/31/02

Determination of Seismic Coefficient time Histories for Potential Sliding Masses along Cut Slope behind ISFSI Pad

Calc. Number GEO.DCPP.01.25

Record of Revisions

Rev. No.	Reason for Revision	Revision Date
00	Initial Issue	11/07/01
01	Revised test to incorporate PG&E NQS, UFSP, and Geosciences and its reviewers' comments including: 1) clarification of SHAKE program in the software section, 2) addition of 2 figures showing the velocity and displacement time histories of the rotated time histories, 3) addition of record of revision sheet, and 4) minor editorial changes.	12/13/01

Calculation Title: Determination of Seismic Coefficient Time Histories for Potential Sliding Masses along Cut Slope behind ISFSI Pad

Calculation No.: GEO.DCPP.01.25

Revision No.: 1

Calculation Author: Zhi-Liang Wang

Calculation Date: 12/13/01

PURPOSE

As required by Geomatrix Consultants, Inc. Work Plan entitled, "Laboratory Testing of Soil and Rock Samples, Slope Stability Analyses, and Excavation Design for Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site," the purpose of this calculation package is to provide the seismic response of the DCPP ISFSI slope and seismic coefficient time histories for potential sliding masses identified in calculation package GEO.DCPP.01.24.

ASSUMPTION

1. Response time histories of the potential sliding wedges can be approximated by averaging an appropriate number of nodal time histories within the wedge. This is a reasonable assumption because the material is stiff enough that the response of the rock wedge is very similar to the input time history.

INPUT

1. Five sets of rock motions originating on the Hosgri fault: Transmittal from PG&E Geosciences dated September 28, 2001 (Attachment 1).
2. Direction of down-slope movement along Section I-I': Transmittal from William Lettis & Associates dated August 3, 2001 (Attachment 2).
3. Orientation (azimuth) of the strike of the Hosgri fault: Transmittal from William Lettis & Associates dated August 23, 2001 (Attachment 3).
4. Direction of positive fault parallel component on Hosgri fault: Transmittal from PG&E Geosciences dated October 18, 2001 (Attachment 4).
5. Rotated motions from set 1 and set 5, from calculation package GEO.DCPP.01.26.

Dynamic Properties for Finite Element Analyses

Properties required for the dynamic finite element analyses include the unit weight, shear modulus at low shear strain, G_{max}, and relationships describing the modulus reduction and damping ratio increase with increasing shear strains.

Uniformity of materials

In the stability analyses (see calculation package GEO.DCPP.01.24), several material properties and shear strength parameters were considered to compute factors of safety and yield accelerations for potential sliding masses. Because of the existence of the clay beds, tension crack zones, and other zones of discontinuities, the rock mass was treated as non-uniform material for the purpose of stability analysis. For purposes of the seismic response of the slope, the effects from these discontinuities were not considered significant, and the rock slope was simulated as a rock profile having density and shear wave velocity that varied with depth, based on field shear wave velocity measurements and laboratory unit weights.

Unit weight of rock mass

Unit weights of rock mass were based on field investigations for the ISFSI site as reported in Attachment No.5.

Shear Wave Velocity and Shear Modulus at Low Strain

Shear modulus values at low strain can either be measured in the laboratory using resonant column tests or obtained from field measurements of shear wave velocity. When available, estimates of G_{max} based on field measurements of shear wave velocity are preferable to laboratory test data. The shear modulus at low strain is related to the shear wave velocity by the following relationship:

$$G_{max} = \frac{\gamma}{g}(V_s)^2$$

where: G_{max} = shear modulus at low strain

γ = unit weight of material

g = acceleration due to gravity

V_s = shear wave velocity

Results of shear wave velocity measurements performed at the power block area were presented in the Long Term Seismic Program report (PG&E, 1988). Additional shear wave velocity measurements were made in the slopes behind the ISFSI pad during the current investigation. The results of these field measurements are presented in calculation package GEO.DCPP.01.21. A copy of the average shear wave velocity with depth in two borings behind the ISFSI slope is shown in Attachment 5. Based on the results of these investigations, a shear wave velocity distribution with depth was selected for use in the dynamic analyses, and is shown on the finite element mesh on Figure 6.

Modulus Reduction and Damping Relationships with Strain

In the iterative equivalent-linear procedure used in QUAD4M, relationships of the variation of modulus reduction factor and damping ratio with shear strain are used to select strain-compatible shear moduli and damping ratios for each element. The variation of shear modulus reduction factor and damping ratio with shear strain for rock in the vicinity of the power block area was estimated on the basis of cyclic triaxial and resonant column tests performed on rock cores in 1978, as presented in Attachment 5. The data are presented on Figures 7 and 8 for the modulus reduction factor and damping ratio, respectively. The modulus reduction curve shown on Figure 7 from the manual of the SHAKE program was selected for the current analysis, which roughly corresponds to the median value of the range obtained from the rock core tests. For the variation of damping ratio with shear strain, the curve defining the lower bound of the shaded zone for the DCPP rock was selected for use in the current analysis.

METHODOLOGY

Earthquake-induced seismic coefficient time histories (and their peak values, k_{max}) for the potential sliding surfaces were computed using the two-dimensional dynamic finite element analysis program QUAD4M (Hudson and others, 1994). This is a time-step analysis that incorporates a Rayleigh damping approach and allows the use of different damping ratios in different elements. The program QUAD4M was verified in calculation package GEO.DCPP.01.34.

The program uses equivalent-linear, strain-dependent modulus and damping properties and an iterative procedure to estimate the non-linear strain-dependent soil and rock properties.

Selection of Input Motions

Geosciences Department of PG&E developed five sets of possible earthquake rock motions for the ISFSI site (see Attachment No. 1 as confirmed in Attachment 6) to be used as input to the analysis. These motions are estimated to originate on the Hosgri fault about 4.5 km west of the plant site. Both fault normal and fault parallel components were determined for each of the five sets of motions. The fault parallel component incorporated the fling effect; its positive direction was specified in the southeasterly fault direction (see Attachment No. 3 as confirmed in Attachment 5). The fault normal component has a direction normal to the fault, and its polarity can be either positive or negative depending on the assumed location of the initiation of the rupture. Based on Attachments 2 and 3 as confirmed in Attachment 7, the best estimate of the direction of movement along cross section I-I' (as shown in Figure 1) is 36 ± 10 degrees (counter-clockwise) from the direction of the strike of the Hosgri fault (i.e., to the southeast; see Attachment No. 2). The value of 10 degrees is used to address the uncertainties associated with the relative orientation between the fault and the analytical section. The fault normal component can be at $\pm$ 90 degrees from fault parallel direction, that is 36+90 = 126 (or 36-90 = -54) degrees from the direction of section I-I'. From these relations, the ground motion component along section I-I' can be determined from the specified components along the fault normal and fault parallel directions. The component along section I-I' will be referred to as the rotated component.

The rotated component along section I-I' direction is the sum of the projections of the fault normal and fault parallel components along the direction of section I-I'. The formulation is as follows:

$$II^{+} = F_P \cos(\phi) + F_N \sin(\phi)$$

and

$$II^{-} = F_P \cos(\phi) - F_N \sin(\phi)$$

in which the F_P and F_N are fault parallel and fault normal components of the acceleration time histories, II^{+} is the component along section I-I' (for a positive fault normal component), and II- is the component along section I-I' (for a negative fault normal component). ϕ is the angle between the up-slope direction of section I-I' and the fault parallel direction (southeast). The five sets of earthquake motions on the Hosgri fault are now rotated to earthquake motions along the up-slope direction of cross section I-I'. For a specified angle between section I-I' and the fault direction, there are 10 rotated earthquake motions along I-I' direction, because for each set the positive and negative directions of the fault normal component were considered separately.

The response of the slope was computed using, as input, control motions specified at the horizontal ground surface in the free field, approximately 800 feet from the toe of the slope. The originally developed five sets of potential earthquake motions all fit the ISFSI design spectrum. These motions were first rotated to the direction of cross section I-I' as described above. Then, approximate earthquake-induced displacements initially were computed for each set using a rigid sliding block model based on the Newmark approach (see calculation package GEO.DCPP.01.26). The two sets of rotated motions that produced the highest deformation in the rigid sliding block analysis (based on Table 1 of GEO.DCPP.01.26) were selected as input motions for the two-dimensional dynamic response analyses. These two sets of rotated motions were from set 1 and set 5 as described in calculation package GEO.DCPP.01.26. The acceleration time histories of these two motions are presented in Figures 2 and 3 for set 1 and set 5 motions, respectively. The corresponding velocity and displacement time histories are shown in Figures 4 and 5. The positive values indicate motions in the up-slope direction of the section I-I', that is estimated to be, at most, 46 degrees (counter-clockwise) from the direction of the strike of the Hosgri fault.

Because the base of the finite element mesh is at a depth of 300 feet, and because the QUAD4M program allows the input motion to be applied only at the base, the base motion was first computed by deconvolving the surface ground motion. The control motions specified at the ground surface (in the free field beyond the toe of the slope) were deconvolved using a one-dimensional wave propagation analysis SHAKE (Geomatrix version, 1995; see "Software" section) to obtain motions at the level of the base of the two-dimensional finite-element model. Calculation package GEO.DCPP.01.34 shows that, when using the base motion developed from SHAKE, the program QUAD4M can produce reasonably similar surface ground motions in the free field. This calculation package verified that the deconvolved motions could be specified as input (outcropping) motions at the base of the two-dimensional model. The rock below this depth was modeled as an elastic half-space that has the same shear wave velocity as the rock just above it.

Finite Element Model and Boundary Conditions

A finite element representation of the slope at ISFSI site along cross section I-I' is shown on Figure 6. The minimum thickness of the mesh layer (8 feet) was selected to allow propagation of shear waves having frequencies up to 25 Hz. The bedrock underlying the slope was modeled to a depth of about 300 feet below the horizontal free field near the toe of the slope. The base of the finite element mesh is treated as an elastic half-space. For the nodes at the two lateral boundaries, the dynamic displacement is allowed in the horizontal direction only when the horizontal input motion is applied at the base. In order to avoid unrealistic reflections from the lateral boundaries, we extended the lateral boundaries horizontally to a significant distance from the ISFSI site. Because the response is needed only at the specified potential sliding masses (located between the toe and about two-thirds the height of the slope), the laterally extended portion of the mesh does not accurately match the topography beyond these locations. The extended boundary was used only to improve the numerical accuracy of the response in the immediate vicinity of the slope, and not to model the response of the entire hillside.

SOFTWARE

The computer program QUAD4M was verified in calculation package GEO.DCPP.01.34.

The computer program SHAKE (modified by Geomatrix, 1995) was used to compute base motions in this calculation package. SHAKE originally was developed at the University of California, Berkeley (Schnabel, Lysmer, and Seed, 1972). Geomatrix modified the code to increase the sizes of arrays to accommodate more time history data points and more layer numbers. To verify the accuracy of the modified version of SHAKE (Geomatrix, 1995), we also applied two other independently modified versions of SHAKE. These two versions are SHAKE91, modified by the University of California, Davis (Idriss and Sun, 1991), and SHAKE96S, modified by International Civil Engineer Consultants (ICEC, 1995). SHAKE96S was independently verified by ICEC using the theoretical methods documented in Tseng and Hamasaki (1996). A test was performed involving deconvolution of ground motions using the design ground motions (with peak acceleration close to 1g) and the analytical profile developed for the ISFSI site. The maximum difference between the three deconvolved motions obtained using the three versions of SHAKE was on the order of 10^{-6}g, demonstrating that the results from SHAKE (Geomatrix, 1995) were appropriate for use in this project. The results of these verification runs are included on the enclosed compact disc.

ANALYSIS

The results of the dynamic analyses provide a distribution of the earthquake-induced accelerations and stresses within all elements of the modeled slope profile (cross section I-I'). Using the rotated input motion developed from sets 1 and 5, computed peak accelerations along the slope surface are presented on Figure 9. Contours of computed peak acceleration within the slope, using input motion sets 1 and 5, are shown on Figure 10 and 11, respectively. Acceleration time histories were calculated for a total of 26 locations within three potential sliding masses (namely 1b, 2c, and 3c), as shown in Figure 12. These sliding masses have the least computed yield accelerations among potential sliding masses along the various clay beds within the slope, as shown in GEO.DCPP.01.24. The locations of these potential sliding masses are presented on Figure 12. Average acceleration time histories were estimated for each mass (using the acceleration time histories computed at locations inside the three masses) and are presented in Figure 13 and 14 for input motion sets 1 and 5, respectively.

Section I-I' is oriented 36 degrees from the direction of the Hosgri fault strike, and its highest elevation is about 750 feet. In order to investigate the sensitivity of the computed seismic response to the variations in the orientation of the section analyzed, a cross section was selected that has an orientation slightly different from that of I-I'. This section basically is along the ridge of the slope behind the ISFSI site, and extends as high as 1100 feet in elevation, whereas section I-I' levels out at elevation 750 feet.

The computed peak surface accelerations are presented in Figure 15 for input motion set 1. Figure 15 shows that the differences in terms of peak surface accelerations between the two sections in the zone of interest are not significant. This result shows that the computed seismic responses are not sensitive to slight changes in the orientation of section I-I', or in the total height of the hillside included in the analysis.

RESULTS

The computed peak surface accelerations indicate some amplification (up to 35%) along the up-slope direction for set 5 motions, as shown on Figure 9. The amplification effects for set 1 are not significant. The computed peak acceleration contours (as shown on Figures 10 and 11) indicate a decrease in accelerations with depth below the slope. The calculated average accelerations for potential sliding mass 1b show a slight increase compared with the input motion due to the amplification effect at the slope surface, while the deeper sliding masses 2c and 3c show a slight decrease due to the reduction of peak accelerations with depth. The waveforms of the computed average acceleration (as shown on Figures 13 and 14) are generally similar to the input motions shown in Figures 2 and 3. This is because the material of the slope is composed basically of rock mass with relatively high shear wave velocities.

REFERENCES

1. Geomatrix Consultants, Inc. Work Plan, Laboratory Testing of Soil and Rock Samples, Slope Stability Analyses, and Excavation Design for Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site, Revision 2, dated October 8, 2000.
2. Geosciences Calculation Package GEO.DCPP.01.21, Revision 1, Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPP ISFSI Site.
3. Geosciences Calculation Package GEO.DCPP.01.24, Revision 1, Stability and yield acceleration analysis of cross-section I-I'.
4. Geosciences Calculation Package GEO.DCPP.01.26, Revision 1, Determination of Potential Earthquake-Induced Displacements of Potential Sliding Masses on DCPP ISFSI Slope (Newmark Analysis).
5. Geomatrix Consultants, Inc., 1995, Modification of Program SHAKE.
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7. Hudson, M., Idriss, I.M. and Beikae, M, 1994, QUAD4M (program and User's manual) Center for Geotechnical Modeling, Department of Civil & Environmental Engineering, University of California, Davis, California.
8. Idriss, I.M., and Sun, Joseph I., 1991, User's manual for SHAKE91, program modified based on the original SHAKE program published in December 1972 by Schnabel, Lysmer, and Seed, Center for Geotechnical Modeling, Department of Civil &

Environmental Engineering, University of California, Davis, California. November 1992.

9. PG&E, 1988, Final Report of the Diablo Canyon Long Term Seismic Program, July.
10. Schnabel, P.B., Lysmer. J. and Seed, H.B., SHAKE, A computer program for earthquake response analysis of horizontally layered sites, EERC Report No. 72-12, University of California, Berkeley, December.
11. Tseng and Hamasaki, 1996.

ATTACHMENTS

1. 09/28/2001, PG&E Geosciences, Robert K. White, Re: Confirmation of transmittal of inputs for DCPP ISFSI slope stability analyses, pages 25 through 27.
2. 08/3/2001, William Lettis & Associates, Inc., Jeff Bachhuber, Re: Ground Motion Directional Components, pages 28 and 29.
3. 08/23/2001, William Lettis & Associates, Inc., Jeff Bachhuber, Re: Revised Estimates for Hosgri Fault Azimuth, DCPP ISFSI Project, pages 30 and 31.
4. 10/18/2001, PG&E Geosciences, Joseph Sun, Re: Positive direction of the fault parallel component time history on the Hosgri fault, pages 32 through 35.
5. 10/25/2001, PG&E Geosciences, Robert White, Re: Input parameters for calculations, pages 36 through 41.
6. PG&E Geosciences, Robert White, Re: Confirmation of preliminary inputs for DCPP ISFSI site, pages 42 through 44.
7. 11/1/2001, PG&E Geosciences, Robert White, Re: Confirmation of additional inputs to calculations for DCPP ISFSI site, pages 45 through 48

ENCLOSURE

Compact disc labeled, "PG&E DCPP ISFSI, GEO.DCPP.01.24, Rev. 1; GEO.DCPP.01.25, Rev. 1; and GEO.DCPP.01.26 , Rev. 1, December 13, 2001," and containing the input and output files for determination of seismic coefficient time histories for potential sliding masses along cut slope behind ISFSI pad.

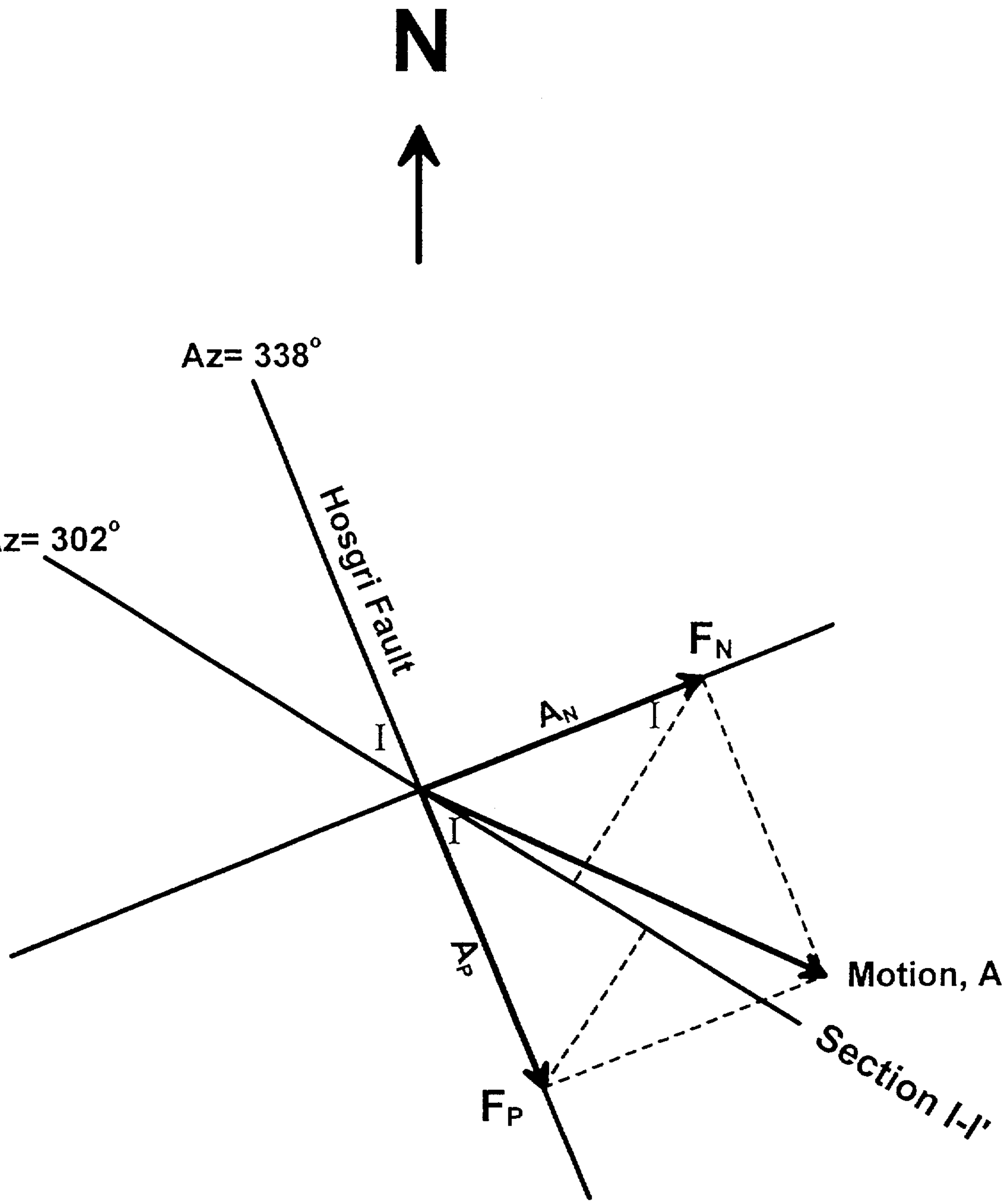

Figure 1. Orientations of Section I-I' and Hosgri Fault.

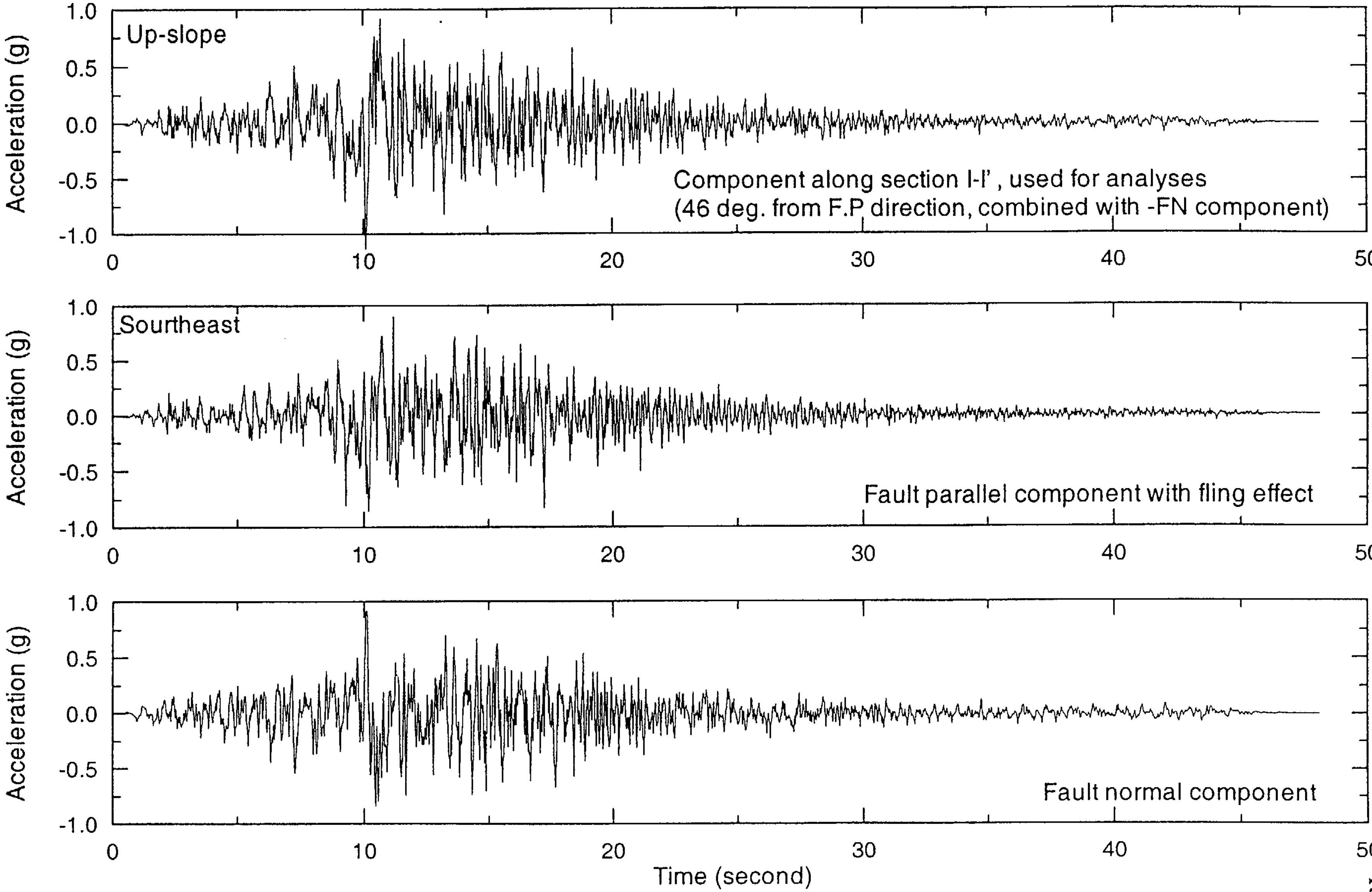

Figure 2. Acceleration time histories of fault normal, fault parallel and rotated I-I components of Set 1.

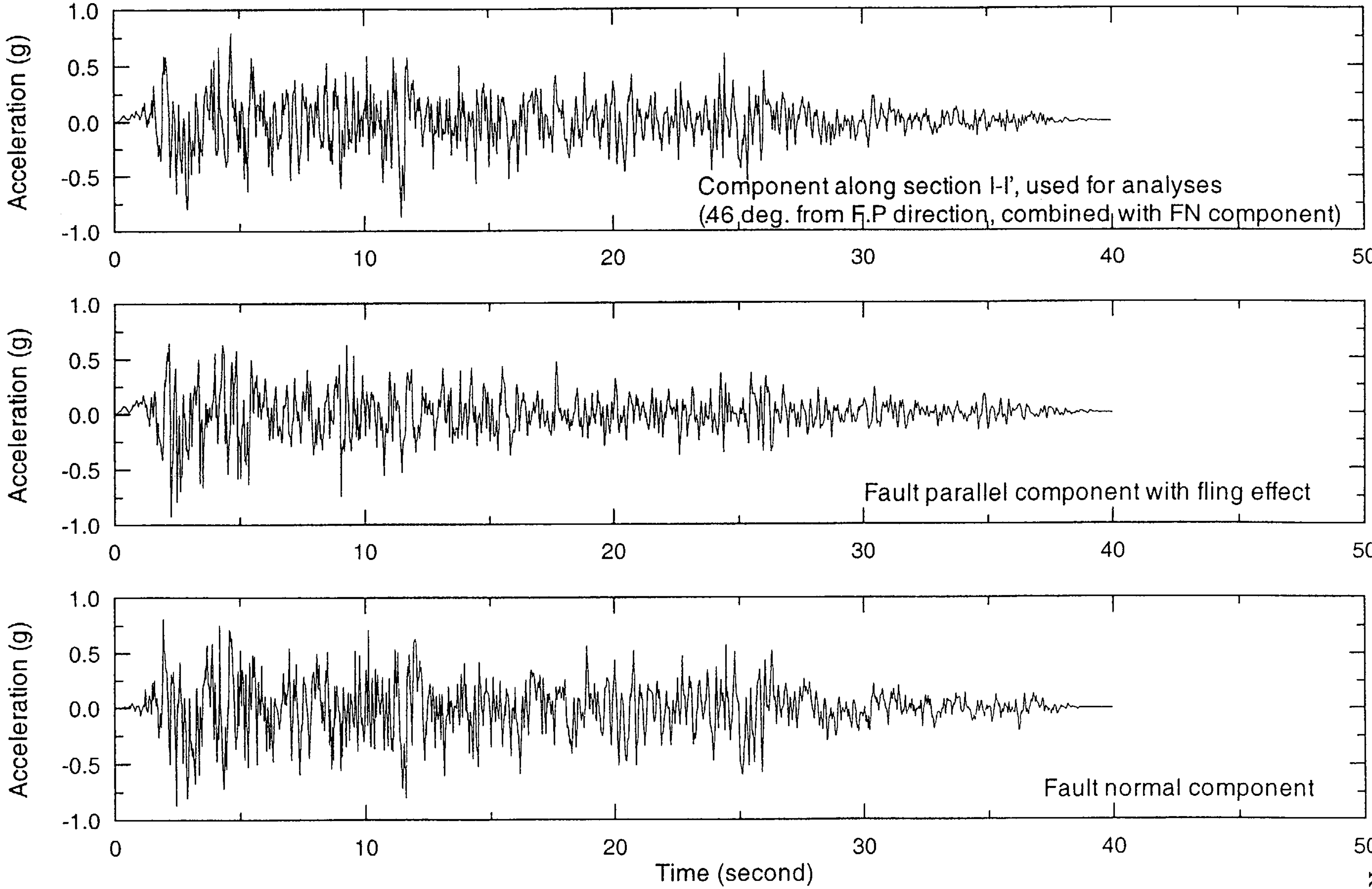

Figure 3. Acceleration time histories of fault normal, fault parallel and rotated I-I' components of Set 5.

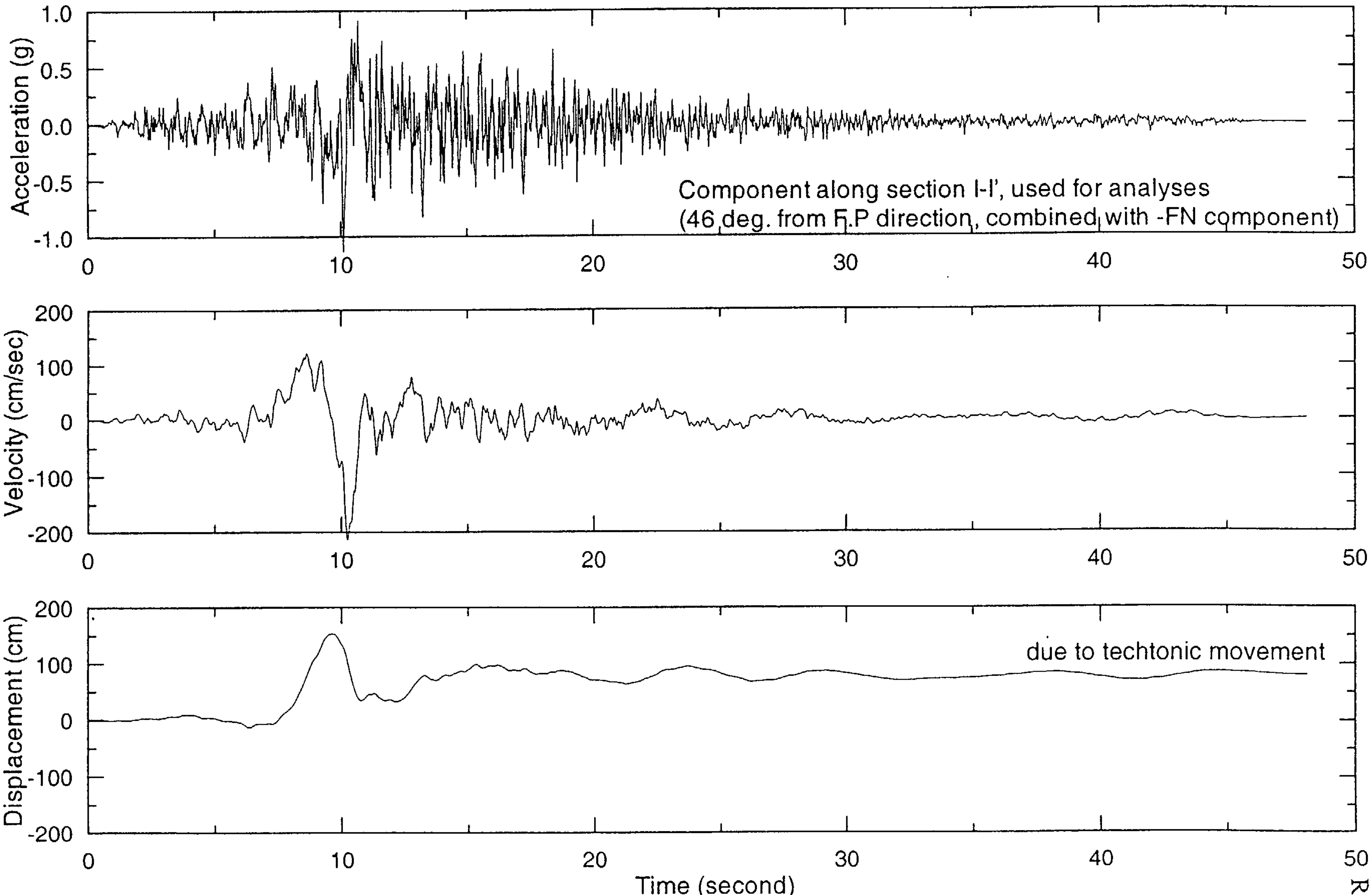

Figure 4. Time histories of acceleration, velocity, and displacement from I-I' components of set 1.

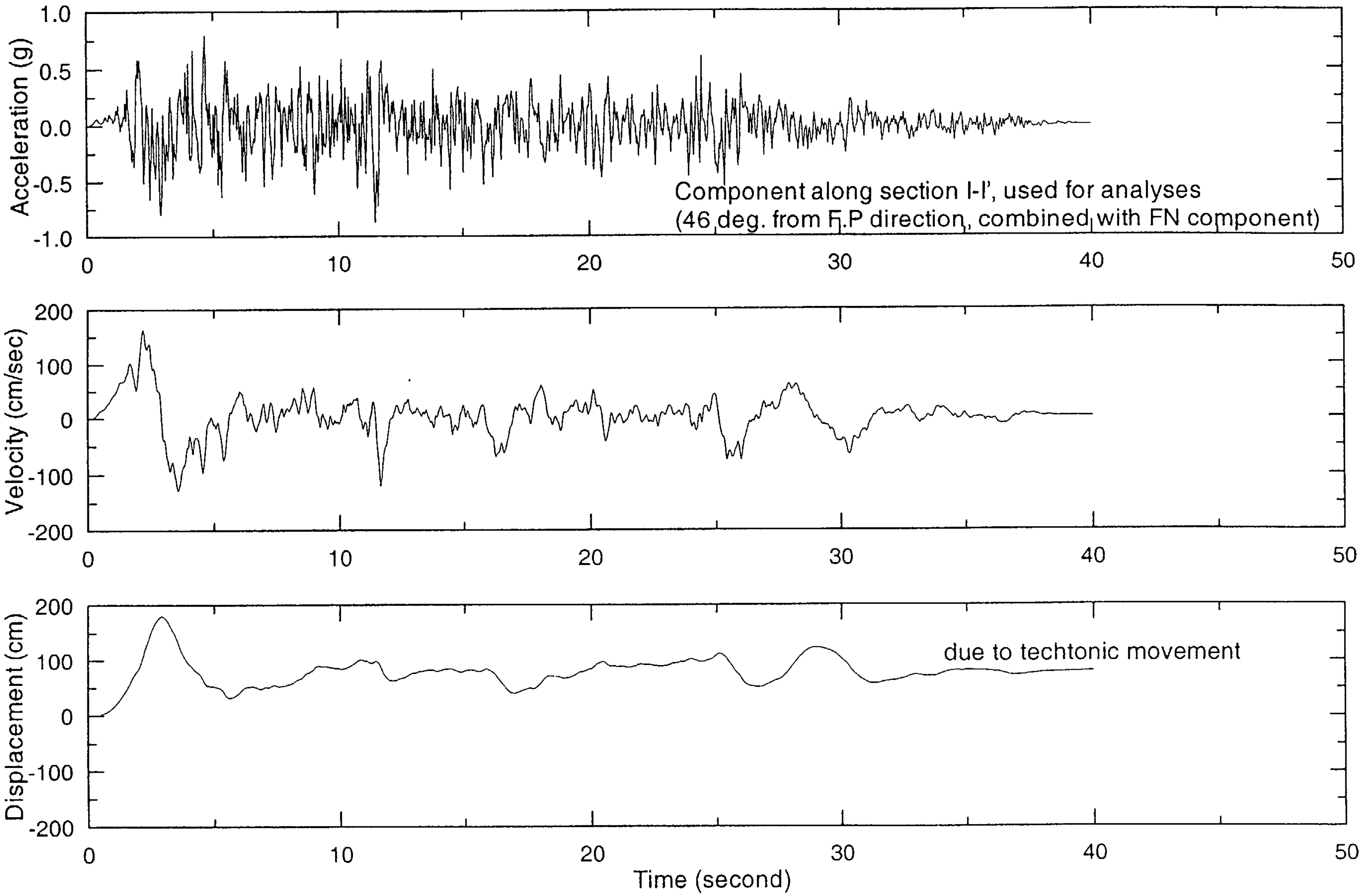

Figure 5. Time histories of acceleration, velocity, and displacement from I-I' components of set 5.

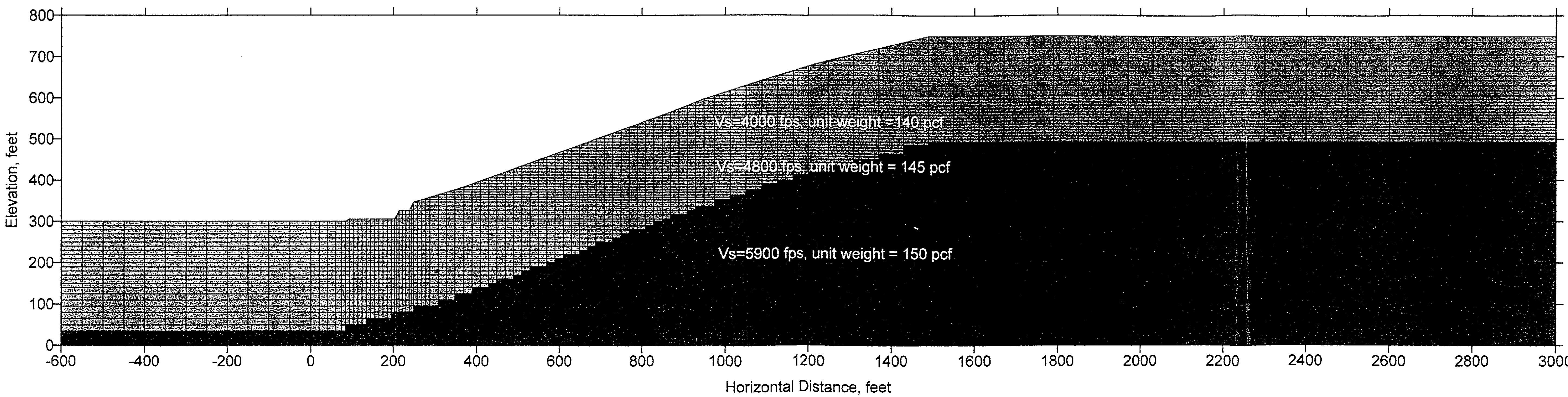

Figure 6. Finite Element Representation of Slope at ISFSI Site, Cross Section I-I.

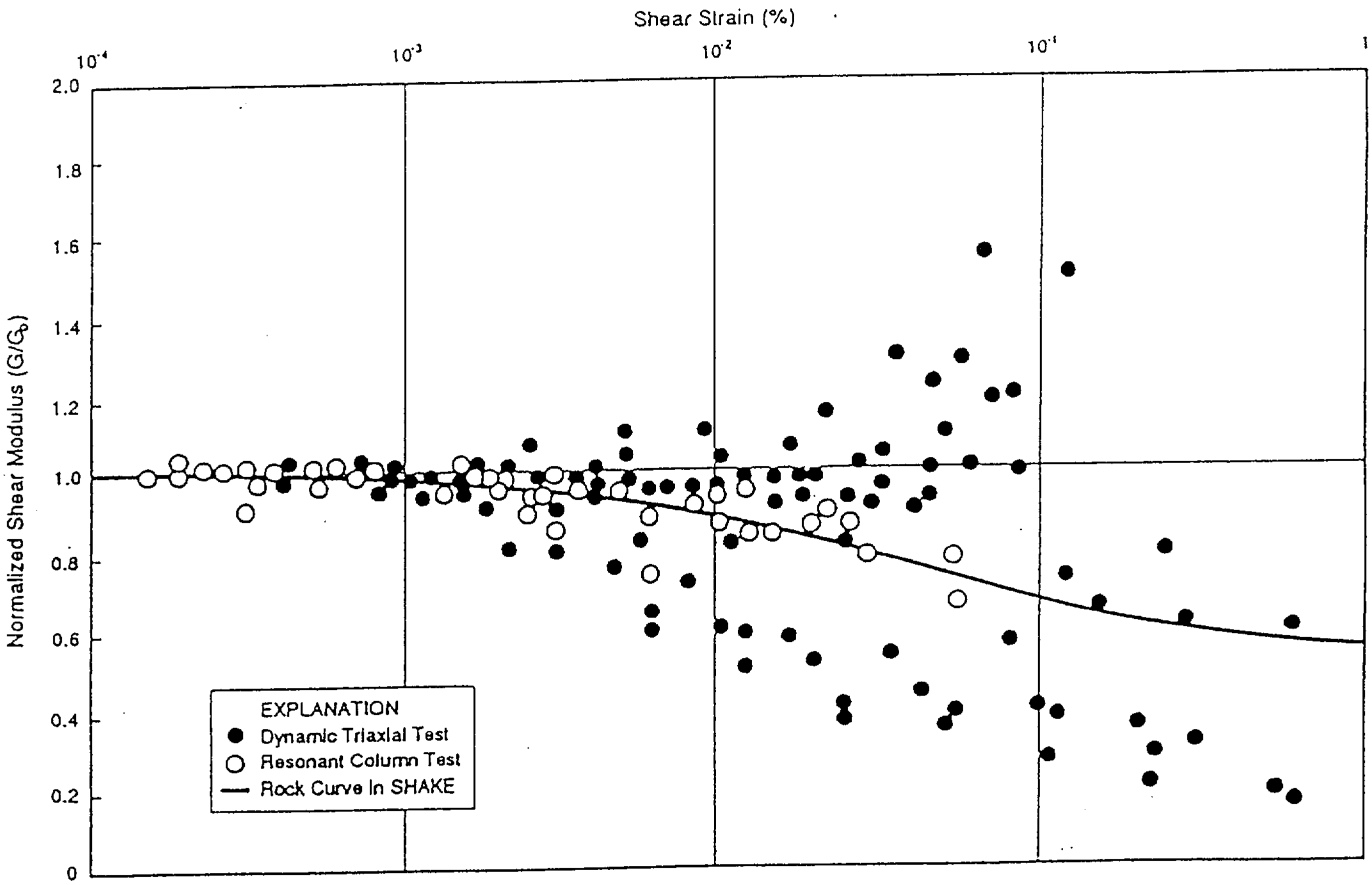

Figure 7

Variation of shear modulus with shear strain for the site rock based on 1978 laboratory test data.

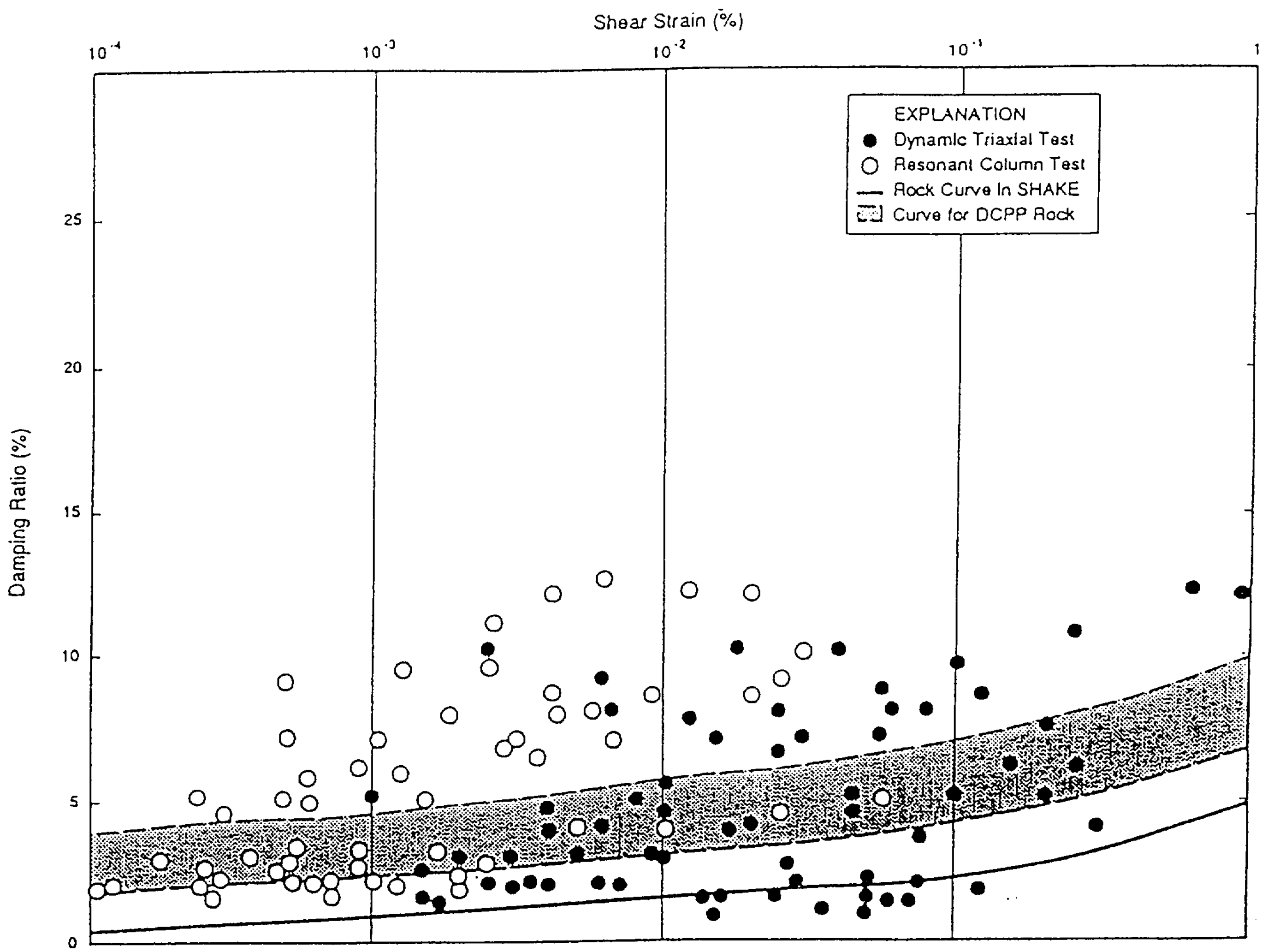

Figure 8

Variation of damping ratio with shear strain for the site rock based on 1977 laboratory test data.

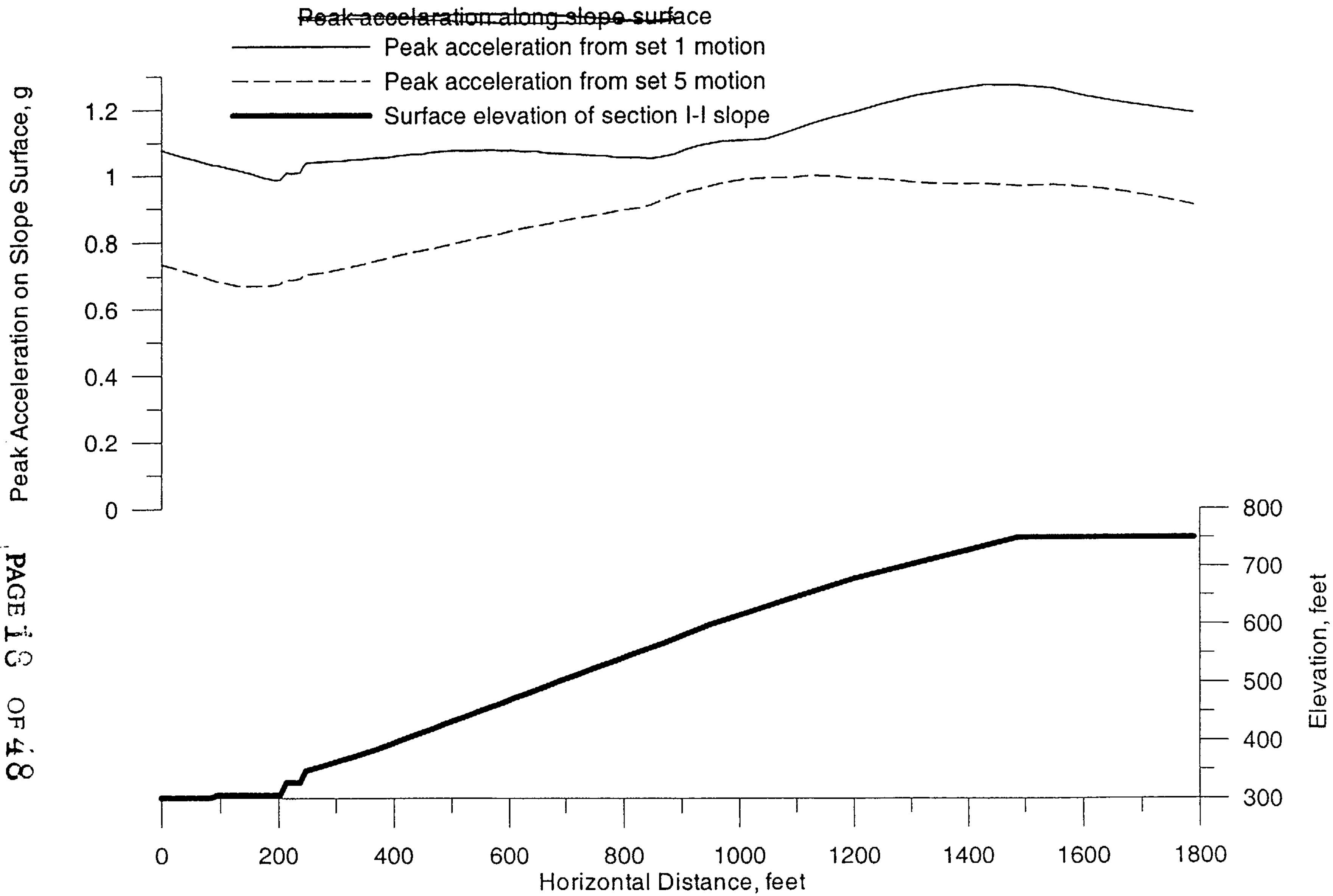

Figure 9. Computed peak acceleration along slope surface

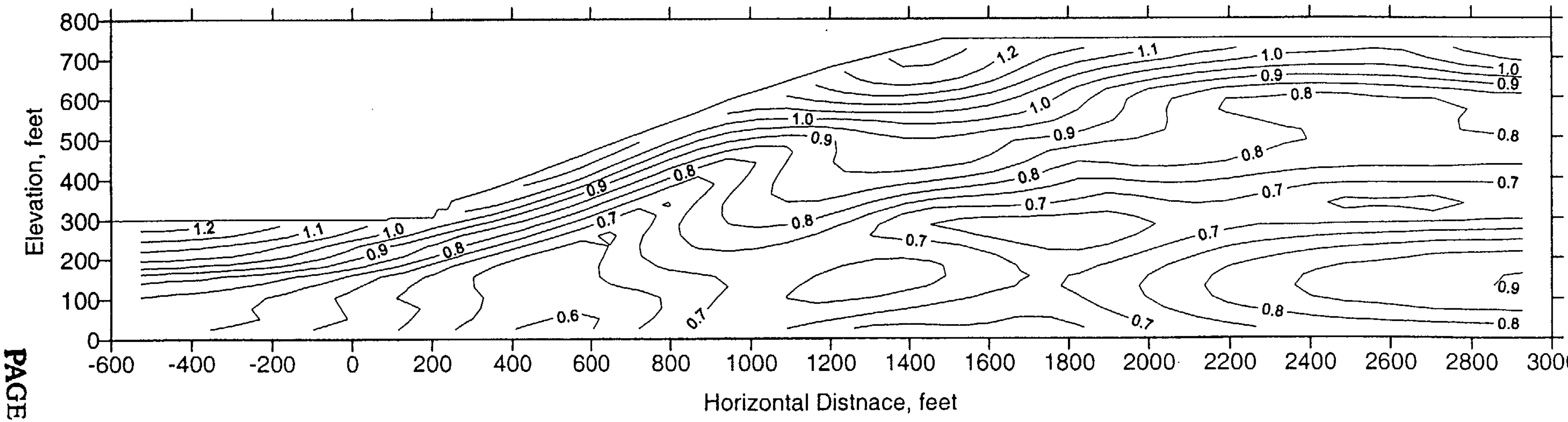

Figure 10. Contours of peak acceleration induced by motion set 1 along section I-I'.

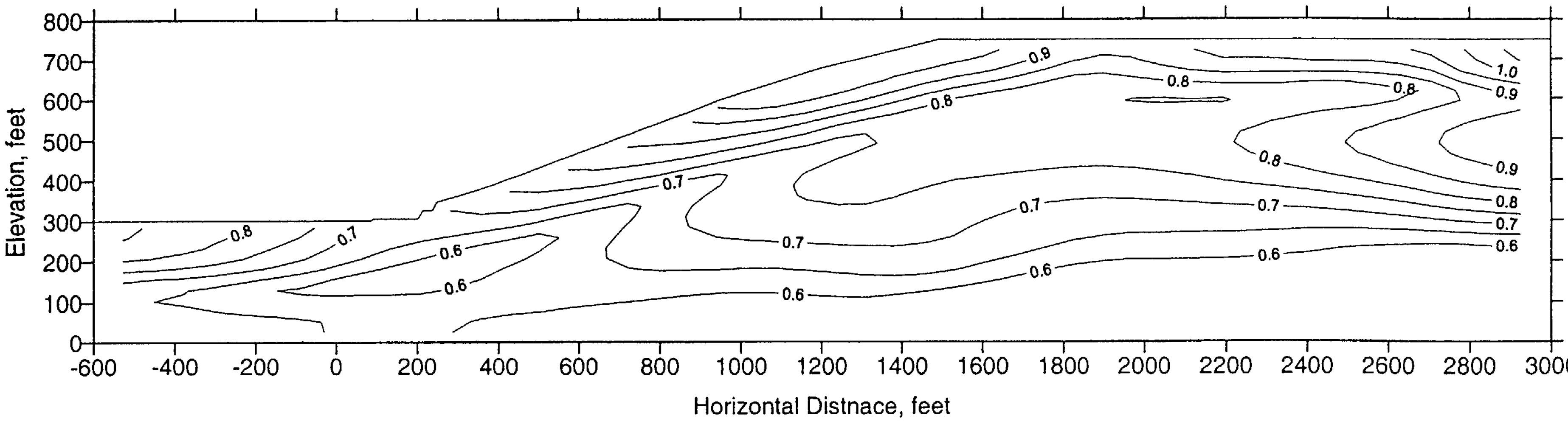

Figure 11. Contours of peak acceleration induced by motion set 5 along section I-I'.

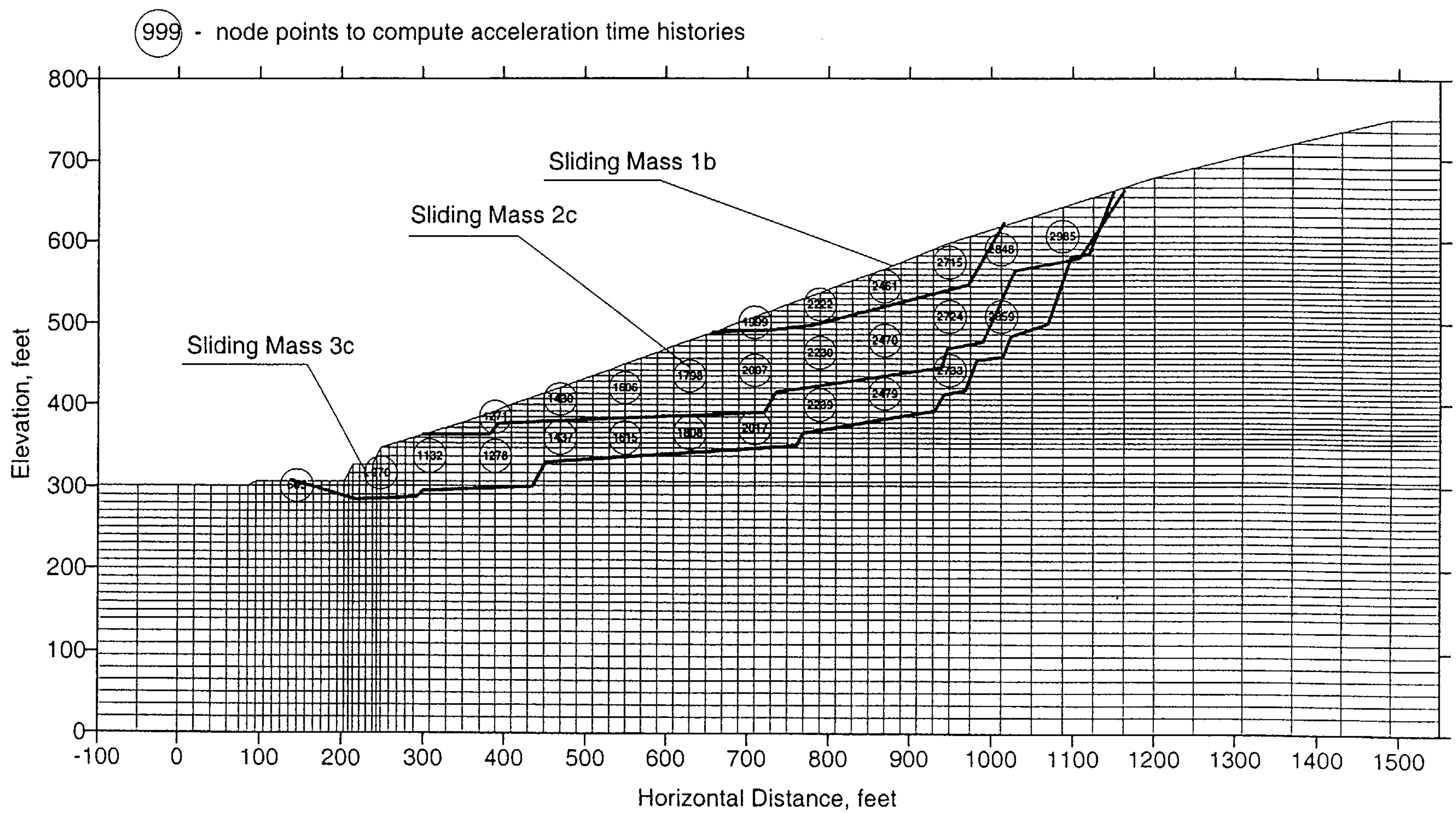

Figure 12. Potential sliding masses and node points for computed acceleration time histories

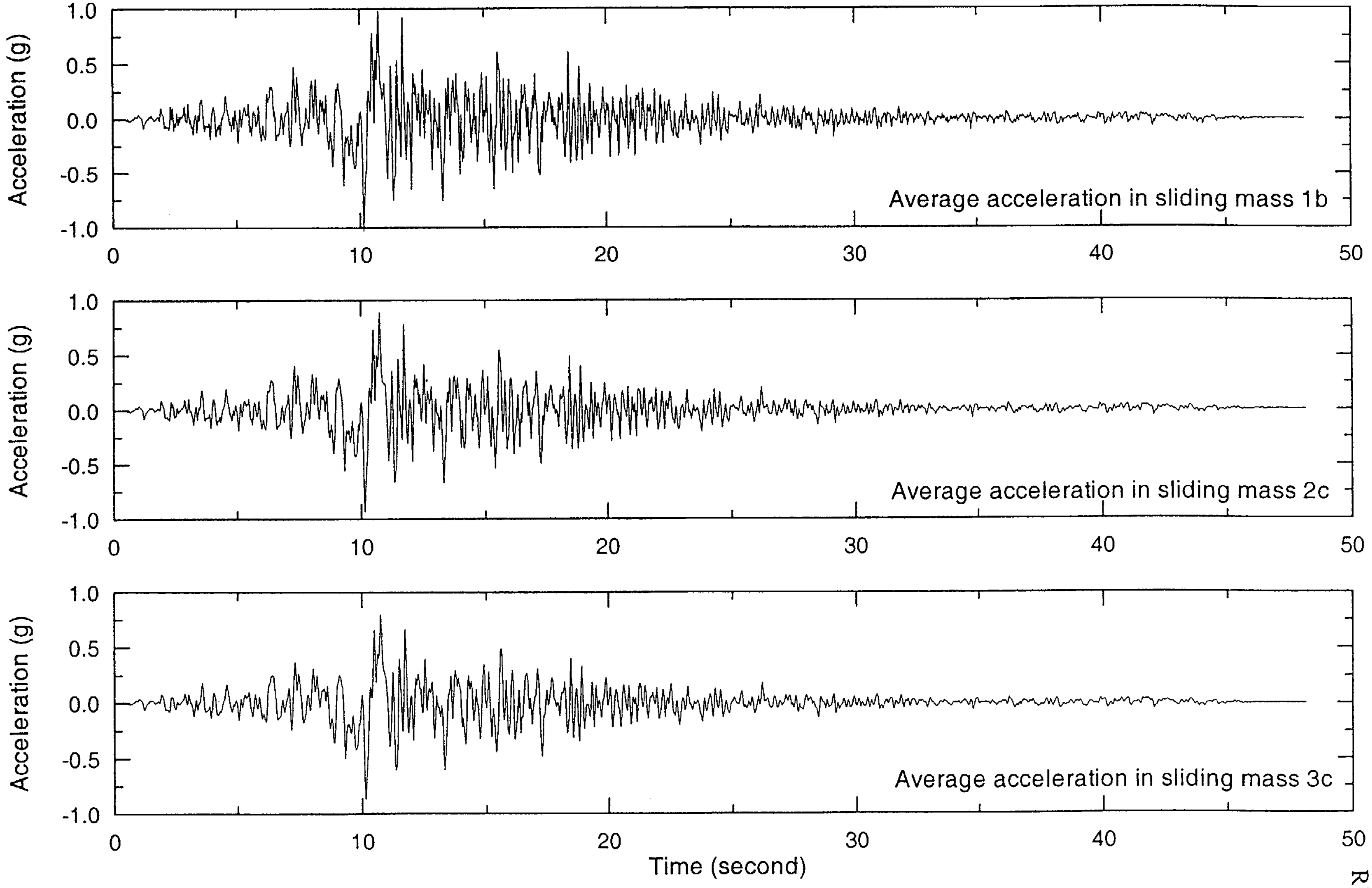

Figure 13. Average acceleration time histories of potential sliding masses using input motion set 1

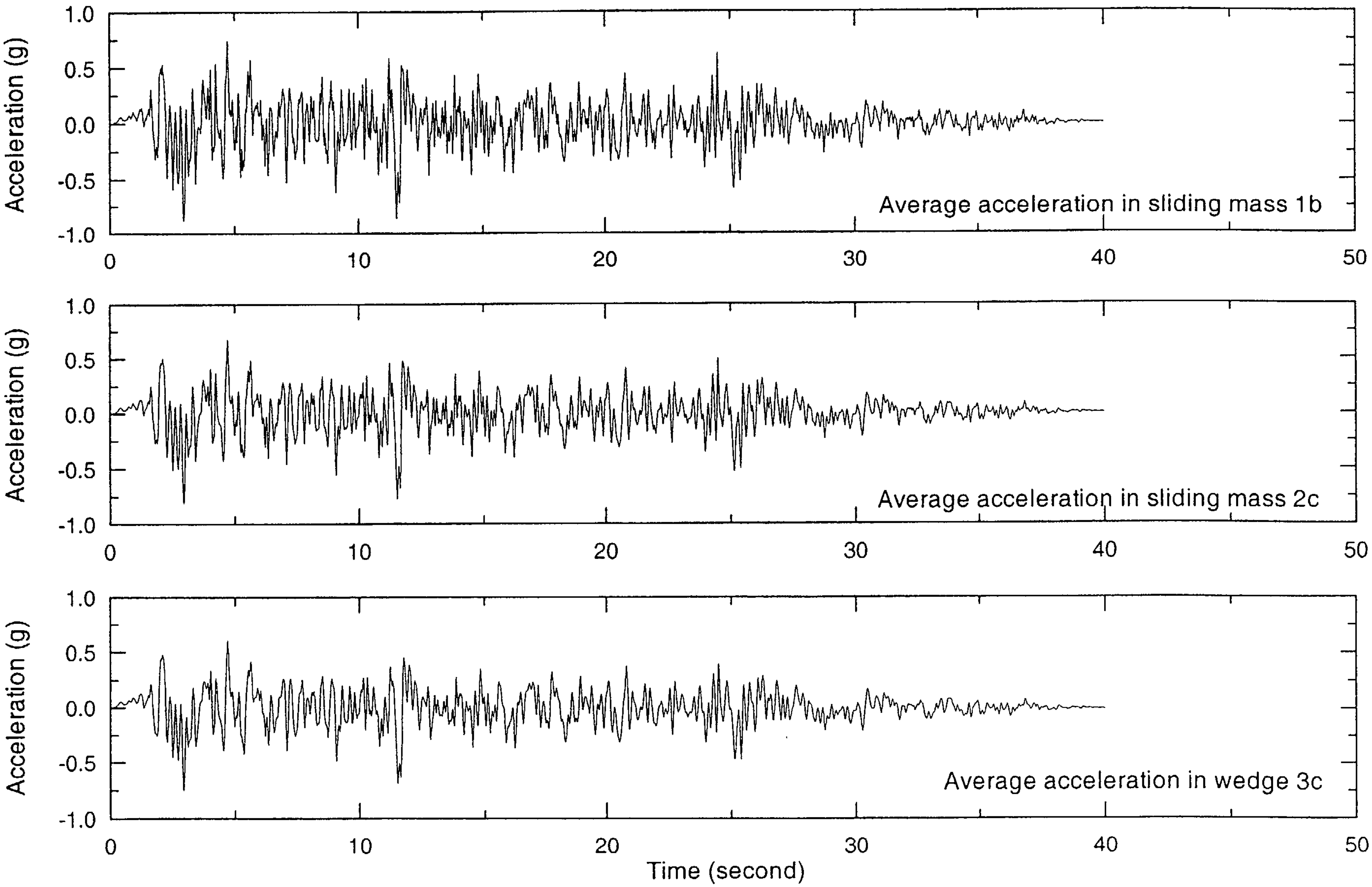

Figure 14. Average acceleration time histories of potential sliding masses using input motion set 5.

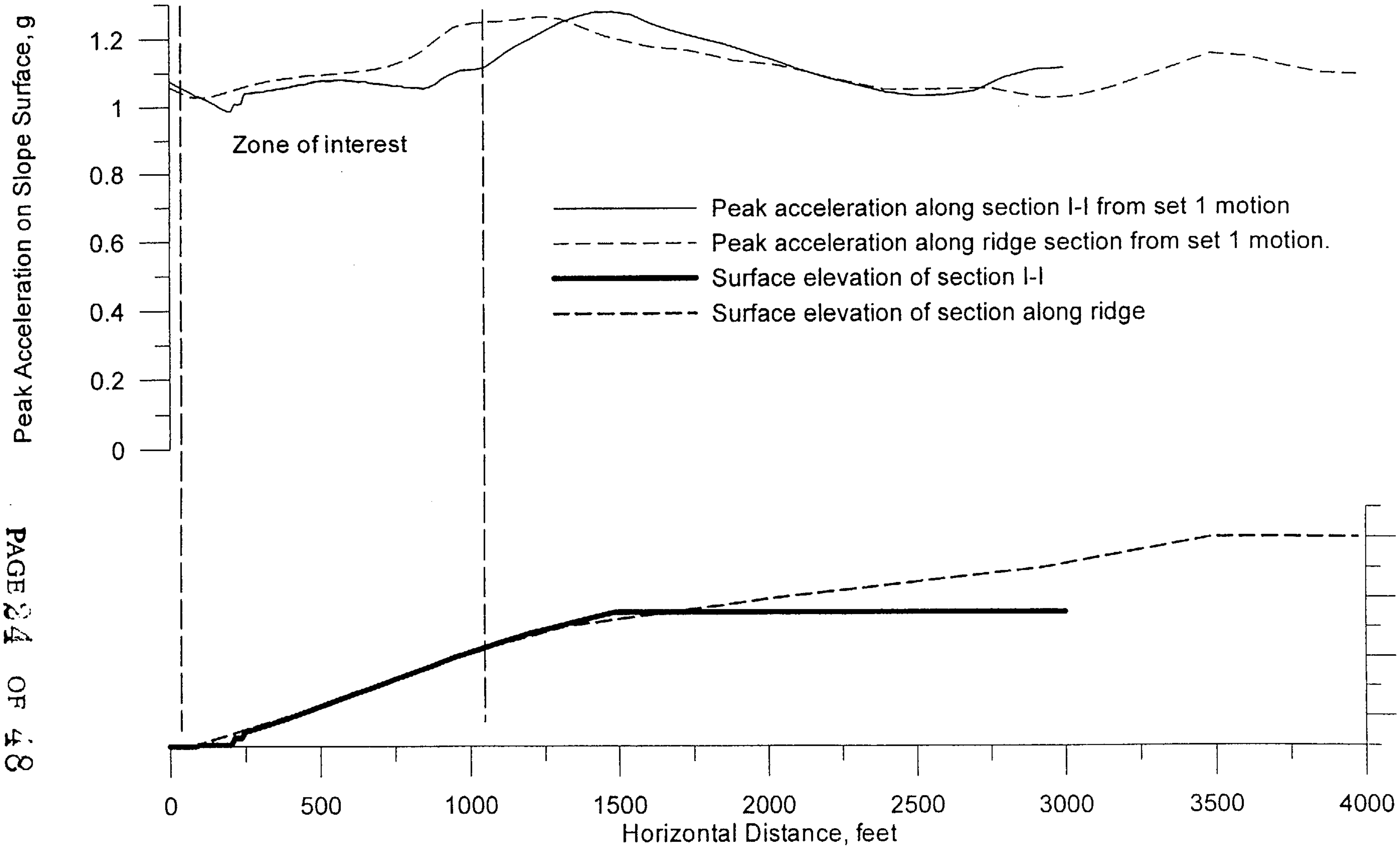

Figure 15. Variations of computed peak acceleration along slope surface.

ATTACHMENT 1

Pacific Gas and Electric Company

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GEO.DCPP.01.25

REVISION 1

Dr. Faiz Makdisi
Geomatrix Consultants
2101 Webster Street
Oakland, CA 94612

September 28, 2001

Re: Confirmation of transmittal of inputs for DCPP ISFSI slope stability analyses

DR. MAKDISI:

This is to confirm transmittal of inputs related to slope stability analyses you are scheduled to perform for the Diablo Canyon Power Plant (DCPP) Independent Spent Fuel Storage Installation (ISFSI) under the Geomatrix Work Plan entitled "Laboratory Testing of Soil and Rock Samples, Slope Stability Analyses, and Excavation Design for the Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site."

Inputs transmitted include:

Drawing entitled "Figure 21-19, Cross Section I-I'," dated 9/27/01, labeled "Draft," and transmitted to you via overnight mail under cover letter from Jeff Bachhuber of WLA and dated 9/27/01.

Time histories in Excel file entitled "time_histories_3comp_rev1.xls," dated 8/17/2001, file size 3,624 KB, which I transmitted to you via email on 8/17/2001.

Please confirm receipt of these items and forward confirmation to me in writing.

Please note that both these inputs are preliminary until the calculations they are part of have been fully approved. At that time, I will inform you in writing of their status. These confirmation and transmittal letters are the vehicles for referencing input sources in your calculations.

Although the Work Plan does not so state, as you are aware all calculations are required to be performed as per Geosciences Calculation Procedure GEO.001, entitled "Development and Independent Verification of Calculations for Nuclear Facilities," revision 3. All of your staff assigned to this project have been previously trained under this procedure.

I am also attaching a copy of the Work Plan. Please make additional copies for members of your staff assigned to this project, review the Work Plan with them, and have them sign Attachment 1. Please then make copies of the signed attachment and forward to me.

If you have any questions, feel free to call.

Thanks.

Rob White

ROBERT K. WHITE

Attachment

cc: Chris Hartz

ATTACHMENT 2

WLA MEMORANDUM
William Lettis & Associates, Inc.
1777 Botelho Drive, Suite 262, Walnut Creek, California 94596
Voice: (925) 256-6070 FAX: (925) 256-6076

TO: Dr. Faiz Makdisi - Geomatrix Consultants, Inc.
FROM: Jeff L. Bachhuber - William Lettis & Associates, Inc.
DATE: August 3, 2001

RE: Ground Motion Directional Components

FAIZ:

At the request of Robert K. White of PG&E Geosciences Department, we prepared this memorandum that documents our review of ground motion directional components for slope stability analyses at the PG&E DCPP ISFSI site. It is our understanding that you will be rotating ground motions developed by PG&E to the best-estimated downslope failure direction and require an appropriate rotation angle from the Hosgri fault parallel direction.

Based on our geologic characterization, the most likely slope failure direction would be along cross section I-I' on the attached figure 21-3, or along an azimuth orientation of about 302° ±10°. We believe that this value is conservatively realistic.

Please call me if you have any questions or require further input for this issue.

Cc: Rob White/Bill Page - PG&E Geosciences

ATTACHMENT 3

WLA William Lettis & Associates, Inc.
1777 Botelho Drive, Suite 262, Walnut Creek, California 94596
Voice: (925) 256-6070 FAX: (925) 256-6076

MEMORANDUM

TO: Dr. Faiz Makdisi - Geomatrix Consultants, Inc.
FROM: Jeff L. Bachhuber - William Lettis & Associates, Inc.
DATE: August 23, 2001

RE: Revised Estimates for Hosgri Fault Azimuth, DCPP ISFSI Project

FAIZ:

This memorandum provides a revised strike azimuth of 338° for the Hosgri fault for evaluation of ground motion directional components for slope stability analyses at the PG&E DCPP ISFSI site. The revised azimuth presented in this memorandum supercedes the previous estimated azimuths (328° to 335°) presented in our memorandum dated August 8, 2001, and is based on a re-evaluation of fault maps in the PG&E LTSP (1988), and ISFSI project Calculation Package GEO.01.21.

The revised estimated average strike for the Hosgri fault nearest the ISFSI site (between Morro Bay and San Luis Bay) is 338°. Figure 21-23 of Calculation Package GEO.01.21, which previously showed an azimuth of 340° for the Hosgri fault, will be revised to correspond to this re-interpreted average strike. Discrete faults and local reaches of the fault zone exhibit variations in strike azimuth between about 328° and 338°, but the average overall strike of 338° is believed to be the best approximation for the ground motion modeling.

Please call me if you have any questions or require further input for this issue.

[signature]

Jeff Bachhuber

Cc: Rob White/Bill Page - PG&E Geosciences

ATTACHMENT 4

Pacific Gas & Electric Company
Geosciences Department

P.O. Box 770000, Mail Code N4C
San Francisco, CA 94177
Fax: (415) 973-5778

TELEFAX COVER SHEET

Date: Oct 18 '01

Number of pages including cover sheet: 3

To: Faiz Makdisi
Company: Geomatrix

Phone: (510) 663-4100
Fax: (510) 663-4141
cc:

From: Joseph Sun
Company: PG&E

Phone: (415) 973-2460
Fax: (415) 973-5778

REMARKS: ☐ Per request ☐ For review ☐ Reply ASAP ☐ Please comment

Faiz,

The fault parallel with fling ground motions positive is to the southeast. We will follow up with a formal transmittal of the calc package to you

Joseph

c:\data\forms\fax cover.doc

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number GEO.DCPP.01.14
Revision 1
Date October 15, 2001
Calc Pages: 26
Verification Method: A
Verification Pages: 17 & 8 Attachments

TITLE: Development of time histories with Fling

PREPARED BY: [signature] DATE October 15, 2001

Norman Abrahamson — Printed Name
Geosciences — Organization

VERIFIED BY: [signature] DATE October 15, 2001

Joseph Sun — Printed Name
Geosciences — Organization

APPROVED BY: [signature] DATE 10/15/01

Lloyd Cluff — Printed Name
Geosciences — Organization

REGISTERED GEOLOGIST — LLOYD S. CLUFF — No. 1725 — STATE OF CALIFORNIA
Expires: 12/31/02

REGISTERED GEOLOGIST — LLOYD S. CLUFF — No. EG567 — CERTIFIED ENGINEERING GEOLOGIST — STATE OF CALIFORNIA
Expires: 12/31/02

6. BODY OF CALCULATIONS

Step 1: S-wave arrival times

The approximate arrival times of the S-waves is estimated by visual inspection of the velocity time histories (Figures 1, 2, 3, 4, and 5). The selected arrival times are listed in Table 6-1.

Table 6- 1. Time of Fling

Set	Reference Time History	Approximate Arrival time of S-waves	Arrival Time of fling (t_1) (sec)	Polarity*
1	Lucerne	8.0	7.1	-1
2a	Yarimca	9.0	8.5	-1
3	LGPC	4.0	3.4	-1
5	El Centro (1940)	1.5	0.0	1
6	Saratoga	4.5	3.7	-1

* The polarity is applied to the fault parallel time history from calculations GEO.DCPP.01.13 (rev 1) to cause constructive interference between the S-wave and the fling (eq. 5-2).

A fling arrival time is selected by visual inspection of the interference of the velocity of the transient motion and the fling (Figures 1, 2, 3, 4, and 5). The selected fling arrival time are listed in Table 6-1.

Since DCPP is on the east side of the Hosgri fault and the fault has right-lateral slip, the permanent tectonic deformation at the site will be to the southeast. In the time histories the fling has a positive polarity. Since the tectonic deformation will be to the southeast, the positive direction of the fault parallel time history is defined to the southeast.

Step 2: Fling Time History

Using the values of A, ω, and T_{fling} given in input 4-1, and the values of t_1 given in Table 6-1, the fling time history is determined using eq. (5-1). The computed fling time histories for the 5 sets are shown in Figures 1, 2, 3, 4, and 5.

ATTACHMENT 5

Pacific Gas and Electric Company

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Fax 415/973-5778

GEO.DCPP.01.25

REVISION 1

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

October 25, 2001

Re: Input parameters for calculations

DR. MAKDISI:

As required by Geosciences Calculation Procedure GEO.001, entitled "Development and Independent Verification of Calculations for Nuclear Facilities," rev. 4, I am providing you with the following input items for your use in preparing calculations.

1. The shear wave velocity profiles obtained in borings BA98-1 and BA98-3 in 1998 are presented in Figure 21-42, attached, of Calculation GEO.DCPP.01.21, entitled "Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPP ISFSI Site," rev. 0, and can be so referenced. These profiles were previously presented in Figure 10 of the WLA report entitled "Geologic and Geophysical Investigation, Dry Cask Storage Facility, Borrow and Water Tank Sites," dated January 5, 1999.

2. The average unit weight of rock obtained from the hillside has been determined to be 140 pounds per cubic foot, as documented in a data report entitled "Rock Engineering Laboratory Testing - GeoTest Unlimited."

3. Regarding the time histories provided to you on 8/17/01, since the tectonic deformation will be to the southeast, the positive direction of the fault parallel time history is defined as to the southeast, as described in Geosciences Calculation GEO.DCPP.01.14, entitled "Development of Time Histories with Fling," rev. 1, page 4.

4. The source of the shear modulus and damping curves are Figures Q19-22 and Q19-23, attached, from PG&E, 1989, Response to NRC Question 19 dated December 13, 1988, and can be so referenced.

Regarding format of calculations, please observe the following:

Contents of CD-ROMs attached to calculations should be listed in the calculation, including title, size, and date saved associated with each file on the CD-ROM. If the number of files is considerable, a simple screen dump of the CD-ROM contents is sufficient.

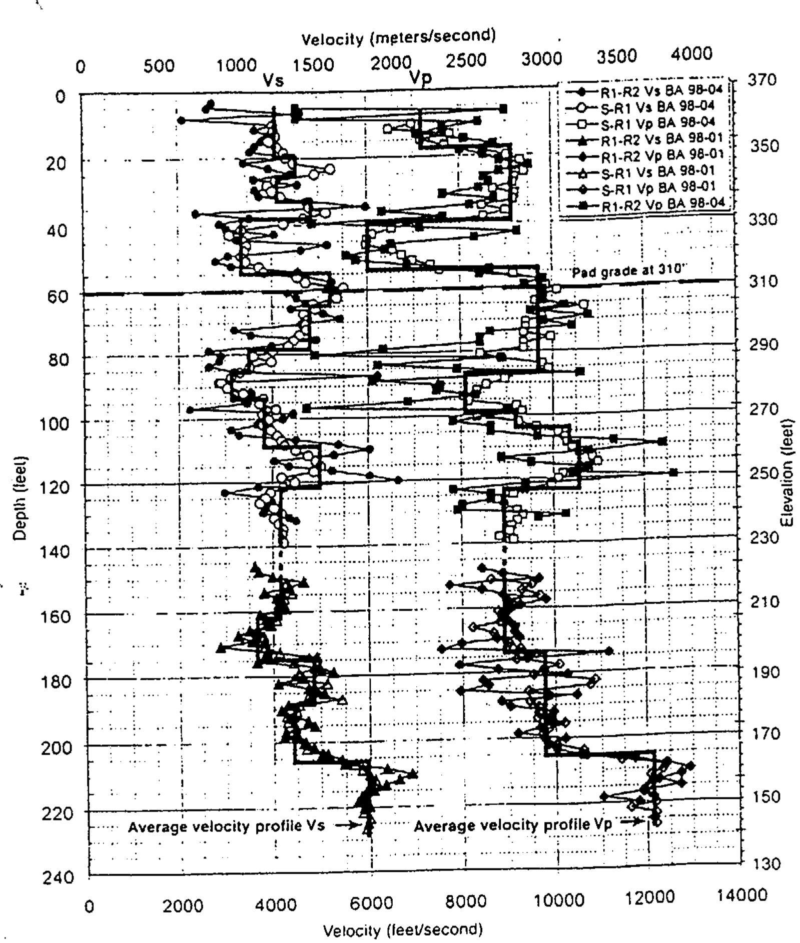
If you have any questions regarding the above, please call me.

Robert K White

ROBERT K. WHITE

Attachments

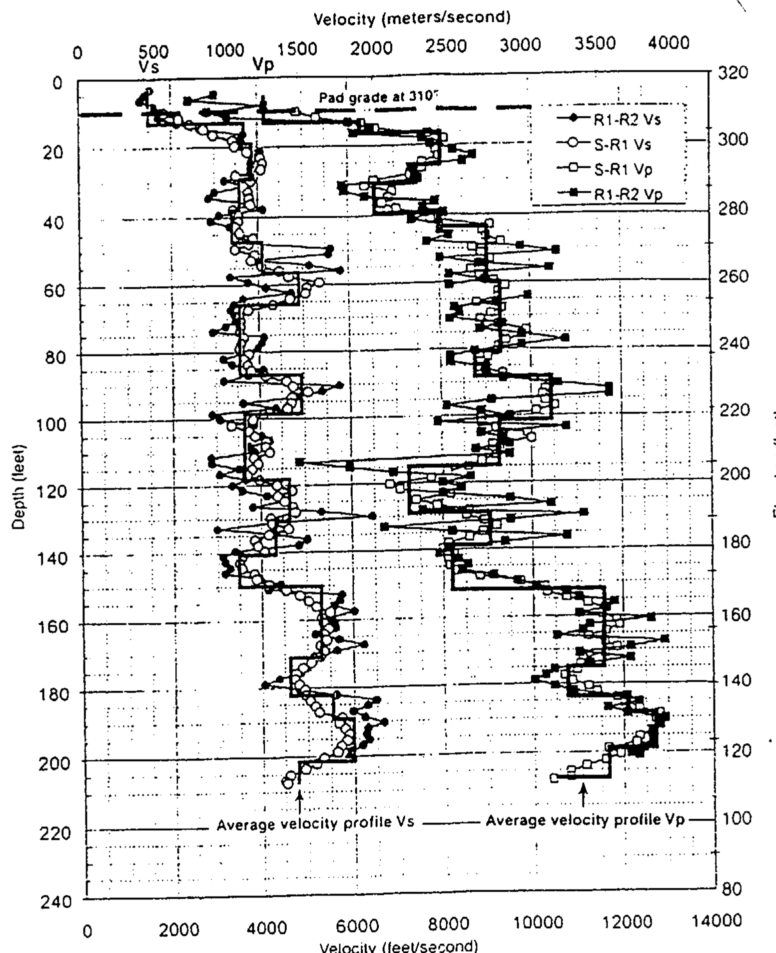
Borings 98BA-1 and 98BA-4



Note: Average velocity profiles interpreted from data.

R1 - R2 = Receiver-to-receiver velocity (3.3-foot spacing)
S-R1 = Source-to-receiver velocity (10.3-foot spacing)

Boring 98BA-3



Modified from GeoVision (1998), DCPP ISFSI SAR Section 2.6 Topical Report Appendix C

DIABLO CANYON ISFSI

FIGURE 21-42
ISFSI SITE SUSPENSION LOGS AND INTERPRETED AVERAGE SEISMIC VELOCITIES

GEO.DCPP.01.21 REV 0 October 15, 20[illegible]

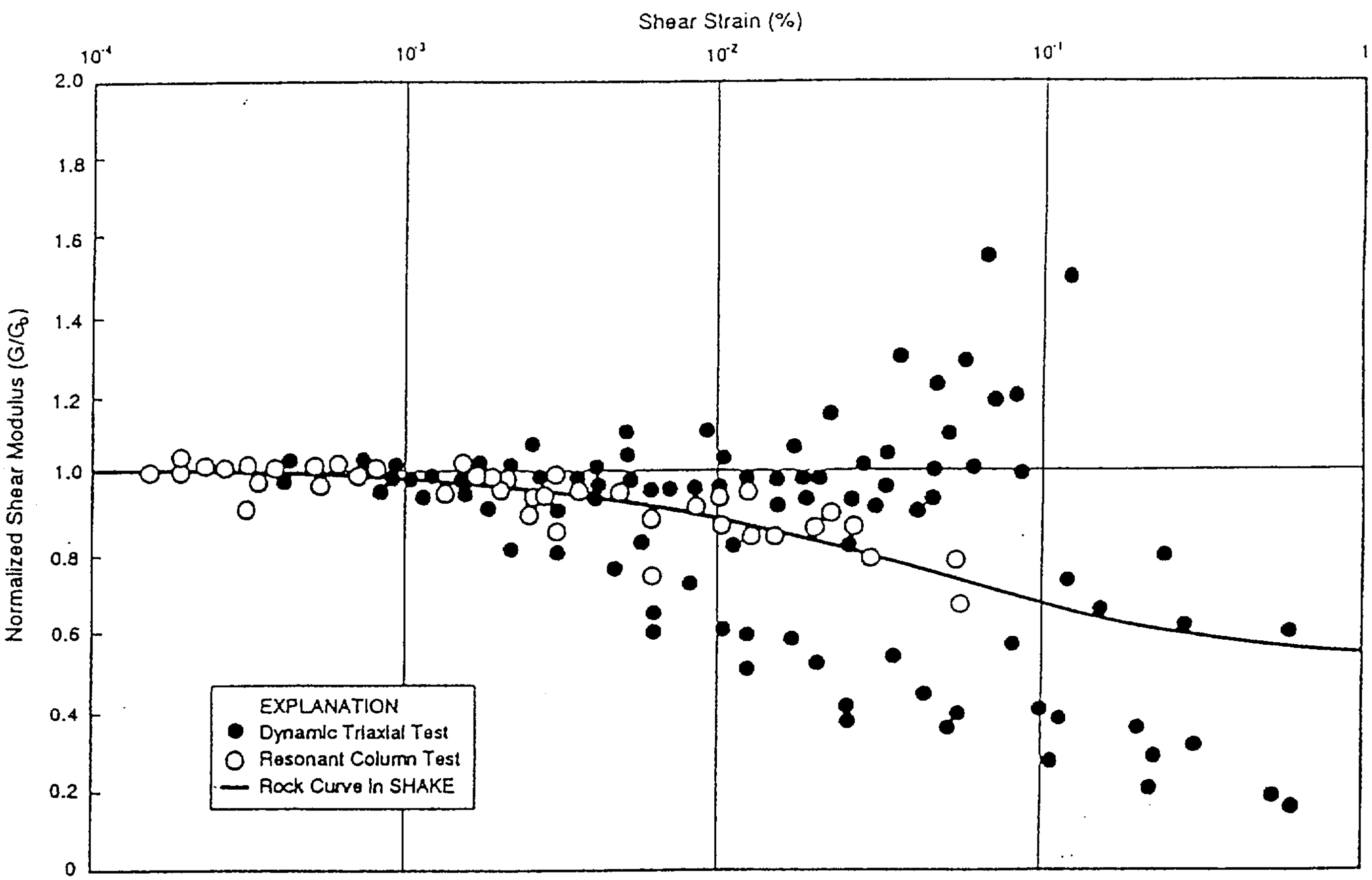


Figure Q19-22

Variation of shear modulus with shear strain for the site rock based on 1978 laboratory test data.

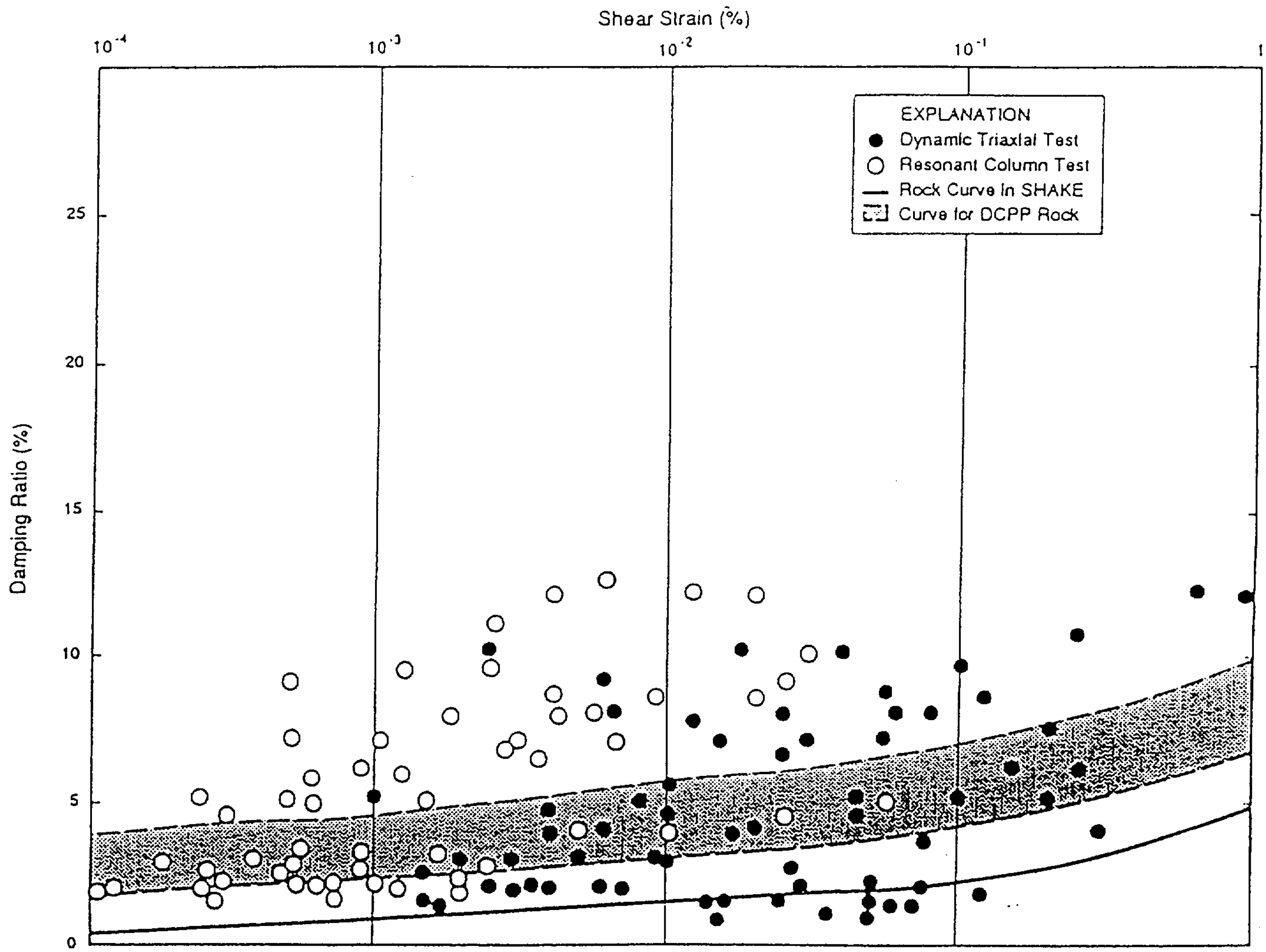


Figure Q19-23

Variation of damping ratio with shear strain for the site rock based on 1977 laboratory test data.

ATTACHMENT 6

Pacific Gas and Electric Company

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GEO.DCPP.01.25

REVISION 1

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

October 31, 2001

Re: Confirmation of preliminary inputs to calculations for DCPP ISFSI site

DR. MAKDISI:

A number of inputs to calculations for the DCPP ISFSI slope stability analyses have been provided to you in a preliminary fashion. This letter provides confirmation of those inputs in a formal transmittal. A description of the preliminary inputs and their formal confirmation follow.

Letter to Faiz Makdisi from Rob White dated June 24, 2001. Subject: Recommended rock strength design parameters for DCPP ISFSI site slope stability analyses.

This letter recommended using $\phi = 50$ degrees for the preliminary rock strength envelope in your stability analyses, and indicated that this value would be confirmed once calculations had been finalized and approved. Calculations GEO.DCPP.01.16, rev. 0, and GEO.DCPP.01.19, rev. 0, are approved and this recommended value is confirmed.

Letter to Faiz Makdisi from Rob White dated September 28, 2001. Subject: Confirmation of transmittal of inputs for DCPP ISFSI slope stability analyses.

This letter provided confirmation of transmittal of cross section I-I' and time histories, and indicated that these preliminary inputs would be confirmed once calculations had been approved. Calculation GEO.DCPP.01.21, rev. 0, is approved and section I-I' as described in the September 28 letter is confirmed. A copy of the figure from the approved calculation is attached. Calculations GEO.DCPP.01.13, rev. 1, and GEO.DCPP.01.14, rev. 1, are both approved and time histories as described in the September 28 letter are confirmed. A CD of the time histories from the approved calculations is attached.

Email to Faiz Makdisi from Joseph Sun dated October 24, 2001. Subject: Ground motion parameters for back calculations.

This email provided input for a back calculation to assess conservatism in clay bed properties in the slope. Inputs included maximum displacement per event of 4 inches and a factor of 1.6 with which to multiply ground motions for use in the back calculation analysis. This letter confirms those input values, with the following limitation: these values have not been developed under an approved calculation, therefore should not be used to directly determine clay bed properties for use in forward analyses, but may be used for comparative purposes only, to assess the level of conservatism in those clay bed properties determined in approved calculations

Letter to Faiz Makdisi from Jeff Bachhuber dated October 10, 2001. Subject: Transmittal of Revised Rock Mass Failure Models – DCPP ISFSI Project.

This letter provided you with figures indicating potential rock mass failure models as superimposed on section I-I'. This letter confirms PG&E approval to use these models in your analyses. These figures are labeled drafts and are currently being finalized in a revision to Calculation GEO.DCPP.01.21. Once this revision and the included figures have been approved, I will inform you in writing of their status.

Rob White

ROBERT K. WHITE

Attachments

ATTACHMENT 7

Pacific Gas and Electric Company

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415/973-2792
Fax 415/973-5778

GEO.DCPP.01.25

REVISION 1

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

November 1, 2001

Re: Confirmation of additional inputs to calculations for DCPP ISFSI site

DR. MAKDISI:

Additional inputs to calculations for the DCPP ISFSI slope stability analyses have been provided to you by Jeff Bachhuber of William Lettis Associates. This letter provides confirmation of our acceptance of those inputs in a formal transmittal. A description of those additional inputs and their formal acceptance follow.

Letter to Faiz Makdisi from Jeff Bachhuber dated August 3, 2001. Subject: Ground Motion Directional Components.

This letter recommended using an azimuth of 302 degrees plus or minus 10 degrees for the orientation of the most likely failure surfaces, coinciding with Section I-I'. We concur with this recommendation based on the discussion on page 53 of the approved Calculation GEO.DCPP.01.21, rev. 0, and verification of the orientation of Section I-I' on Calculation Figure 21-4, attached.

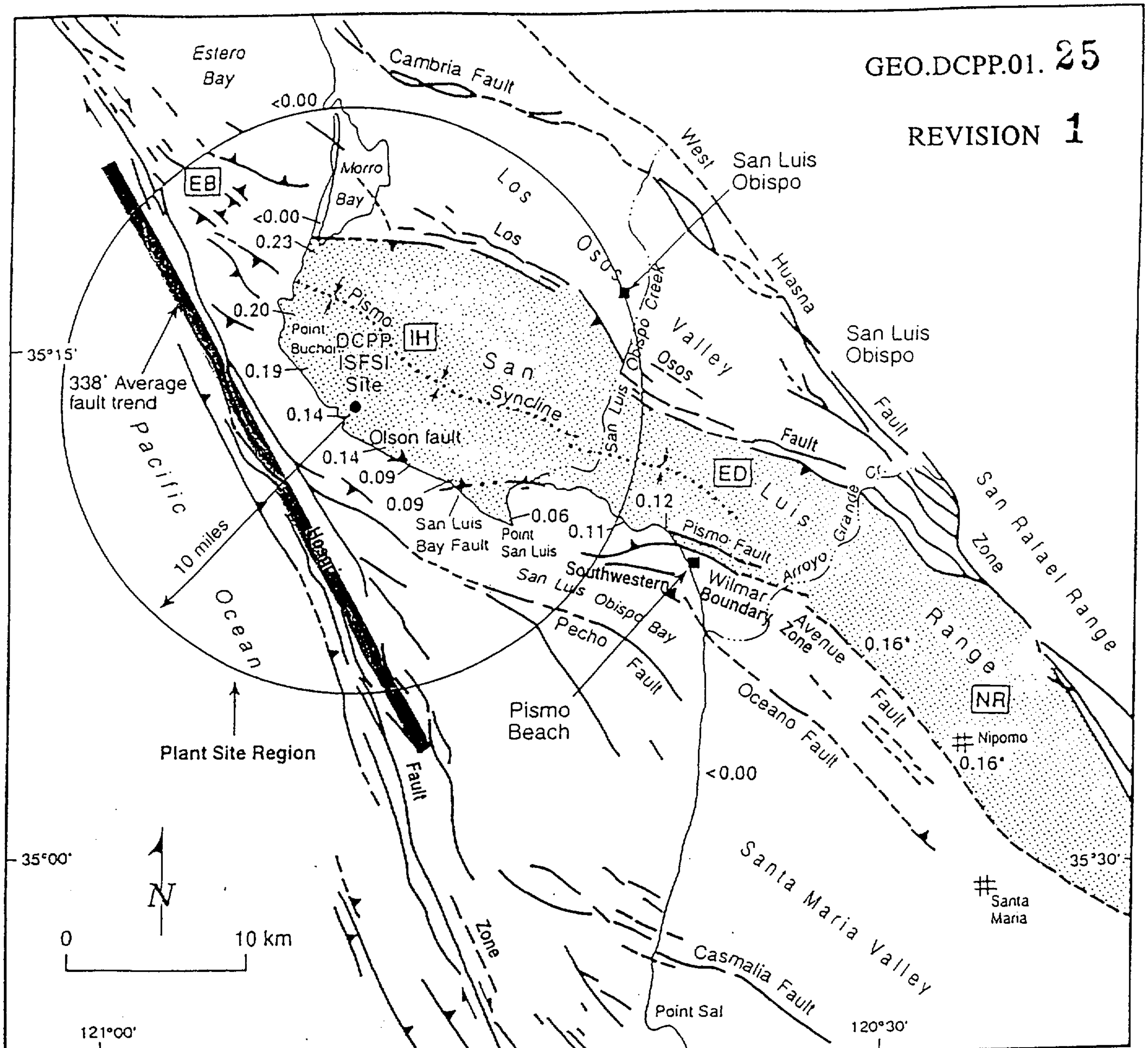
Letter to Faiz Makdisi from Jeff Bachhuber dated August 23, 2001. Subject: Revised Estimates for Hosgri Fault Azimuth, DCPP ISFSI Project.

This letter recommended using an azimuth of 338 degrees for the orientation of the average strike of the Hosgri fault. We concur with this recommendation, based on verification of the orientation as presented in the LTSP plates and as shown on Figure 21-36, attached, of Calculation GEO.DCPP.01.21, rev. 0.

Rob White

ROBERT K. WHITE

Attachments



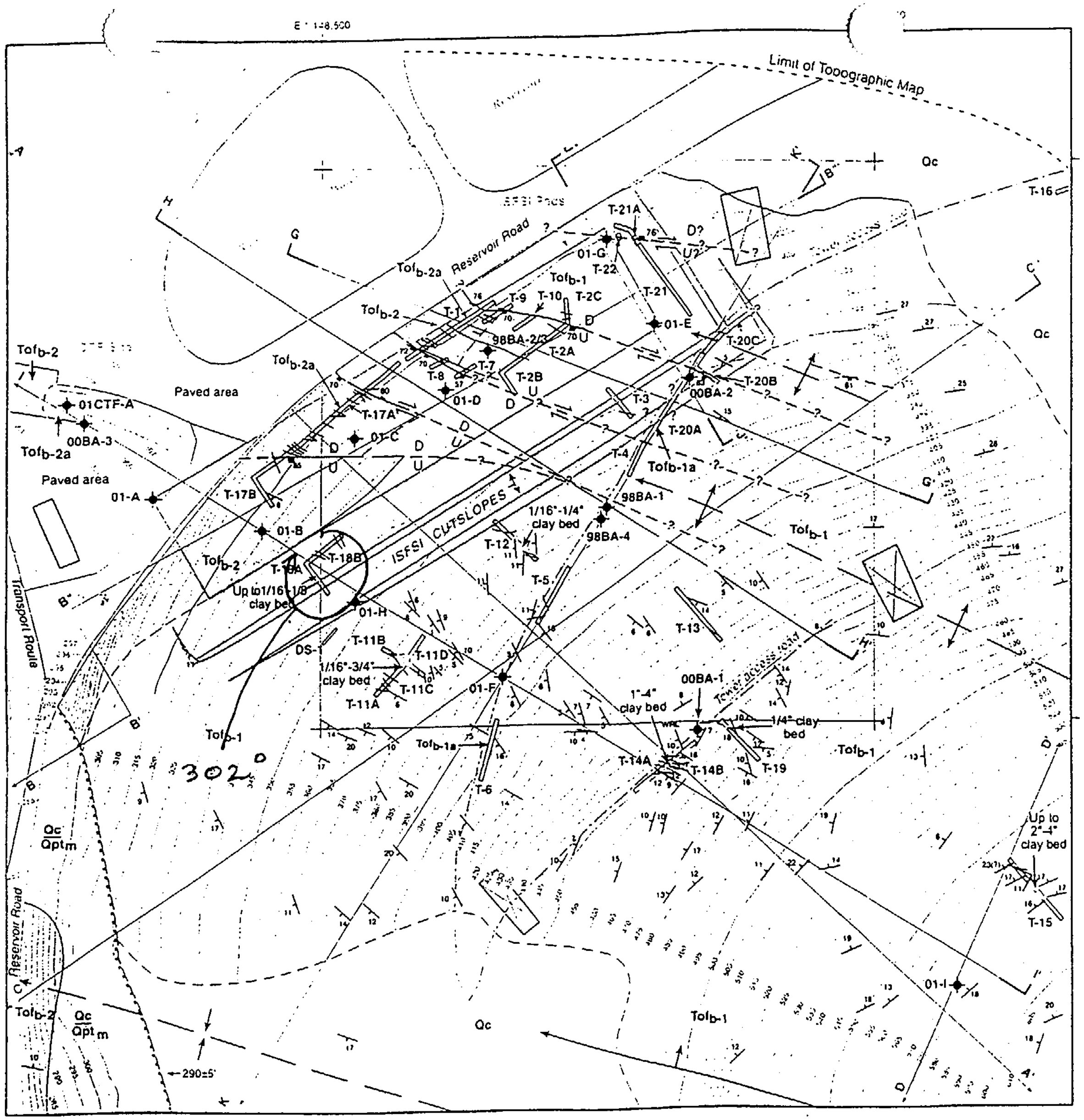
(from PG&E, 1988)

Explanation

- Fault: dashed where approximately located; teeth indicate dip direction of reverse fault; arrows indicate relative sense of displacement
- Syncline axial trace
- 0.14 — Late Pleistocene (post 120,000 years ago) uplift rate (meters/1000 yr)
- 0.16* — Uplift rate (meters/1000 yr) based on the altitude and estimated age (560,000 years) of the Q7 marine terrace

- EB — Estero Bay Subblock
- IH — Irish Hills Subblock
- ED — Edna Subblock
- NR — Newsom Ridge Subblock

SAFETY ANALYSIS REPORT
DIABLO CANYON ISFSI
FIGURE 21-36 REGIONAL STRUCTURE MAP



EXPLANATION

Qc Colluvium

Qpt$_m$ Marine terrace deposit (overlain by Qc)

Obispo Formation (lower and middle Miocene)

DOLOMITE SUBUNIT

Tofb-1 Dolomite, clayey dolomite, dolomitic siltstone to fine-grained dolomitic sandstone, and limestone. The subunit contains occasional discontinuous to continuous (tens to hundreds of feet) clay beds that are generally 1/32 to 1/2-inch thick, but locally are thicker. Rocks in this unit are moderately to well-cemented, medium hard, moderately to slightly weathered, brittle and typically medium strong.

Tofb-1a Friable (poorly cemented) dolomite and dolomitic rocks of subunit Tofb-1. These rocks typically have low hardness, are very weak to weak, and occur as discontinuous zones where weathering and/or alteration has been concentrated.

SANDSTONE SUBUNIT

Tofb-2 Dolomitic medium- to coarse-grained sandstone (arkose to arenitic), and altered sandstone; detrital clasts are composed primarily of dolomitized feldspars, marine fossil fragments, and volcanic rock fragments. Discontinuous clay layers that are generally less than 1/2-inch thick occur locally within the subunit. The rocks are of low to medium hardness, moderately- to well-cemented and typically medium strong.

Tofb-2a Friable (poorly cemented) dolomitic sandstone and sandstone of subunit Tofb-2. These rocks typically are of low hardness and are very weak to weak, and occur as discontinuous zones in places where weathering and/or alteration has been concentrated.

- Strike and dip of bedding
- Minor fault, dip indicated, dashed where inferred, queried where uncertain, arrows show sense of movement, U-upthrown, D-downthrown.
- Small, secondary faults exposed in trench
- Clay beds, thickness indicated
- Geologic contact, solid line where well-defined, dashed where approximate
- 01-C Boring for ISFSI, number indicated (initial number is year drilled)
- A — A' Geologic cross section, arrows indicate end of line is off the map area
- T-4 Exploratory trench, number indicated
- DS-1 Discontinuity survey line in bulldozer cut
- Footprint of 500 kV tower
- Outline of ISFSI Pads and CTF site
- Proposed cut slope above ISFSI Pads
- Axis of anticline, solid arrow shows plunge, dashed where approximate
- Axis of syncline, solid arrow shows plunge, dashed where approximate
- Axis of monocline, solid arrow shows plunge, dashed where approximate
- 290±5' Shoreline angle of marine terrace wave-cut platform (buried), elevation indicated (Q_5 terrace; see Figure 21-24)

N

0 50 100 150 200

Contour interval = 5 feet

ISFSI Cutslope is a schematic representation and is not final

DIABLO CANYON ISFSI

FIGURE 21-4
GEOLOGIC MAP OF ISFSI AND CTF SITES

NUCLEAR POWER GENERATION
CF3.ID4
ATTACHMENT 7.2

Index No. 402	
Binder No.	

TITLE: CALCULATION COVER SHEET

Unit(s): 1 & 2

File No.: 52.27

Responsible Group: Civil

Calculation No.: 52.27.100.736

No. of Pages 3 pages + Index (4 pages) + 1 Attachment (49 pages)

Design Calculation YES [x] NO [ ]

System No. 42C

Quality Classification Q (Safety-Related)

Structure, System or Component: Independent Spent Fuel Storage Facility

Subject: Determination of Earthquake-Induced Displacements of Potential Sliding Masses on ISFSI Slope (GEO.DCPP.01.26, Rev. 1)

Electronic calculation YES [ ] NO [x]

Computer Model	Computer ID	Program Location	Date of Last Change

Registered Engineer Stamp: Complete A or B

A. Insert PE Stamp or Seal Below	B. Insert stamp directing to the PE stamp or seal
Expiration Date:	***REGISTERED ENGINEERS' STAMPS AND EXPIRATION DATES ARE SHOWN ON DWG 063618***

NOTE 1: Update DCI promptly after approval.
NOTE 2: Forward electronic calculation file to CCTG for uploading to EDMS.

TITLE: CALCULATION COVER SHEET

CALC No. 52.27.100.736, R0

RECORD OF REVISIONS

Rev No.	Status	Reason for Revision	Prepared By:	LBIE Screen	LBIE	Check Method*	LBIE Approval		Checked	Supervisor	Registered Engineer
		Remarks	Initials/ LAN ID/ Date	Yes/ No/ NA	Yes/ No/ NA		PSRC Mtg. No.	PSRC Mtg. Date	Initials/ LAN ID/ Date	Initials/ LAN ID/ Date	Signature/ LAN ID/ Date
0	F	Acceptance of Geosciences Calc. No. GEO.DCPP.01.26, Rev. 1. Calc. supports current edition of 10CFR72 DCPP License Application to be reviewed by NRC prior to implementation. Prepared per CF3.ID17.	AFT2 AT 12/15/01	[ ] Yes [ ] No [x] NA	[ ] Yes [ ] No [x] NA	[ ] A [ ] B [x] C	N/A	N/A	N/A	[signature] LJS2 12/17/01	[signature] LJS2 12/17/01
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					

*Check Method: A: Detailed Check, B: Alternate Method (note added pages), C: Critical Point Check

SUBJECT Determination of Earthquake-Induced Displacements of Potential Sliding Masses on ISFSI Slope

MADE BY A. Tafoya DATE 12/15/01 CHECKED BY N/A DATE

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1- This table cross references between Geosciences calculation numbers and DCPP (Civil Group's) calculation numbers. This section is For Information Only.

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(For Information Only)

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1	GEO.DCPP.01.01	Development of Young's Modulus and Poisson's Ratios for DCPP ISFSI Based on Field Data	52.27.100.711	
2	GEO.DCPP.01.02	Determination of Probabilistically Reduced Peak Bedrock Accelerations for DCPP ISFSI Transporter Analyses	52.27.100.712	
3	GEO.DCPP.01.03	Development of Allowable Bearing Capacity for DCPP ISFSI Pad and CTF Stability Analyses	52.27.100.713	
4	GEO.DCPP.01.04	Methodology for Determining Sliding Resistance Along Base of DCPP ISFSI Pads	52.27.100.714	
5	GEO.DCPP.01.05	Determination of Pseudostatic Acceleration Coefficient for Use in DCPP ISFSI Cutslope Stability Analyses	52.27.100.715	
6	GEO.DCPP.01.06	Development of Lateral Bearing Capacity for DCPP CTF Stability Analyses	52.27.100.716	
7	GEO.DCPP.01.07	Development of Coefficient of Subgrade Reaction for DCPP ISFSI Pad Stability Checks	52.27.100.717	
8	GEO.DCPP.01.08	Determination of Rock Anchor Design Parameters for DCPP ISFSI Cutslope	52.27.100.718	
9	GEO.DCPP.01.09	Determination of Applicability of Rock Elastic Stress-Strain Values to Calculated Strains Under	52.27.100.719	Calculation to be replaced by letter

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(For Information Only)

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		DCPP ISFSI Pad		
10	GEO.DCPP.01.10	Determination of SSER 34 Long Period Spectral Values	52.27.100.720	
11	GEO.DCPP.01.11	Development of ISFSI Spectra	52.27.100.721	
12	GEO.DCPP.01.12	Development of Fling Model for Diablo Canyon ISFSI	52.27.100.722	
13	GEO.DCPP.01.13	Development of Spectrum Compatible Time Histories	52.27.100.723	
14	GEO.DCPP.01.14	Development of Time Histories with Fling	52.27.100.724	
15	GEO.DCPP.01.15	Development of Young's Modulus and Poisson's Ratio Values for DCPP ISFSI Based on Laboratory Data	52.27.100.725	
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17	GEO.DCPP.01.17	Determination of Mean and Standard Deviation of Unconfined Compression Strengths for Hard Rock at DCPP ISFSI Based on Laboratory Tests	52.27.100.727	
18	GEO.DCPP.01.18	Determination of Basic Friction Angle Along Rock Discontinuities at DCPP ISFSI Based on Laboratory Tests	52.27.100.728	
19	GEO.DCPP.01.19	Development of Strength Envelopes for Jointed Rock Mass at DCPP ISFSI Using	52.27.100.729	

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22	GEO.DCPP.01.22	Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site	52.27.100.732	
23	GEO.DCPP.01.23	Pseudostatic Wedge Analyses of DCPP ISFSI Cutslopes (SWEDGE Analysis)	52.27.100.733	
24	GEO.DCPP.01.24	Stability and Yield Acceleration Analysis of Cross-Section I-I'	52.27.100.734	
25	GEO.DCPP.01.25	Determination of Seismic Coefficient Time Histories for Potential Siding Masses Along Cut Slope Behind ISFSI Pad	52.27.100.735	
26	GEO.DCPP.01.26	Determination of Earthquake-Induced Displacements of Potential Sliding Masses on ISFSI Slope	52.27.100.736	
27	GEO.DCPP.01.27	Cold Machine Shop Retaining Wall Stability	52.27.100.737	
28	GEO.DCPP.01.28	Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route	52.27.100.738	

SUBJECT Determination of Earthquake-Induced Displacements of Potential Sliding Masses on ISFSI Slope

MADE BY A. Tafoya KT DATE 12/15/01 CHECKED BY N/A DATE

Cross-Index
(For Information Only)

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29	GEO.DCPP.01.29	Determination of Seismic Coefficient Time Histories for Potential Sliding Masses on DCPP ISFSI Transport Route	52.27.100.739	
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31	GEO.DCPP.01.31	Development of Strength Envelopes for Clay Beds at DCPP ISFSI	52.27.100.741	
32	GEO.DCPP.01.32	Verification of Computer Program SPCTLR.EXE	52.27.100.742	
33	GEO.DCPP.01.33	Verification of Program UTEXAS3	52.27.100.743	
34	GEO.DCPP.01.34	Verification of Computer Code - QUAD4M	52.27.100.744	
35	GEO.DCPP.01.35	Verification of Computer Program DEFORMP	52.27.100.745	
36	GEO.DCPP.01.36	Reserved	52.27.100.746	
37	GEO.DCPP.01.37	Development of Freefield Ground Motion Storage Cask Spectra and Time Histories for the Used Fuel Storage Project	52.27.100.747	

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number	GEO.DCPP.01.26
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Date	12/13/01
Calc Pages:	46
Verification Method:	A
Verification Pages:	1

TITLE: Determination of Earthquake-Induced Displacements of Potential Sliding Masses on ISFSI Slope

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Exp. 12/31/02

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PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

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PREPARED BY: Zhiliang Wang DATE 12/13/01

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Determination of Earthquake-Induced Displacements of Potential Sliding Masses on DCPP ISFSI Slope

Calc. Number GEO.DCPP.01.26

Record of Revisions

Rev. No.	Reason for Revision	Revision Date
00	Initial Issue	11/07/01
01	Revised test to incorporate PG&E NQS, UFSP, and Geosciences and its reviewers' comments including: 1) addition of record of revision sheet, and 2) minor editorial changes.	12/13/01

Calculation Title: Determination of Earthquake-Induced Displacements of Potential Sliding Masses on DCPP ISFSI Slope
Calculation No.: GEO.DCPP.01.26
Revision No.: 1
Calculation Author: Zhi-Liang Wang
Calculation Date: 12/13/01

PURPOSE

As required by Geomatrix Consultants, Inc. Work Plan entitled, "Laboratory Testing of Soil and Rock Samples, Slope Stability Analyses, and Excavation Design for Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site," the purpose of this calculation package is to estimate earthquake-induced permanent displacements of potential sliding masses (on the cut slope behind the ISFSI pad) using Newmark-type analyses.

ASSUMPTIONS

Not applicable.

INPUT

1. Five sets of rock motions originating on the Hosgri fault: Transmittal from PG&E Geosciences dated September 28, 2001 (Attachment 1).
2. Direction of down slope movement along Section I-I': Transmittal from William Lettis & Associates dated August 3, 2001 (Attachment 2).
3. Orientation (azimuth) of the strike of the Hosgri fault: Transmittal from William Lettis & Associates dated August 23, 2001 (Attachment 3).
4. Direction of positive fault parallel component on Hosgri fault: Transmittal from PG&E Geosciences dated October 18, 2001 (Attachment 4).
5. Yield accelerations and locations for potential sliding masses from calculation package GEO.DCPP.01.24, revision 1.
6. Average acceleration time histories in potential sliding masses from calculation package GEO.DCPP.01.25, revision 1.

METHODOLOGY

Development of Rotated Motions along Section I-I'

Geosciences Department of PG&E developed five sets of possible earthquake rock motions for the ISFSI site (see Attachment 1 as confirmed in Attachment 6) to be used as input to the analysis. These motions are estimated to originate on the Hosgri fault about 4.5 km west of the plant site. Both fault normal and fault parallel components were determined for each of the five sets of motions. The fault parallel component incorporated the fling effect and its positive direction was specified in the southeasterly fault direction (see Attachment No. 4 as confirmed in Attachment 5). The fault normal component has a direction normal to the fault strike, and its polarity can be either positive or negative depending on the assumed location of the initiation of the rupture. Based on Attachments 2 and 3 as confirmed in Attachment 7, the best estimate of up-slope direction along cross section I-I' (as shown in Figure 1) is 36 degrees (counter-clockwise) from the direction of the strike of the Hosgri fault. (i.e., to the southeast). The fault normal component can be at $\pm$ 90 degrees from the fault parallel direction, that is 36+90 = 126 (or 36-90 = -54) degrees from the direction of section I-I'. From these relations, the ground motion component along section I-I' can be determined from the specified components along the fault normal and fault parallel directions. The component along section I-I' will be referred to as the rotated component.

The rotated component along the direction of section I-I' direction is the sum of the projections of the fault normal and fault parallel components along the direction of section I-I'. The formulation is as follows:

$$II^{+} = F_P \cos(\phi) + F_N \sin(\phi)$$

and

$$II^{-} = F_P \cos(\phi) - F_N \sin(\phi)$$

in which the F_P and F_N are fault parallel and fault normal components of the acceleration time histories, II^{+} is the component along section I-I' for the positive fault normal component, and II^{-} is the component along section I-I' for the negative fault normal component. ϕ is the angle between the up-slope direction of section I-I' and the fault parallel direction (southeast). The five sets of earthquake motions on the Hosgri fault now are rotated to earthquake motions along the up-slope direction of cross section I-I'. For a specified angle between section I-I' and the fault direction, there are 10 rotated earthquake motions along the I-I' direction, because the positive and negative directions of the fault normal component were considered separately.

Procedures for Calculation of Permanent Displacement

The procedure used to estimate permanent displacements involves the following steps.

1. A yield acceleration, k_y, at which a potential sliding surface would develop a factor of safety of unity, is estimated using limit equilibrium, pseudo-static slope stability methods. The yield acceleration depends on the slope geometry, the ground water conditions, the undrained shear strength of the slope material, and the location of the potential sliding surface. The analyses are presented in calculation package GEO.DCPP.01.24.
2. The seismic coefficient time history (and the maximum seismic coefficient, k_{max}) induced within a potential sliding mass is estimated using two-dimensional dynamic finite element methods. The seismic coefficient is the ratio of the force induced by an earthquake in a sliding block to the total mass of that block. Alternatively, the seismic coefficient time history can be obtained directly by averaging acceleration values from several different finite elements within the sliding block at each time interval. These analyses are presented in calculation package GEO.DCPP.01.25.
3. For a specified potential sliding mass, the seismic coefficient time history for that mass is compared with the yield acceleration, k_y. When the seismic coefficient exceeds the yield acceleration, down-slope movement will occur along the direction of the assumed failure plane. The movement will decelerate and will stop after the level of the induced acceleration drops below the yield acceleration, and the relative velocity of the sliding mass drops to zero. The accumulated permanent down-slope displacement is calculated by double-integrating the increments of the seismic coefficient time history that exceed the yield acceleration. The results of these computations are presented below.

SOFTWARE

The program DEFORMP was validated in GEO.DCPP.01.35 and used in this package for the displacement computation.

ANALYSIS

Because the slope at the ISFSI site is a rock slope, and its seismic response is anticipated to be generally similar to the input rock motions, the earthquake-induced deformation was first estimated using a Newmark-type analysis for a sliding block on a rigid plane. An estimated yield acceleration of 0.20g (based on estimates from calculation package GEO.DCPP.01.24) was used to calculate the deformation of the sliding block. The displacement was computed for the negative direction (representing down-slope movement) only. The permanent down-slope displacement of the sliding block was integrated by using the input rock motions in the positive direction (representing the up-slope direction) only. These preliminary displacement estimates were used to help in selecting the ground motion time histories that provided the largest permanent displacement.

Table 1 shows the calculated down-slope permanent displacements (for the five sets of rotated rock motions) using the program DEFORMP, following the Newmark rigid block approach described above. Details of the DEFORMP calculations, including the input and output files, are included in the enclosed compact disc labeled GEO.DCPP.01.26, December 13, 2001. The results (for ϕ=36 degrees) indicate that, on average, ground motion sets 1, 3, and 5 provided the largest displacements (2.9 feet to 2.4 feet). A sensitivity analyses was performed to evaluate the effect of the uncertainty in the direction of section I-I' relative to the fault strike. For this analysis ϕ was varied by $\pm$ 10 degrees. As shown in Table 1, for ϕ = 46 degrees, ground motion set 1 (with a negative fault normal component) and set 5 (with a positive fault normal component) produced the largest displacements (3.3 feet and 2.8 feet, respectively). This is because the fault normal components are stronger than the fault parallel components in most cases, and for ϕ = 46 degrees, the I-I' direction is closer to the fault normal direction. Set 3 motion, when combined with the negative fault normal component, produced 2.8 feet of displacement; however, when combined with the positive fault normal component, it produced much smaller displacement than did set 5.

Based on the above rigid sliding block analyses, two rotated ground motions, set 1 motion (rotated 46 degrees with a negative fault normal component) and set 5 motion (rotated 46 degrees with a positive fault normal component), were used in the two-dimensional finite element analyses as described in calculation package GEO.DCPP.01.25

TABLE 1.
DOWN-SLOPE DISPLACEMENT CALCULATED BASED ON ROTATED INPUT MOTIONS ALONG SECTION I-I'
(DISPLACEMENT UNIT: FEET; YIELD ACCELERATION: 0.2g)

Set No.	Description	Polarity	Ky=0.20		
			$I\text{-}I_{36}$	$I\text{-}I_{46}$	$I\text{-}I_{26}$
Set 1	Lucerne	FN-	2.9	3.3	2.5
		FN+	1.4	1.4	1.5
Set 2a	Yarimca	FN-	2.4	2.8	1.8
		FN+	1.2	1.4	1.1
Set 3	LGPC	FN-	2.5	2.8	2.3
		FN+	1.3	1.2	1.4
Set 5	El Centro	FN-	2.2	2.6	1.8
		FN+	2.4	2.8	2.1
Set 6	Saratoga	FN-	0.9	1.1	0.8
		FN+	0.9	1.0	0.8

RESULTS

Earthquake-Induced Displacements of Existing Slope

The results of stability analyses were reported in calculation package GEO.DCPP.01.24. Using the potential sliding masses having the lowest yield accelerations (namely 1b, 2c, and 3c), the potential for permanent displacements was evaluated using the concept of yield acceleration proposed by Newmark (1965) and modified by Makdisi and Seed (1978) as described above.

The potential sliding masses and the node points where the computed acceleration time histories were used to develop average-acceleration time histories for each sliding mass are presented in Figure 2. The computed average acceleration time histories for potential sliding masses 1b, 2c, and 3c are presented in Figures 3 and 4 for input motion sets 1 and 5, respectively. The computed peak seismic coefficient, k_{max}, for the three potential sliding masses are listed in Table 2. The values ranged between 0.80g and 0.98g for input motion set 1, and between 0.61g and 0.75g for input motion set 5. As expected, the largest potential sliding mass 3c has the lowest peak seismic coefficient for both set 1 and set 5 motions.

The seismic coefficient time histories shown in Figures 3 and 4 were then double-integrated, using the program DEFORMP, to obtain earthquake-induced displacements for any specified yield acceleration. Details of these calculations, including the input and out files, are included in the enclosed compact disc labeled GEO.DCPP.01.26. Note that the positive direction of the rock motions (shown in Figure 1) is consistent with the coordinate system selected for the dynamic analysis; i.e. the horizontal coordinate increases in the up-slope direction. As mentioned before, the integration was made for the ground motion amplitudes exceeding the yield acceleration in the positive direction only, and the resulting displacement was computed for potential sliding in the down-slope direction.

The relationships between calculated displacement and yield acceleration, k_y, for each of the three potential sliding masses considered are presented on Figures 5 and 6 for input motion sets 1 and 5, respectively. The normalized relationships between calculated displacement and yield acceleration ratio, k_y/k_{max}, for the three potential sliding masses considered are presented on Figures 7 and 8 for input motion sets 1 and 5, respectively.

For the yield acceleration values listed in Table 2, the earthquake-induced down-slope displacements for all the potential slip surfaces analyzed were estimated from Figures 5 and 6, and are summarized in Table 2. Computed permanent displacements using set 1 motion as input range from about 3.1 feet for sliding mass 1b, to about 1.4 feet for sliding mass 3c. Computed displacements using ground motion set 5 as input were lower, ranging from 2.4 feet for sliding mass 1b to about ½ foot for sliding mass 3c.

Sliding mass 1b (located in the upper portion of the slope) daylights at a horizontal distance of about 400 feet from the toe of the cut slope behind the pad. As mentioned above, the estimated displacements for this sliding mass ranged between 2.4 and 3.1 feet. Sliding mass 2c (located in the middle portion of the slope) daylights about 100 feet from the toe. The estimated displacements for this sliding mass ranged between 2½ and 3 feet.

Considering the thickness and strength of the reinforced concrete pad, potential sliding mass 3c daylights between the edge of the pad and the toe of the cut slope. The computed displacements for sliding mass 3c ranged between 0.6 and 2 feet. Two additional potential sliding masses were analyzed in addition to 3c: sliding mass 3c-1, which daylights beyond the edge of the ISFSI pad; and sliding mass 3c-2, which daylights at the first bench on the cut slope behind the pad. The computed displacements for sliding mass 3c-1 ranged between 0.4 and 1.2 feet. For sliding mass 3c-2, the computed displacements ranged between 0.8 and 2.0 feet, depending on the input motion used in the analysis. Sliding mass 3c-2 daylights at a horizontal distance of about 70 feet from the edge of the pad.

TABLE 2
COMPUTED DOWN-SLOPE DISPLACEMENTS
USING SET 1 AND SET 5 INPUT MOTIONS

Sliding Mass Location	Input Motion	Yield Acceleration, k_y, (g)	Peak Seismic Coefficient, k_{max}, (g)	Down-slope Displacement, feet
1b	Set 1	0.20	0.98	3.1
2c	Set 1	0.19	0.89	3.1
3c	Set 1	0.25	0.81	1.4
3c-1	Set 1	0.28	0.80	1.2
3c-2	Set 1	0.23	0.81	2.0
1b	Set 5	0.20	0.75	2.4
2c	Set 5	0.19	0.68	2.3
3c	Set 5	0.25	0.61	0.6
3c-1	Set 5	0.28	0.61	0.4
3c-2	Set 5	0.23	0.62	0.8

Earthquake-Induced Displacements for Back-Analysis of Pre-excavated Slope Configuration

An approximate back-analysis was performed for the slope behind the ISFSI pad in its pre-excavated (pre-1971) configuration to evaluate the level of conservatism in the assumed lateral extent and the undrained strength of the clay beds underlying the slope. This analysis is described in calculation package GEO.DCPP.01.24. Ground motions used in this analysis were estimated by approximately scaling, by a factor of 1.6, the median-plus-one standard deviation design ground motions already developed for the ISFSI site. The basis for such an estimate is described in Attachment 8. Accordingly, two rotated input ground motions, set 1 and set 5, were scaled by a factor of 1.6 and integrated to estimate earthquake-induced displacements for various specified yield accelerations. The corresponding displacement-yield acceleration relationships are presented in Figures 9 and 10 for input motion sets 1 and 5, respectively. These displacement relationships were used to estimate appropriate yield accelerations that were in turn used in the back-analysis described in calculation package GEO.DCPP.01.24. It should be noted that the computed displacements shown in Figures 9 and 10 were estimated using the scaled input motions only. The results of dynamic analyses (described in calculation package GEO.DCPP.01.25) indicate that amplification effects of the excavated slope were not significant. That is, the computed average acceleration time histories for potential sliding masses within the slope were not significantly different from the input motions. Thus, using the scaled input motion time histories to compute displacements for use in the approximate back-analysis is considered reasonable and acceptable.

REFERENCES

1. Geomatrix Consultants, Inc. Work Plan, Laboratory Testing of Soil and Rock Samples, Slope Stability Analyses, and Excavation Design for Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site, Revision 2, dated October 8, 2000.
2. Geosciences Calculation Package GEO.DCPP.01.24, Revision 1, Stability and yield acceleration analysis of cross-section I-I'.
3. Geosciences Calculation Package GEO.DCPP.01.25, Revision 1, Determination of seismic coefficient time histories for potential sliding masses along cut slope behind ISFSI pad.
4. Geosciences Calculation Package GEO.DCPP.01.35, Revision 1, verification of computer code – DEFORMP.
5. Makdisi, F.I., and Seed, H.B., 1978, Simplified procedure for estimating dam and embankment earthquake-induced deformations: Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, v. 104, no. GT7, July, pp. 849-867.

6. Newmark, N.M., 1965, Effects of earthquakes on dams and embankments: Geotechnique, v. 15, no. 2, p. 139-160.

ATTACHMENTS

1. 09/28/2001, PG&E Geosciences, Robert K. White, Re: Confirmation of transmittal of inputs for DCPP ISFSI slope stability analyses, pages 20 trough 22.
2. 08/3/2001, William Lettis & Associates, Inc., Jeff Bachhuber, Re: Ground Motion Directional Components, pages 23 and 24.
3. 08/23/2001, William Lettis & Associates, Inc., Jeff Bachhuber, Re: Revised Estimates for Hosgri Fault Azimuth, DCPP ISFSI Project, pages 25 and 26.
4. 10/18/2001, PG&E Geosciences, Joseph Sun, Re: Positive direction of the fault parallel component time history on the Hosgri fault, pages 27 through 30.
5. 10/25/2001, PG&E Geosciences, Robert White, Re: Input parameters for calculations, pages 31 through 36.
6. 10/31/2001, PG&E Geosciences, Robert White, Re: Confirmation of preliminary inputs for DCPP ISFSI site, pages 37 through 39.
7. 11/1/2001, PG&E Geosciences, Robert White, Re: Confirmation of additional inputs to calculations for DCPP ISFSI site, pages 40 through 43.
8. 12/13/01, PG&E Geosciences, letter from Robert White to Faiz Makdisi, Re: Confirmation of ground motion parameters for back-calculations, pages 44 through 46.

ENCLOSURE

Compact disc labeled, "PG&E DCPP ISFSI, GEO.DCPP.01.24, Rev. 1; GEO.DCPP.01.25, Rev. 1; and GEO.DCPP.01.26, Rev. 1, December 13, 2001," and containing the input and output files for computation of earthquake-induced displacements of potential sliding masses.

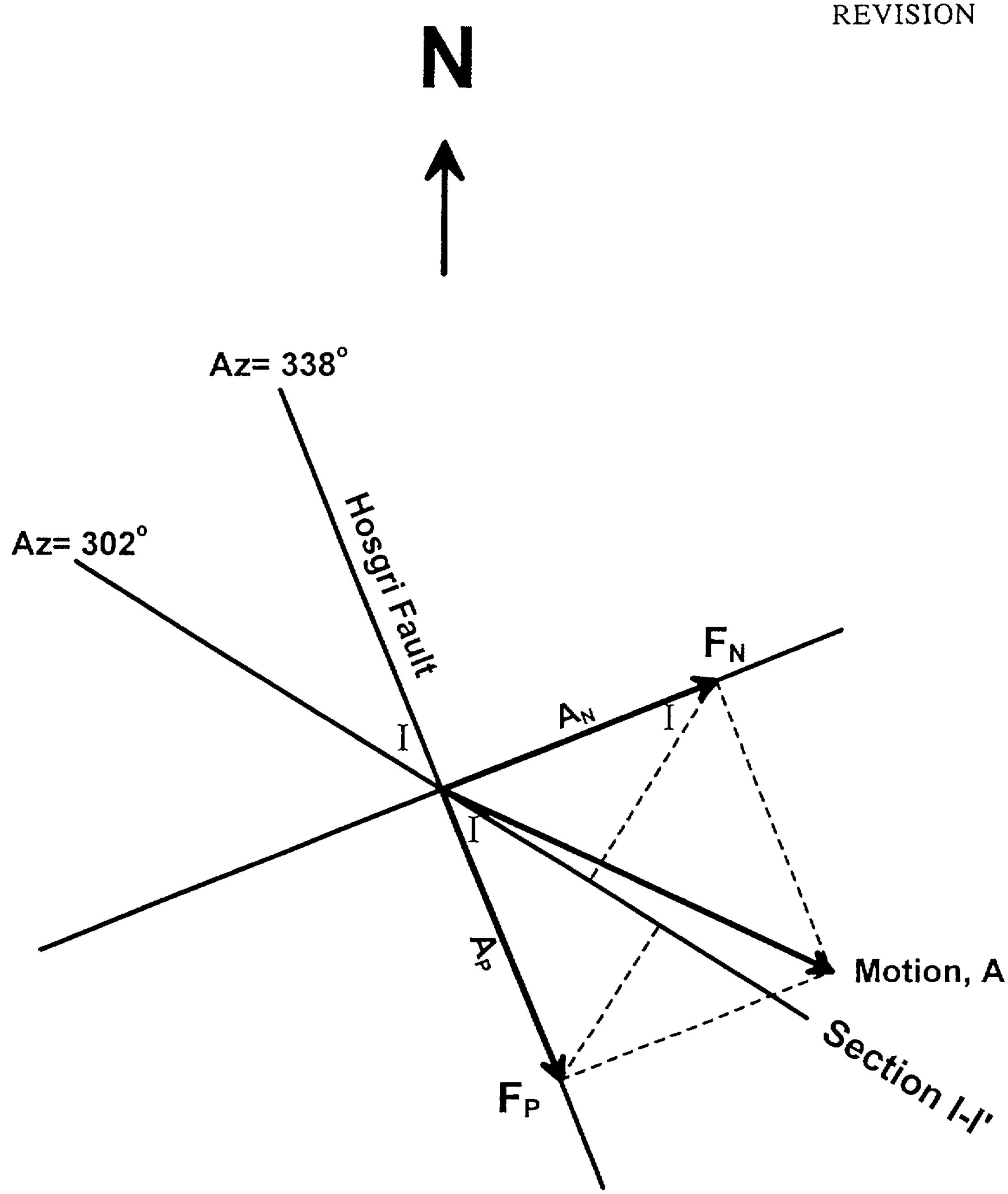

Figure 1. Orientations of Section I-I' and Hosgri Fault.

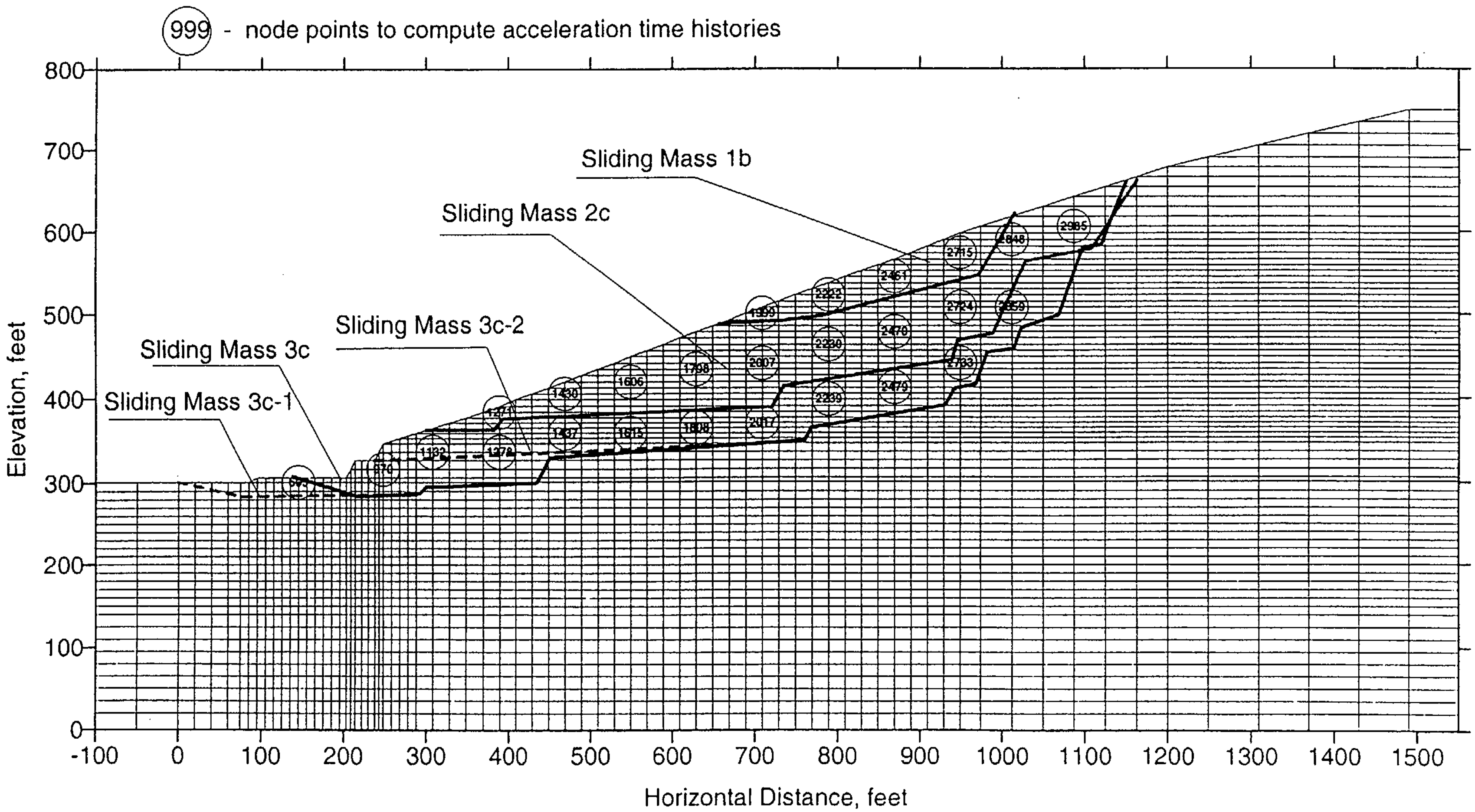

Figure 2. Potential sliding masses and node points for computed acceleration time histories

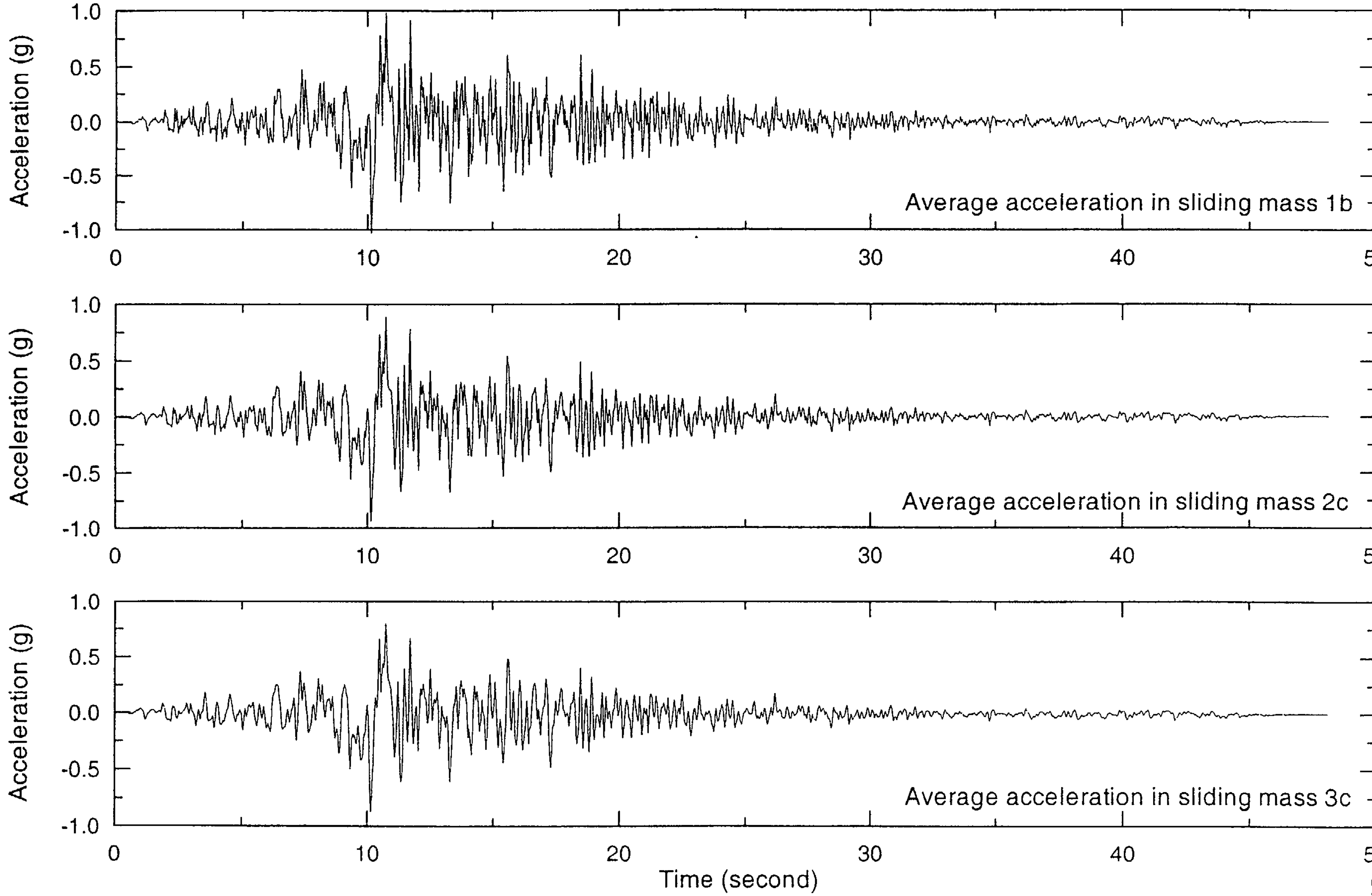

Figure 3. Average acceleration time histories of potential sliding masses using input motion set 1

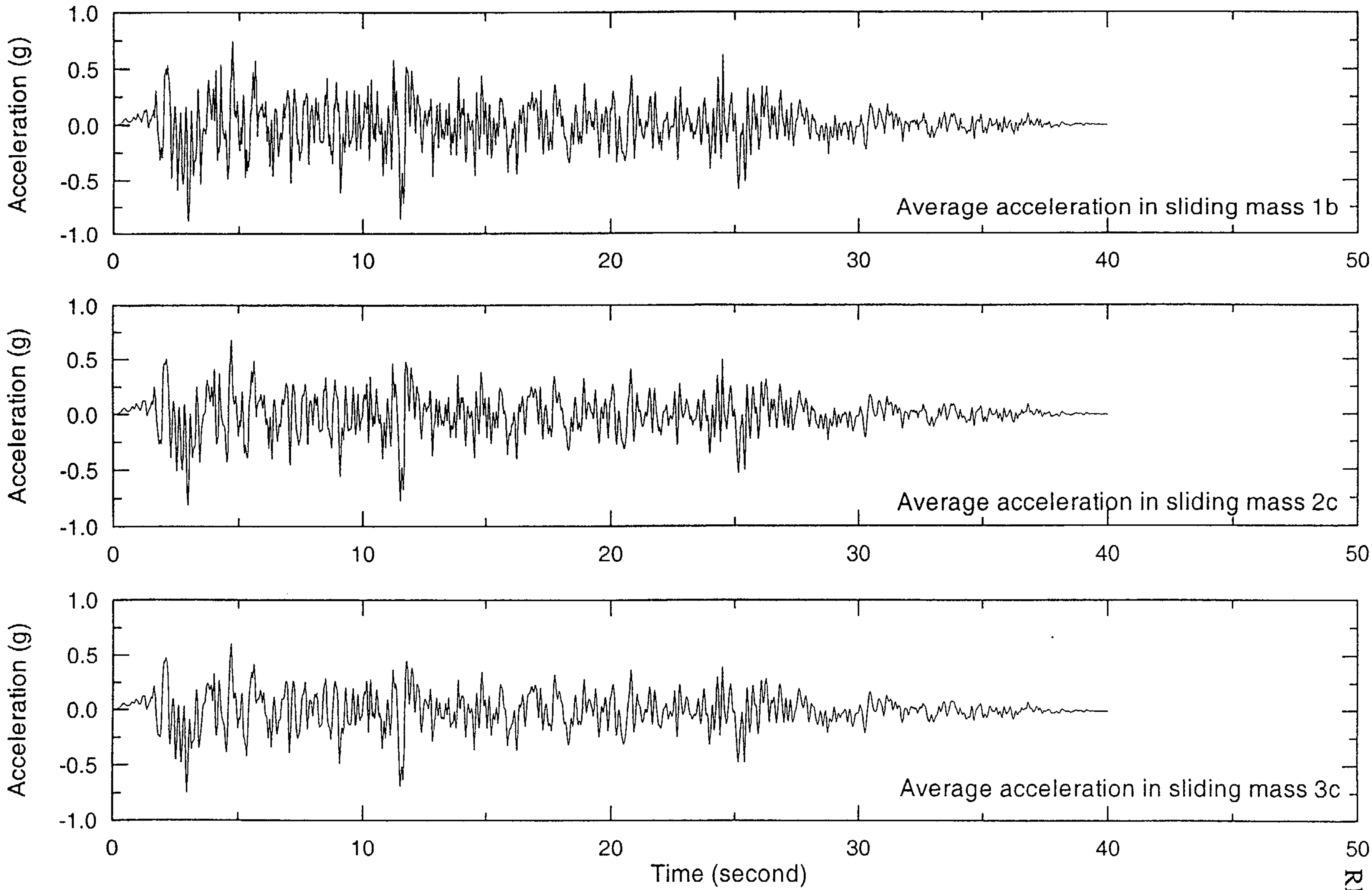

Figure 4. Average acceleration time histories of potential sliding masses using input motion set 5.

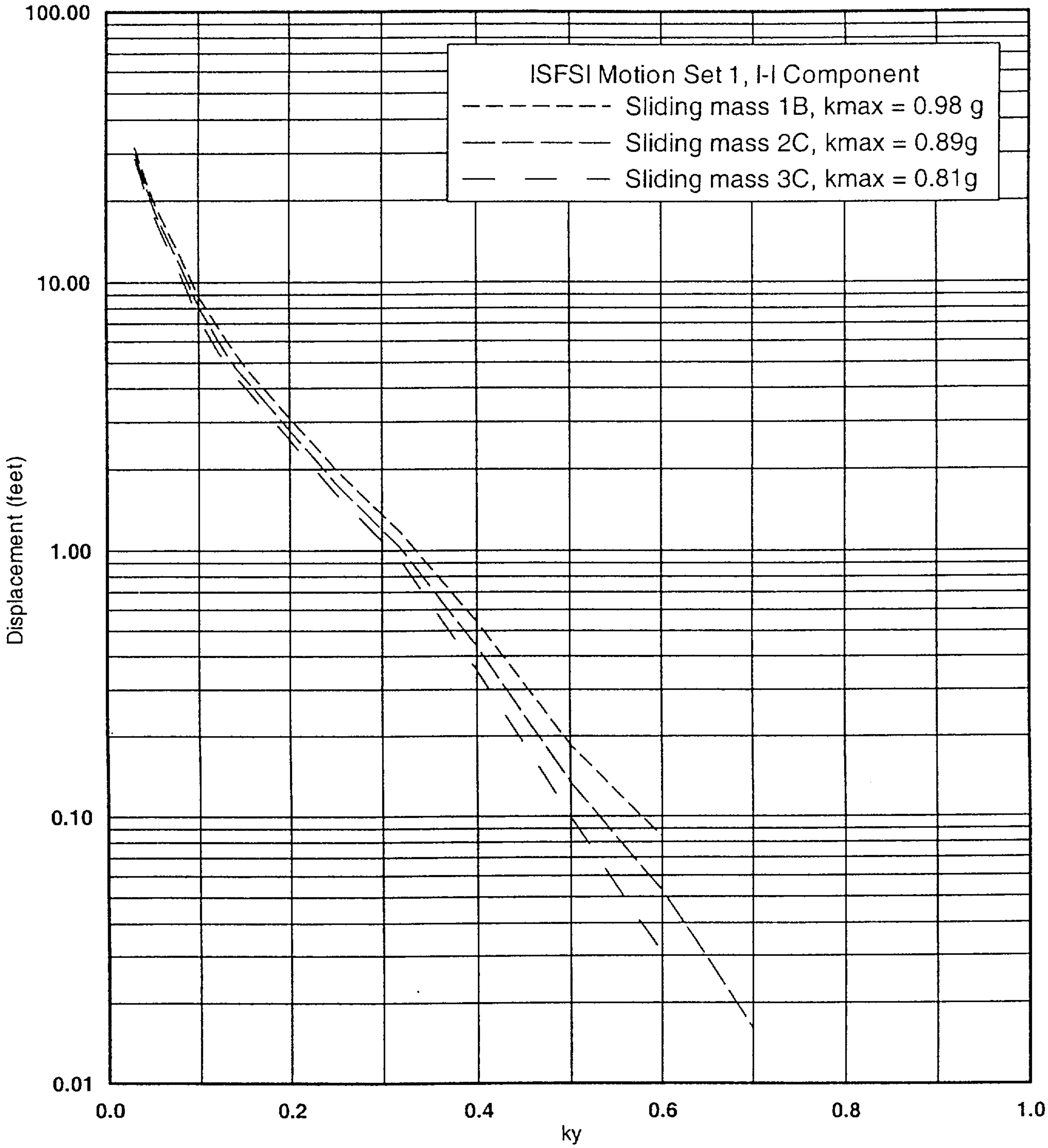

Figure 5. Permanent displacement versus yield acceleration from average acceleration time histories (set 1 input motion).

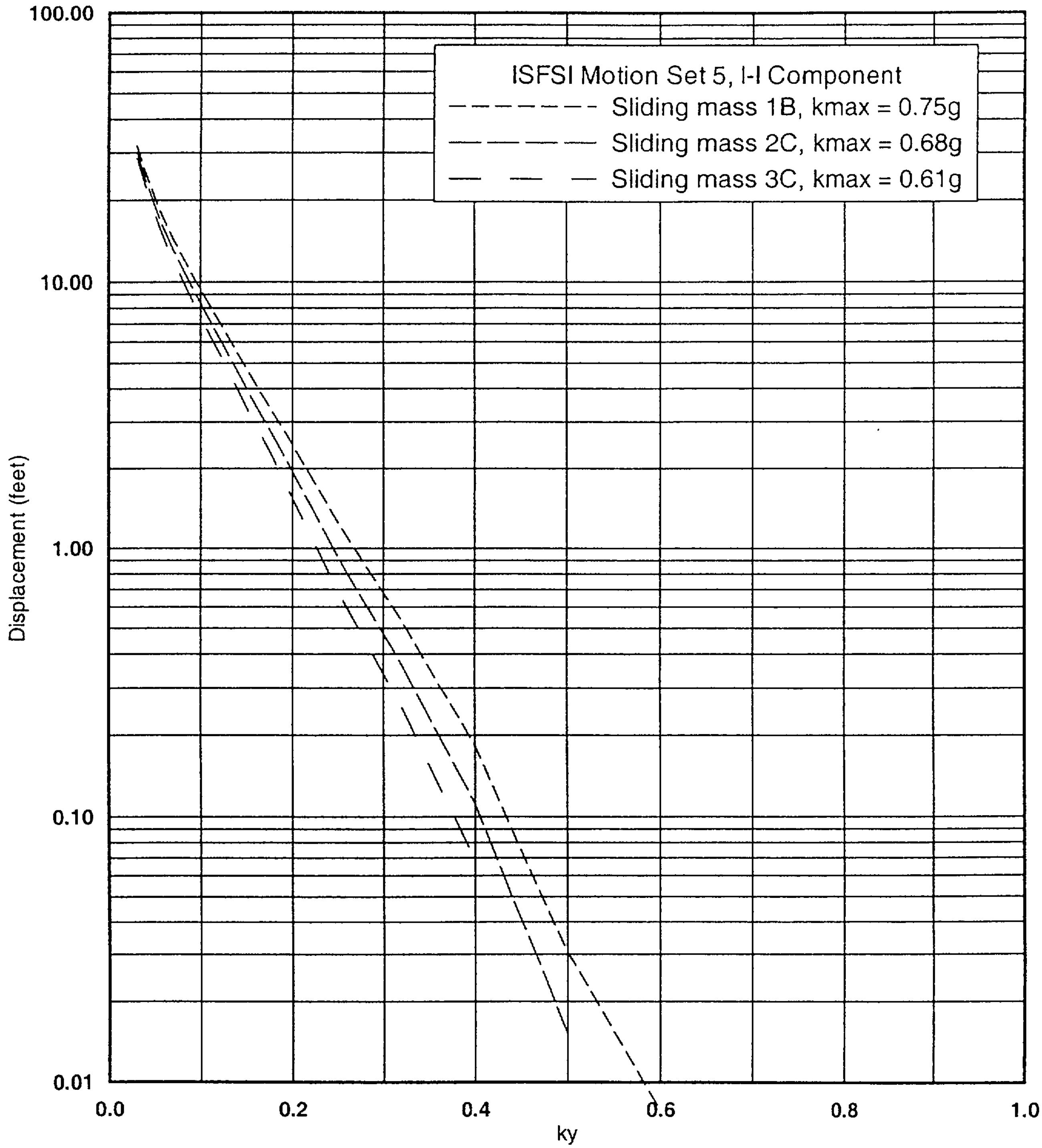

Figure 6. Permanent displacement versus yield acceleration from average acceleration time histories (set 5 input motion).

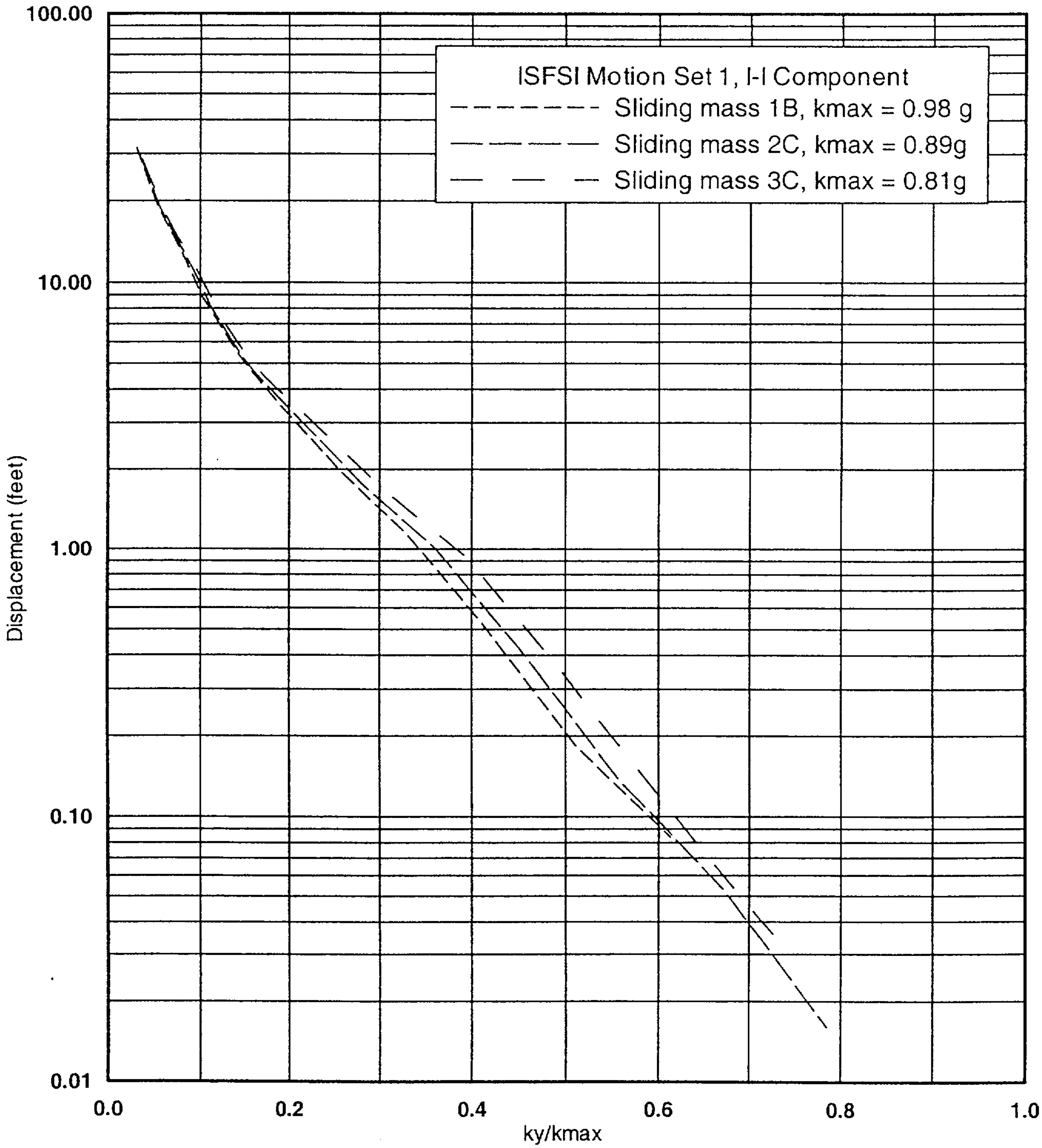

Figure 7. Permanent displacement versus yield acceleration ratio from average acceleration time histories (set 1 input motion).

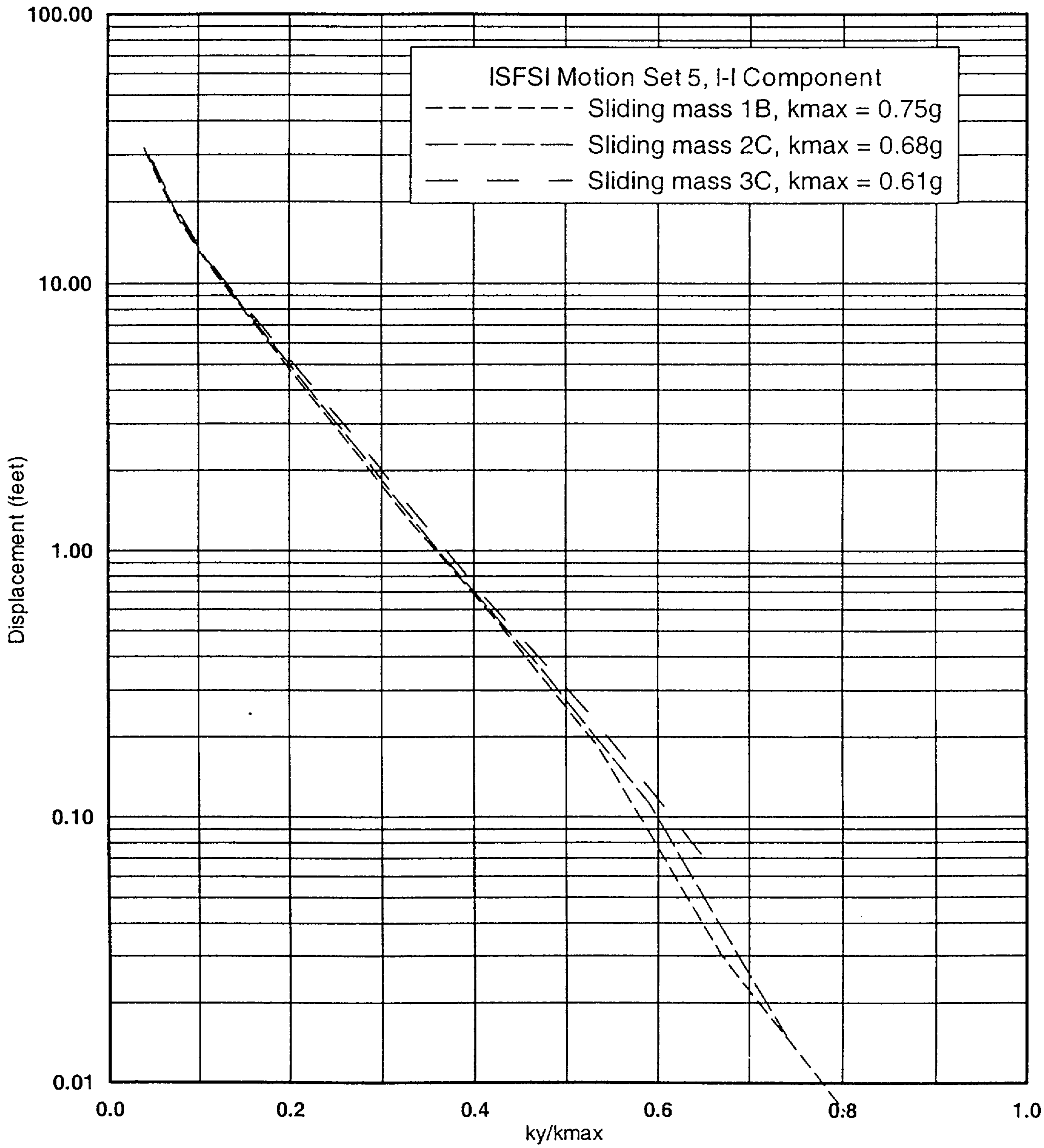

Figure 8. Permanent displacement versus yield acceleration ratio from average acceleration time histories (set 5 input motion).

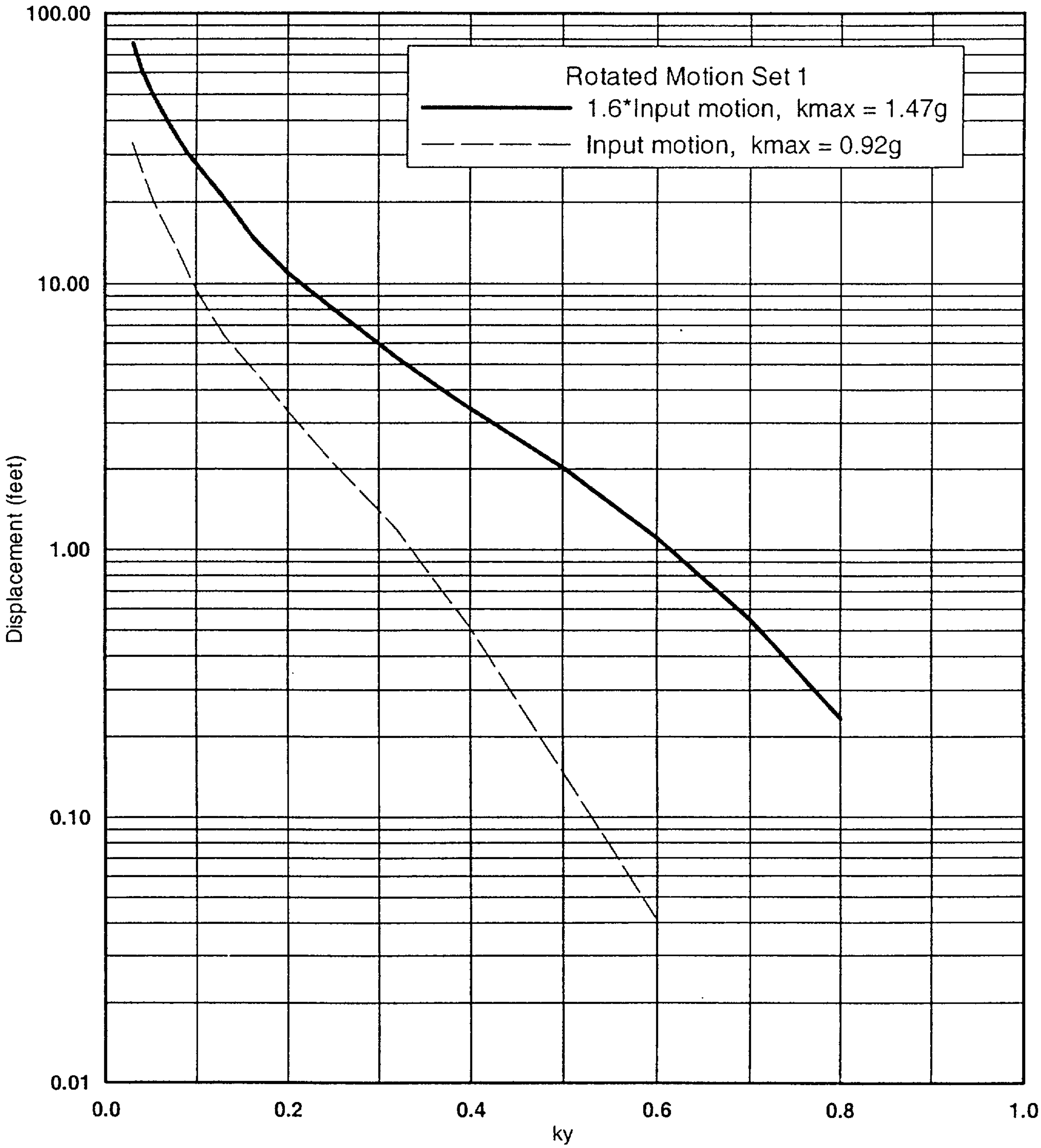

Figure 9. Permanent displacement versus yield acceleration from scalied input acceleration time histories- rotated motion set 1

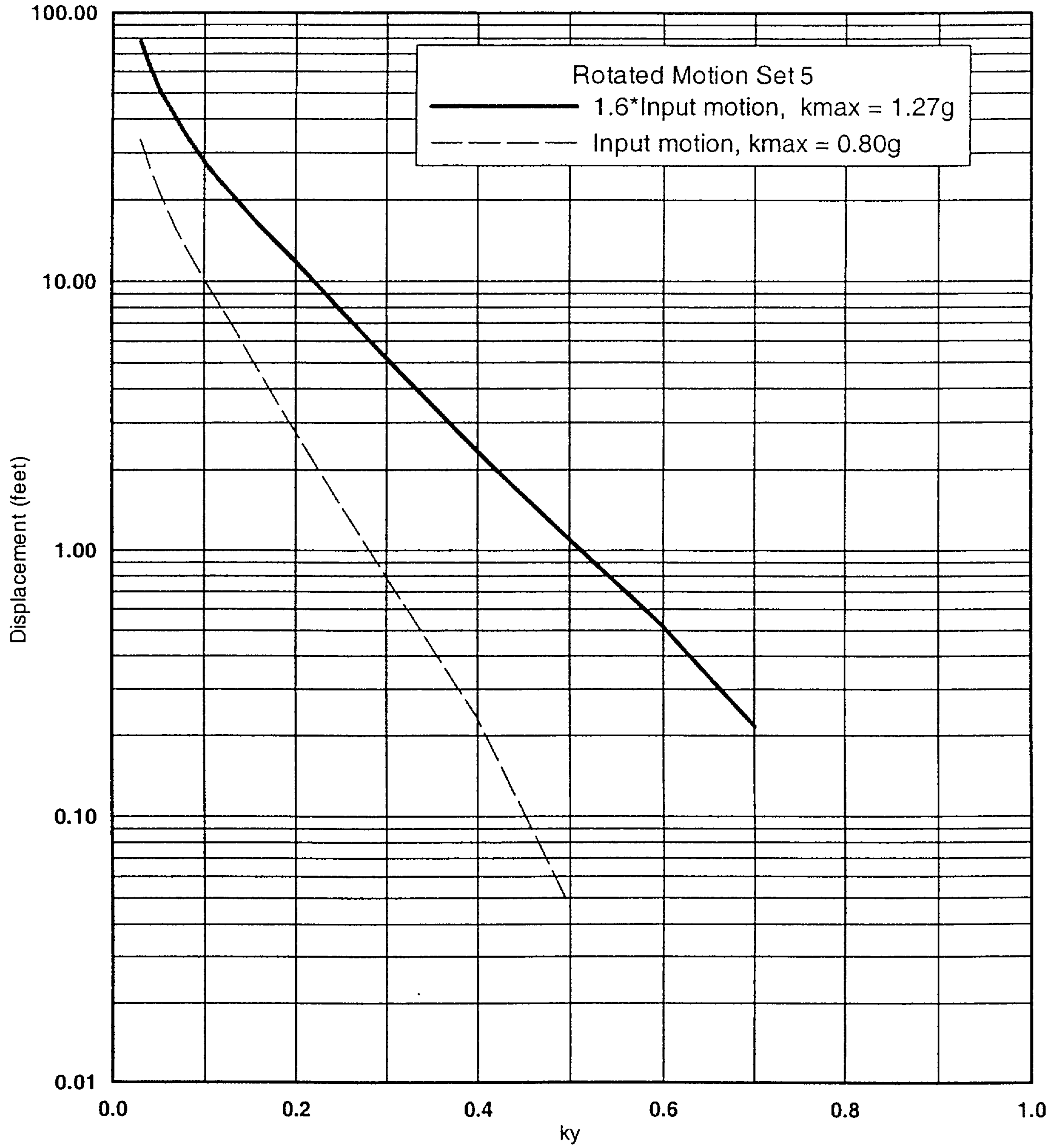

Figure 10. Permanent displacement versus yield acceleration from scaled input acceleration time histories- rotated motion set 5.

ATTACHMENT 1

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GEO.DCPP.01.26
REVISION 1

PG&E

Dr. Faiz Makdisi
Geomatrix Consultants
2101 Webster Street
Oakland, CA 94612

September 28, 2001

Re: Confirmation of transmittal of inputs for DCPP ISFSI slope stability analyses

DR. MAKDISI:

This is to confirm transmittal of inputs related to slope stability analyses you are scheduled to perform for the Diablo Canyon Power Plant (DCPP) Independent Spent Fuel Storage Installation (ISFSI) under the Geomatrix Work Plan entitled "Laboratory Testing of Soil and Rock Samples, Slope Stability Analyses, and Excavation Design for the Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site."

Inputs transmitted include:

Drawing entitled "Figure 21-19, Cross Section I-I'," dated 9/27/01, labeled "Draft," and transmitted to you via overnight mail under cover letter from Jeff Bachhuber of WLA and dated 9/27/01.

Time histories in Excel file entitled "time_histories_3comp_rev1.xls," dated 8/17/2001, file size 3,624 KB, which I transmitted to you via email on 8/17/2001.

Please confirm receipt of these items and forward confirmation to me in writing.

Please note that both these inputs are preliminary until the calculations they are part of have been fully approved. At that time, I will inform you in writing of their status. These confirmation and transmittal letters are the vehicles for referencing input sources in your calculations.

trans2fm1.doc:rkw:9/28/01

Although the Work Plan does not so state, as you are aware all calculations are required to be performed as per Geosciences Calculation Procedure GEO.001, entitled "Development and Independent Verification of Calculations for Nuclear Facilities," revision 3. All of your staff assigned to this project have been previously trained under this procedure.

I am also attaching a copy of the Work Plan. Please make additional copies for members of your staff assigned to this project, review the Work Plan with them, and have them sign Attachment 1. Please then make copies of the signed attachment and forward to me.

If you have any questions, feel free to call.

Thanks.

Rob White

ROBERT K. WHITE

Attachment

cc: Chris Hartz

ATTACHMENT 2

WLA William Lettis & Associates, Inc.
1777 Botelho Drive, Suite 262, Walnut Creek, California 94596
Voice: (925) 256-6070 FAX: (925) 256-6076

~~MEMORANDUM~~

TO: Dr. Faiz Makdisi - Geomatrix Consultants, Inc.
FROM: Jeff L. Bachhuber - William Lettis & Associates, Inc.
DATE: August 3, 2001

RE: Ground Motion Directional Components

FAIZ:

At the request of Robert K. White of PG&E Geosciences Department, we prepared this memorandum that documents our review of ground motion directional components for slope stability analyses at the PG&E DCPP ISFSI site. It is our understanding that you will be rotating ground motions developed by PG&E to the best-estimated downslope failure direction and require an appropriate rotation angle from the Hosgri fault parallel direction.

Based on our geologic characterization, the most likely slope failure direction would be along cross section I-I' on the attached figure 21-3, or along an azimuth orientation of about 302° ±10°. We believe that this value is conservatively realistic.

Please call me if you have any questions or require further input for this issue.

Cc: Rob White/Bill Page - PG&E Geosciences

ATTACHMENT 3

WLA
William Lettis & Associates, Inc.
1777 Botelho Drive, Suite 262, Walnut Creek, California 94596
Voice: (925) 256-6070 FAX: (925) 256-6076

MEMORANDUM

TO: Dr. Faiz Makdisi - Geomatrix Consultants, Inc.
FROM: Jeff L. Bachhuber - William Lettis & Associates, Inc.
DATE: August 23, 2001

RE: Revised Estimates for Hosgri Fault Azimuth, DCPP ISFSI Project

FAIZ:

This memorandum provides a revised strike azimuth of 338° for the Hosgri fault for evaluation of ground motion directional components for slope stability analyses at the PG&E DCPP ISFSI site. The revised azimuth presented in this memorandum supercedes the previous estimated azimuths (328° to 335°) presented in our memorandum dated August 8, 2001, and is based on a re-evaluation of fault maps in the PG&E LTSP (1988), and ISFSI project Calculation Package GEO.01.21.

The revised estimated average strike for the Hosgri fault nearest the ISFSI site (between Morro Bay and San Luis Bay) is 338°. Figure 21-23 of Calculation Package GEO.01.21, which previously showed an azimuth of 340° for the Hosgri fault, will be revised to correspond to this re-interpreted average strike. Discrete faults and local reaches of the fault zone exhibit variations in strike azimuth between about 328° and 338°, but the average overall strike of 338° is believed to be the best approximation for the ground motion modeling.

Please call me if you have any questions or require further input for this issue.

Jeff Bachhuber

Cc: Rob White/Bill Page - PG&E Geosciences

ATTACHMENT 4

Pacific Gas & Electric Company
Geosciences Department

P.O. Box 770000, Mail Code N4C
San Francisco, CA 94177
Fax: (415) 973-5778

TELEFAX COVER SHEET

Date: Oct 18 '01

Number of pages including cover sheet: 3

To: Faiz Makdisi
Company: Geomatrix

Phone: (510) 663-4100
Fax: (510) 663-4141
cc:

From: Joseph Sun
Company: PG&E

Phone: (415) 973-2460
Fax: (415) 973-5778

REMARKS: ☐ Per request ☐ For review ☐ Reply ASAP ☐ Please comment

Faiz,

The fault parallel with fling ground motions positive is to the southeast. We will follow up with a formal transmittal of the calc package to you

Joseph

c:\data\forms\fax cover.doc

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number *GEO.DCPP.01.14*
Revision *1*
Date *October 15, 2001*
Calc Pages: *26*
Verification Method: *A*
Verification Pages: *17 & 8 Attachments*

TITLE: *Development of time histories with Fling*

PREPARED BY: [signature] DATE *October 15, 2001*

Norman Abrahamson — Printed Name
Geosciences — Organization

VERIFIED BY: [signature] DATE *October 15, 2001*

Joseph Sun — Printed Name
Geosciences — Organization

APPROVED BY: [signature] DATE *10/15/01*

Lloyd Cluff — Printed Name
Geosciences — Organization

REGISTERED GEOLOGIST
LLOYD S. CLUFF
No. 1725
STATE OF CALIFORNIA

Expires: 12/31/02

REGISTERED GEOLOGIST
LLOYD S. CLUFF
No. EG567
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

Expires: 12/31/02

Calc Number: GEO.DCPP.01.14
Rev Number: 1
Sheet Number: 4 of 26
Date: 10/12/01

6. BODY OF CALCULATIONS

Step 1: S-wave arrival times

The approximate arrival times of the S-waves is estimated by visual inspection of the velocity time histories (Figures 1, 2, 3, 4, and 5). The selected arrival times are listed in Table 6-1.

Table 6- 1. Time of Fling

Set	Reference Time History	Approximate Arrival time of S-waves	Arrival Time of fling (t_1) (sec)	Polarity*
1	Lucerne	8.0	7.1	-1
2a	Yarimca	9.0	8.5	-1
3	LGPC	4.0	3.4	-1
5	El Centro (1940)	1.5	0.0	1
6	Saratoga	4.5	3.7	-1

* The polarity is applied to the fault parallel time history from calculations GEO.DCPP.01.13 (rev 1) to cause constructive interference between the S-wave and the fling (eq. 5-2).

A fling arrival time is selected by visual inspection of the interference of the velocity of the transient motion and the fling (Figures 1, 2, 3, 4, and 5). The selected fling arrival time are listed in Table 6-1.

Since DCPP is on the east side of the Hosgri fault and the fault has right-lateral slip, the permanent tectonic deformation at the site will be to the southeast. In the time histories the fling has a positive polarity. Since the tectonic deformation will be to the southeast, the positive direction of the fault parallel time history is defined to the southeast.

Step 2: Fling Time History

Using the values of A, ω, and T_{fling} given in input 4-1, and the values of t_1 given in Table 6-1, the fling time history is determined using eq. (5-1). The computed fling time histories for the 5 sets are shown in Figures 1, 2, 3, 4, and 5.

ATTACHMENT 5

Pacific Gas and Electric Company

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GEO.DCPP.01.26

REVISION 1

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

October 25, 2001

Re: Input parameters for calculations

DR. MAKDISI:

As required by Geosciences Calculation Procedure GEO.001, entitled "Development and Independent Verification of Calculations for Nuclear Facilities," rev. 4, I am providing you with the following input items for your use in preparing calculations.

1. The shear wave velocity profiles obtained in borings BA98-1 and BA98-3 in 1998 are presented in Figure 21-42, attached, of Calculation GEO.DCPP.01.21, entitled "Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPP ISFSI Site," rev. 0, and can be so referenced. These profiles were previously presented in Figure 10 of the WLA report entitled "Geologic and Geophysical Investigation, Dry Cask Storage Facility, Borrow and Water Tank Sites," dated January 5, 1999.

2. The average unit weight of rock obtained from the hillside has been determined to be 140 pounds per cubic foot, as documented in a data report entitled "Rock Engineering Laboratory Testing - GeoTest Unlimited."

3. Regarding the time histories provided to you on 8/17/01, since the tectonic deformation will be to the southeast, the positive direction of the fault parallel time history is defined as to the southeast, as described in Geosciences Calculation GEO.DCPP.01.14, entitled "Development of Time Histories with Fling," rev. 1, page 4.

4. The source of the shear modulus and damping curves are Figures Q19-22 and Q19-23, attached, from PG&E, 1989, Response to NRC Question 19 dated December 13, 1988, and can be so referenced.

Regarding format of calculations, please observe the following:

Contents of CD-ROMs attached to calculations should be listed in the calculation, including title, size, and date saved associated with each file on the CD-ROM. If the number of files is considerable, a simple screen dump of the CD-ROM contents is sufficient.

If you have any questions regarding the above, please call me.

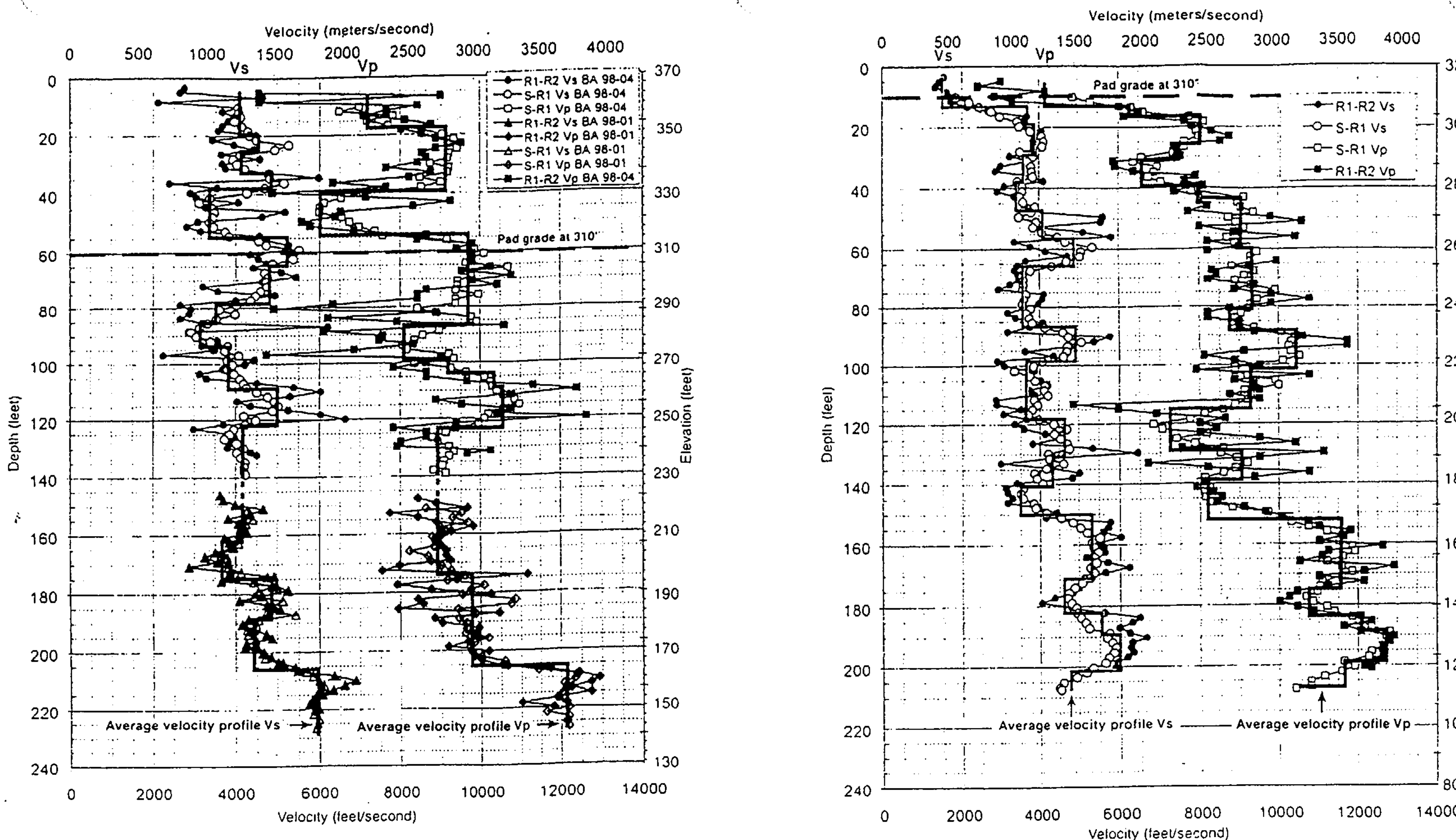
Robert K White

ROBERT K. WHITE

Attachments

Borings 98BA-1 and 98BA-4

Boring 98BA-3



Note: Average velocity profiles interpreted from data.

R1 - R2 = Receiver-to-receiver velocity (3.3-foot spacing)
S-R1 = Source-to-receiver velocity (10.3-foot spacing)

Modified from GeoVision (1998), DCPP ISFSI
SAR Section 2.6 Topical Report Appendix C

DIABLO CANYON ISFSI

FIGURE 21-42
ISFSI SITE SUSPENSION LOGS AND
INTERPRETED AVERAGE SEISMIC VELOCITIES

GEO DCPP.01.21 REV 0 October 15, 2001

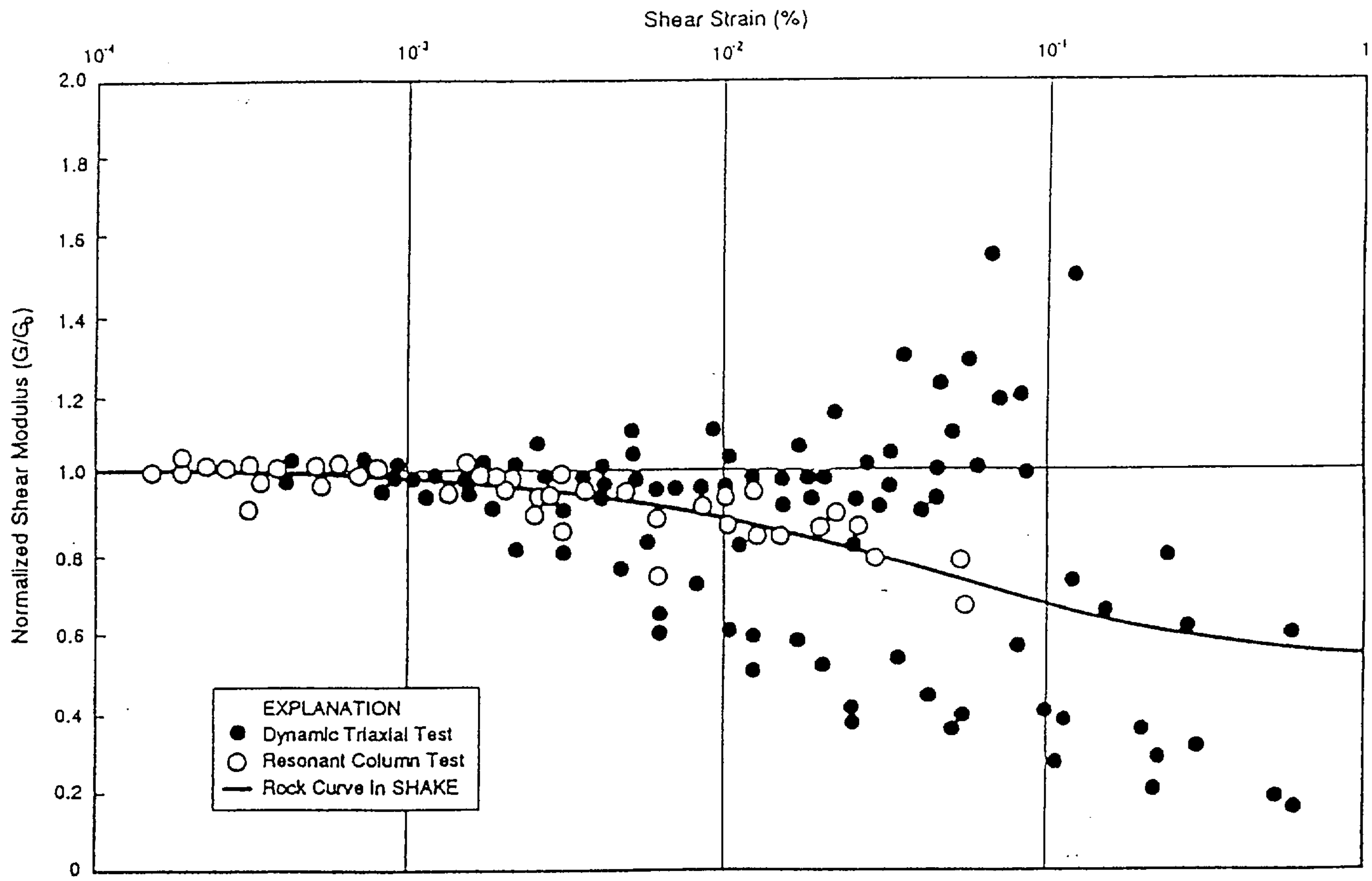


Figure Q19-22

Variation of shear modulus with shear strain for the site rock based on 1978 laboratory test data.

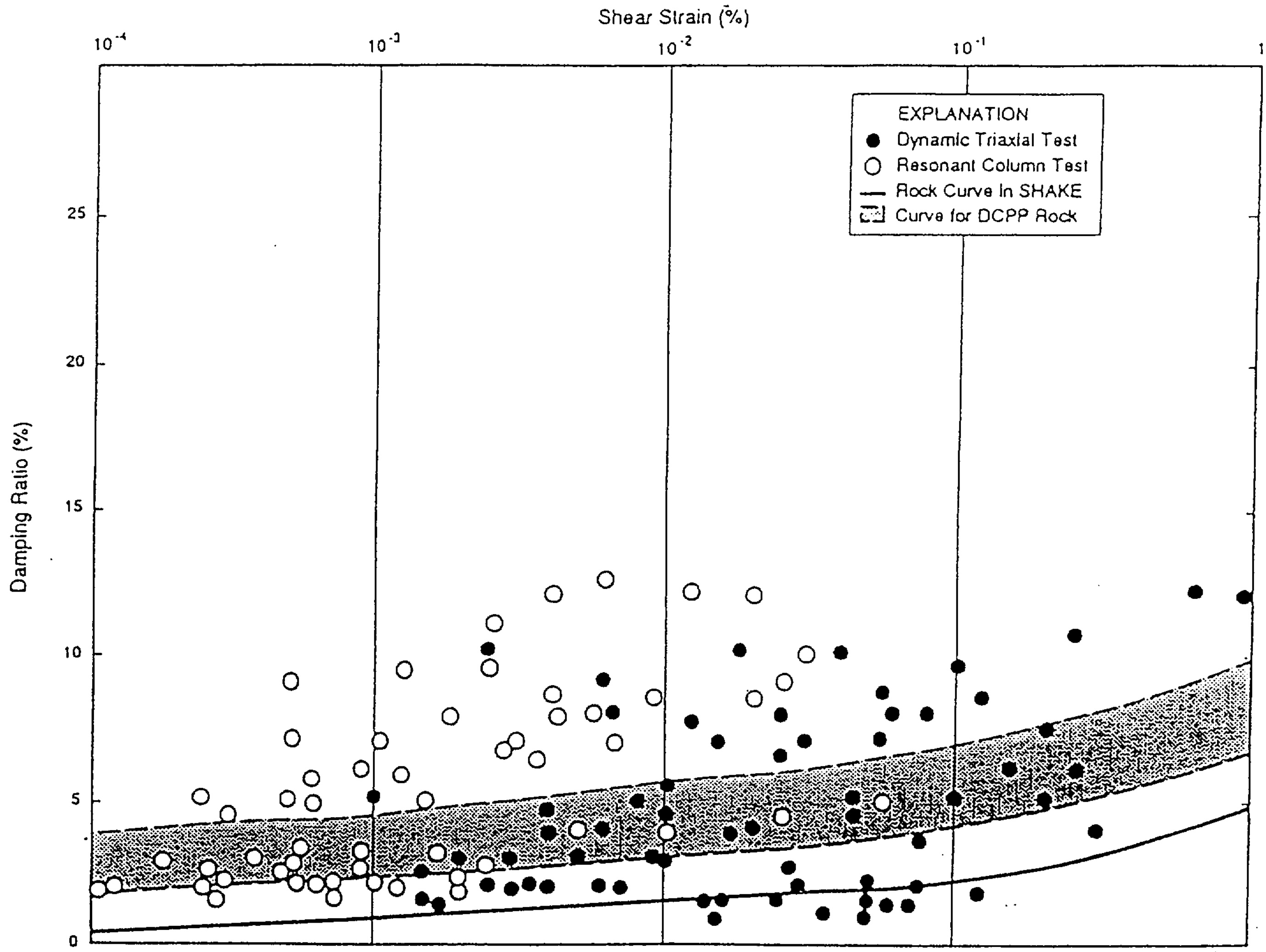


Figure Q19-23

Variation of damping ratio with shear strain for the site rock based on 1977 laboratory test data.

ATTACHMENT 6

Pacific Gas and Electric Company
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GEO.DCPP.01.26

REVISION 1

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

October 31, 2001

Re: Confirmation of preliminary inputs to calculations for DCPP ISFSI site

DR. MAKDISI:

A number of inputs to calculations for the DCPP ISFSI slope stability analyses have been provided to you in a preliminary fashion. This letter provides confirmation of those inputs in a formal transmittal. A description of the preliminary inputs and their formal confirmation follow.

Letter to Faiz Makdisi from Rob White dated June 24, 2001. Subject: Recommended rock strength design parameters for DCPP ISFSI site slope stability analyses.

This letter recommended using $\phi = 50$ degrees for the preliminary rock strength envelope in your stability analyses, and indicated that this value would be confirmed once calculations had been finalized and approved. Calculations GEO.DCPP.01.16, rev. 0, and GEO.DCPP.01.19, rev. 0, are approved and this recommended value is confirmed.

Letter to Faiz Makdisi from Rob White dated September 28, 2001. Subject: Confirmation of transmittal of inputs for DCPP ISFSI slope stability analyses.

This letter provided confirmation of transmittal of cross section I-I' and time histories, and indicated that these preliminary inputs would be confirmed once calculations had been approved. Calculation GEO.DCPP.01.21, rev. 0, is approved and section I-I' as described in the September 28 letter is confirmed. A copy of the figure from the approved calculation is attached. Calculations GEO.DCPP.01.13, rev. 1, and GEO.DCPP.01.14, rev. 1, are both approved and time histories as described in the September 28 letter are confirmed. A CD of the time histories from the approved calculations is attached.

ltr2fm3.doc:rkw:10/31/01

Email to Faiz Makdisi from Joseph Sun dated October 24, 2001. Subject: Ground motion parameters for back calculations.

This email provided input for a back calculation to assess conservatism in clay bed properties in the slope. Inputs included maximum displacement per event of 4 inches and a factor of 1.6 with which to multiply ground motions for use in the back calculation analysis. This letter confirms those input values, with the following limitation: these values have not been developed under an approved calculation, therefore should not be used to directly determine clay bed properties for use in forward analyses, but may be used for comparative purposes only, to assess the level of conservatism in those clay bed properties determined in approved calculations

Letter to Faiz Makdisi from Jeff Bachhuber dated October 10, 2001. Subject: Transmittal of Revised Rock Mass Failure Models – DCPP ISFSI Project.

This letter provided you with figures indicating potential rock mass failure models as superimposed on section I-I'. This letter confirms PG&E approval to use these models in your analyses. These figures are labeled drafts and are currently being finalized in a revision to Calculation GEO.DCPP.01.21. Once this revision and the included figures have been approved, I will inform you in writing of their status.

Rob White

ROBERT K. WHITE

Attachments

ATTACHMENT 7

Pacific Gas and Electric Company

Geosciences
245 Market Street, Room 418B
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San Francisco, CA 94177
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Fax 415/973-5778

GEO.DCPP.01.26

REVISION 1

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

November 1, 2001

Re: Confirmation of additional inputs to calculations for DCPP ISFSI site

DR. MAKDISI:

Additional inputs to calculations for the DCPP ISFSI slope stability analyses have been provided to you by Jeff Bachhuber of William Lettis Associates. This letter provides confirmation of our acceptance of those inputs in a formal transmittal. A description of those additional inputs and their formal acceptance follow.

Letter to Faiz Makdisi from Jeff Bachhuber dated August 3, 2001. Subject: Ground Motion Directional Components.

This letter recommended using an azimuth of 302 degrees plus or minus 10 degrees for the orientation of the most likely failure surfaces, coinciding with Section I-I'. We concur with this recommendation based on the discussion on page 53 of the approved Calculation GEO.DCPP.01.21, rev. 0, and verification of the orientation of Section I-I' on Calculation Figure 21-4, attached.

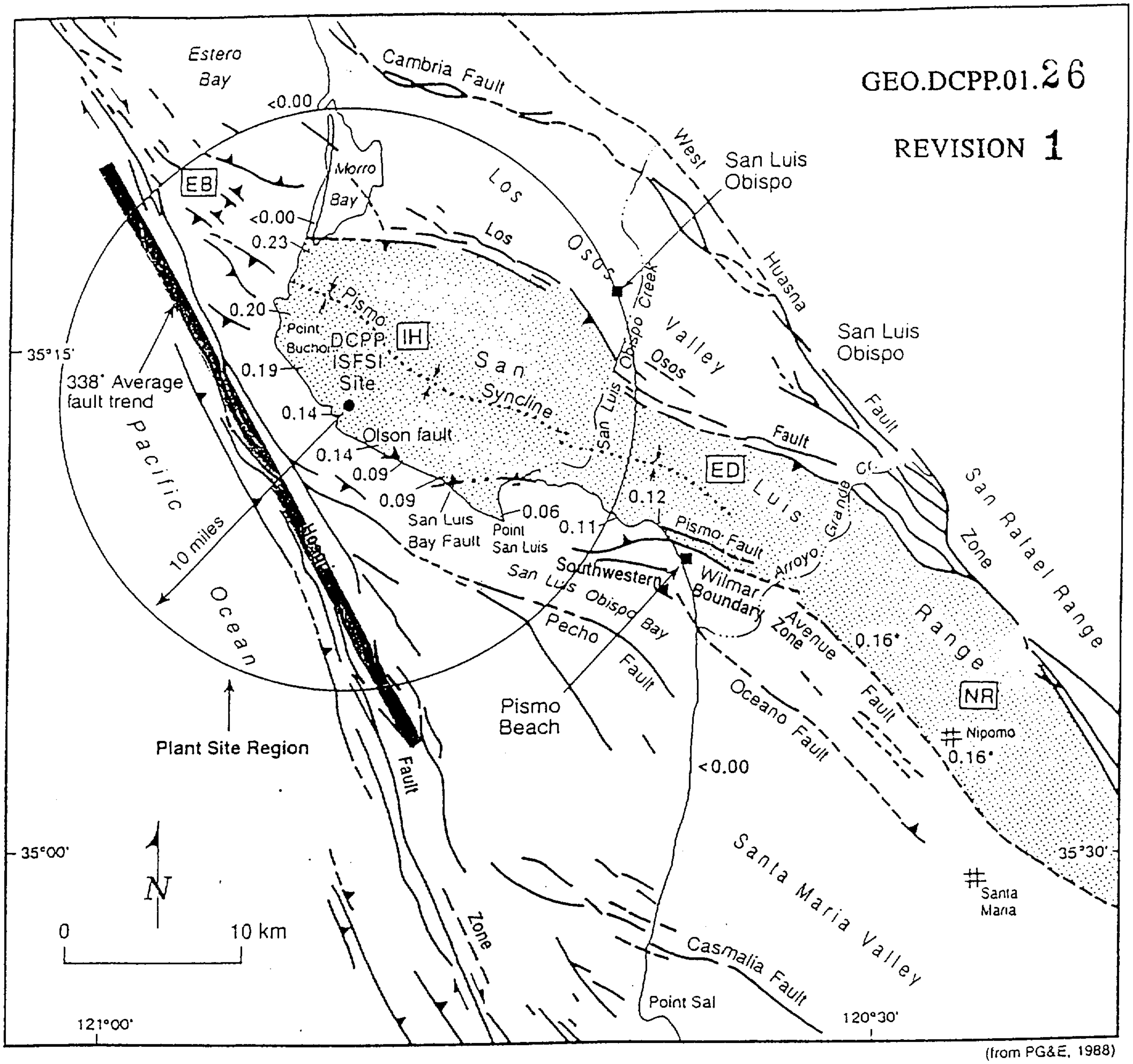
Letter to Faiz Makdisi from Jeff Bachhuber dated August 23, 2001. Subject: Revised Estimates for Hosgri Fault Azimuth, DCPP ISFSI Project.

This letter recommended using an azimuth of 338 degrees for the orientation of the average strike of the Hosgri fault. We concur with this recommendation, based on verification of the orientation as presented in the LTSP plates and as shown on Figure 21-36, attached, of Calculation GEO.DCPP.01.21, rev. 0.

Rob White

ROBERT K. WHITE

Attachments



Explanation

Fault: dashed where approximately located; teeth indicate dip direction of reverse fault; arrows indicate relative sense of displacement

Syncline axial trace

0.14 Late Pleistocene (post 120,000 years ago) uplift rate (meters/1000 yr)

0.16* Uplift rate (meters/1000 yr) based on the altitude and estimated age (560,000 years) of the Q7 marine terrace

EB Estero Bay Subblock

IH Irish Hills Subblock

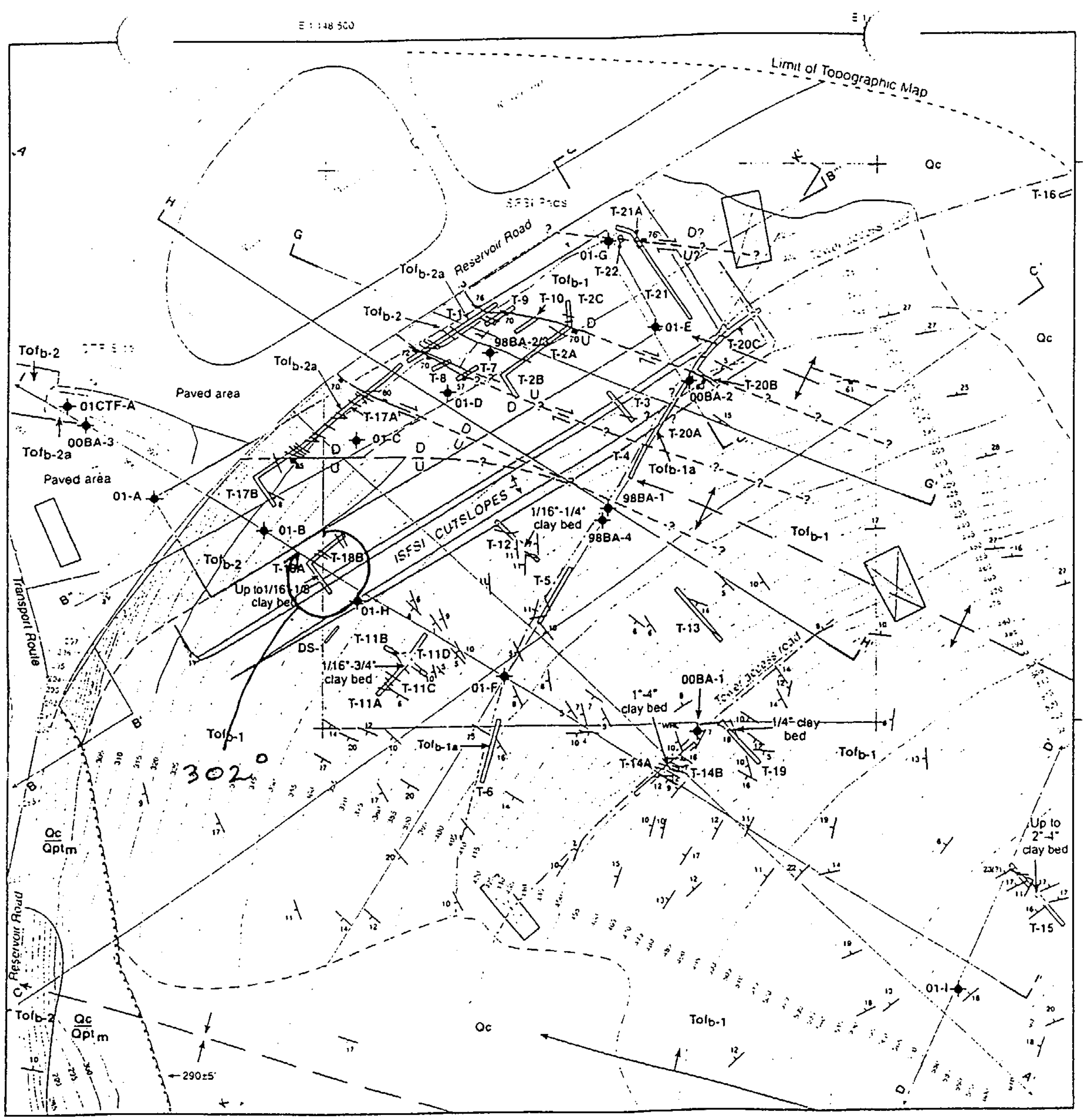
ED Edna Subblock

NR Newsom Ridge Subblock

SAFETY ANALYSIS REPORT

DIABLO CANYON ISFSI

FIGURE 21-36
REGIONAL STRUCTURE MAP



EXPLANATION

Qc — Colluvium

Qptm — Marine terrace deposit (overlain by Qc)

Obispo Formation (lower and middle Miocene)

DOLOMITE SUBUNIT

Tofb-1 — Dolomite, clayey dolomite, dolomitic siltstone to fine-grained dolomitic sandstone, and limestone. The subunit contains occasional discontinuous to continuous (tens to hundreds of feet) clay beds that are generally 1/32 to 1/2-inch thick, but locally are thicker. Rocks in this unit are moderately- to well-cemented, medium hard, moderately to slightly weathered, brittle and typically medium strong.

Tofb-1a — Friable (poorly cemented) dolomite and dolomitic rocks of subunit Tofb-1. These rocks typically have low hardness, are very weak to weak, and occur as discontinuous zones where weathering and/or alteration has been concentrated.

SANDSTONE SUBUNIT

Tofb-2 — Dolomitic medium- to coarse-grained sandstone (arkose to arenitic), and altered sandstone; detrital clasts are composed primarily of dolomitized feldspars, marine fossil fragments, and volcanic rock fragments. Discontinuous clay layers that are generally less than 1/2-inch thick occur locally within the subunit. The rocks are of low to medium hardness, moderately- to well-cemented and typically medium strong.

Tofb-2a — Friable (poorly cemented) dolomitic sandstone and sandstone of subunit Tofb-2. These rocks typically are of low hardness and are very weak to weak, and occur as discontinuous zones in places where weathering and/or alteration has been concentrated.

- Strike and dip of bedding
- Minor fault, dip indicated, dashed where inferred, queried where uncertain, arrows show sense of movement, U-upthrown, D-downthrown
- Small, secondary faults exposed in trench
- Clay beds, thickness indicated
- Geologic contact, solid line where well-defined, dashed where approximate
- 01-C — Boring for ISFSI, number indicated (initial number is year drilled)
- A — A' — Geologic cross section, arrows indicate end of line is off the map area
- T-4 — Exploratory trench, number indicated
- DS-1 — Discontinuity survey line in bulldozer cut
- Footprint of 500 kV tower
- Outline of ISFSI Pads and CTF site
- Proposed cut slope above ISFSI Pads
- Axis of anticline, solid arrow shows plunge, dashed where approximate
- Axis of syncline, solid arrow shows plunge, dashed where approximate
- Axis of monocline, solid arrow shows plunge, dashed where approximate
- Shoreline angle of marine terrace wave-cut platform (buried), elevation indicated (Q5 terrace; see Figure 21-24)

ISFSI Cutslope is a schematic representation and is not final.

N

0 50 100 150 200

Contour interval = 5 feet

DIABLO CANYON ISFSI

FIGURE 21-4
GEOLOGIC MAP OF ISFSI AND CTF SITES

GEO DCPP.01.21 REV 0 Page 125 of 167 October 2001

ATTACHMENT 8

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GEO.DCPP.01. 26

REVISION 1

DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

December 13, 2001

Re: Confirmation of DCPP ISFSI ground motion parameters for back calculation analysis

DR. MAKDISI:

As part of your analysis of the stability of the slope behind the DCPP ISFSI, you are performing a back-calculation analysis of the slope in its pre-excavated (pre-1971) configuration to evaluate the level of conservatism in the assumed lateral extent and the undrained strength of the clay beds underlying the slope. Key parameters required for this analysis, including amount of slope displacement and associated ground motions, are provided below.

Calculation GEO.DCPP.01.21, Rev. 1, pages 59 through 61, indicates that the range of potential slope displacements for past large earthquakes is 3 to 6 inches per event (page 60, attached). For purposes of the back-calculation analysis, a value within this range of 4 inches is recommended.

For purposes of defining the large earthquake causing this value of displacement, it is recommended that you multiply the ground motions provided to you on 8/17/01 (and confirmed in my letter to you dated 10/31/01) by a factor of 1.6, to represent ground motions that are at the 98th percentile (that is, one standard deviation above the 84th percentile ground motions provided).

If you have any questions regarding this information, please call.

Rob White

ROBERT K. WHITE

Attachment

ltr2fm11.doc:rkw:12/13/01

site area (Figure 21-41) (Diablo Canyon ISFSI Data Report A). Similarly the many trenches excavated into the slope, the tower access road cuts, the extensive outcrops exposed by the 1971 borrow cut, and the many borings exposed no tension cracks or fissure fills on the hillslope (Diablo Canyon ISFSI Data Reports A, B and D). Open cracks or soil-filled fissures greater than 1 to 2 feet in width should be easily recognized across the slope given the extensive rock exposure provided by the borrow cut. Therefore, we conservatively assume that any cumulative displacement in the slope greater than 3 feet would have produced features that would be evident in rock slope. The absence of this evidence places a maximum threshold of 3 feet on the amount of cumulative slope displacement that may have occurred in the geologic past.

The hillslope at the ISFSI site is older than at least 300,000 years because remnants of the Q-5 (320,000 yrs) marine terrace are cut into the slope west of the ISFSI site (Figure 21-3). Preservation of the terrace documents that the slope has had minimal erosion since that time. Moreover, gradual reduction of the ridge by erosion at the ISFSI site would not destroy deep tension cracks or deep disruption of the rock mass; these features would be preserved as filled fractures and fissures even as the slope is lowered.

The topographic ridge upon which the ISFSI site is located has experienced strong ground shaking from numerous earthquakes on the Hosgri fault zone during the past 300,000 years. PG&E (1988, p. 3-39) provides a recurrence interval of 11,350 years for an M_W 7.2 earthquake on the Hosgri fault. Therefore, approximately 25 to 30 large earthquakes have occurred during the past 300,000 years without causing ground motions large enough to produce significant (i.e., greater than 3 feet) cumulative slope displacement. Based on the number of earthquakes, the hillslope likely experienced the design earthquake ground motion as described in the ISFSI SAR (PG&E, 2001). Based on the absence of cumulative slope displacement within a limit of resolution of 3 feet, the amount of possible slope displacement during the Hosgri design earthquake is a maximum of 3 feet (if only one such slope displacement has occurred) and more likely about 3 to 6 inches per event (if multiple earthquakes have caused slope displacement with cumulative displacement of up to 3 feet). Slope displacement of 3 to 6 inches,

NUCLEAR POWER GENERATION
CF3.ID4
ATTACHMENT 7.2

Index No. 402
Binder No.

TITLE: CALCULATION COVER SHEET

Unit(s): 1 & 2 File No.: 52.27

Responsible Group: Civil Calculation No.: 52.27.100.738

No. of Pages 3 pages + Index (4 pages) + 1 Attachment (31 pages) Design Calculation YES [x] NO [ ]

System No. 42C Quality Classification Q (Safety-Related)

Structure, System or Component: Independent Spent Fuel Storage Facility

Subject: Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route (GEO.DCPP.01.28, Rev. 0)

Electronic calculation YES [ ] NO [x]

Computer Model	Computer ID	Program Location	Date of Last Change

Registered Engineer Stamp: Complete A or B

A. Insert PE Stamp or Seal Below	B. Insert stamp directing to the PE stamp or seal
Expiration Date:	***REGISTERED ENGINEERS' STAMPS AND EXPIRATION DATES ARE SHOWN ON DWG 063618***

NOTE 1: Update DCI promptly after approval.
NOTE 2: Forward electronic calculation file to CCTG for uploading to EDMS.

TITLE: CALCULATION COVER SHEET

CALC No. 52.27.100.738, R0

RECORD OF REVISIONS

Rev No.	Status	Reason for Revision / Remarks	Prepared By: Initials/ LAN ID/ Date	LBIE Screen Yes/ No/ NA	LBIE Yes/ No/ NA	Check Method*	LBIE Approval PSRC Mtg. No.	LBIE Approval PSRC Mtg. Date	Checked Initials/ LAN ID/ Date	Supervisor Initials/ LAN ID/ Date	Registered Engineer Signature/ LAN ID/ Date
0	F	Acceptance of Geosciences Calc. No. GEO.DCPP.01.28, Rev. 0. Calc. supports current edition of 10CFR72 DCPP License Application to be reviewed by NRC prior to implementation. Prepared per CF3.ID17 requirements.	AFT2 [signature] 12/13/01	[ ] Yes [ ] No [x] NA	[ ] Yes [ ] No [x] NA	[ ] A [ ] B [x] C	N/A	N/A	N/A	[signature] LJS2 12/14/01	[signature] LJS2 12/14/01
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					

*Check Method: A: Detailed Check, B: Alternate Method (note added pages), C: Critical Point Check

SUBJECT Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route

MADE BY A. Tafoya AT DATE 12/13/01 CHECKED BY N/A DATE

Table of Contents:

SUBJECT Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route

MADE BY A. Tafoya AT DATE 12/13/01 CHECKED BY N/A DATE

1- This table cross references between Geosciences calculation numbers and DCPP (Civil Group's) calculation numbers. This section is For Information Only.

Cross-Index
(For Information Only)

Item No.	Geoscience Calc. No.	Title	PG&E Calc. No.	Comments
1	GEO.DCPP.01.01	Development of Young's Modulus and Poisson's Ratios for DCPP ISFSI Based on Field Data	52.27.100.711	
2	GEO.DCPP.01.02	Determination of Probabilistically Reduced Peak Bedrock Accelerations for DCPP ISFSI Transporter Analyses	52.27.100.712	
3	GEO.DCPP.01.03	Development of Allowable Bearing Capacity for DCPP ISFSI Pad and CTF Stability Analyses	52.27.100.713	
4	GEO.DCPP.01.04	Methodology for Determining Sliding Resistance Along Base of DCPP ISFSI Pads	52.27.100.714	
5	GEO.DCPP.01.05	Determination of Pseudostatic Acceleration Coefficient for Use in DCPP ISFSI Cutslope Stability Analyses	52.27.100.715	
6	GEO.DCPP.01.06	Development of Lateral Bearing Capacity for DCPP CTF Stability Analyses	52.27.100.716	
7	GEO.DCPP.01.07	Development of Coefficient of Subgrade Reaction for DCPP ISFSI Pad Stability Checks	52.27.100.717	
8	GEO.DCPP.01.08	Determination of Rock Anchor Design Parameters for DCPP ISFSI Cutslope	52.27.100.718	
9	GEO.DCPP.01.09	Determination of Applicability of Rock Elastic Stress-Strain Values to	52.27.100.719	Calculation to be replaced by letter

Cross-Index
(For Information Only)

Item No.	Geoscience Calc. No.	Title	PG&E Calc. No.	Comments
		Calculated Strains Under DCPP ISFSI Pad		
10	GEO.DCPP.01.10	Determination of SSER 34 Long Period Spectral Values	52.27.100.720	
11	GEO.DCPP.01.11	Development of ISFSI Spectra	52.27.100.721	
12	GEO.DCPP.01.12	Development of Fling Model for Diablo Canyon ISFSI	52.27.100.722	
13	GEO.DCPP.01.13	Development of Spectrum Compatible Time Histories	52.27.100.723	
14	GEO.DCPP.01.14	Development of Time Histories with Fling	52.27.100.724	
15	GEO.DCPP.01.15	Development of Young's Modulus and Poisson's Ratio Values for DCPP ISFSI Based on Laboratory Data	52.27.100.725	
16	GEO.DCPP.01.16	Development of Strength Envelopes for Non-jointed Rock at DCPP ISFSI Based on Laboratory Data	52.27.100.726	
17	GEO.DCPP.01.17	Determination of Mean and Standard Deviation of Unconfined Compression Strengths for Hard Rock at DCPP ISFSI Based on Laboratory Tests	52.27.100.727	
18	GEO.DCPP.01.18	Determination of Basic Friction Angle Along Rock Discontinuities at DCPP ISFSI Based on Laboratory Tests	52.27.100.728	
19	GEO.DCPP.01.19	Development of Strength Envelopes for Jointed Rock	52.27.100.729	

Cross-Index
(For Information Only)

Item No.	Geoscience Calc. No.	Title	PG&E Calc. No.	Comments
		Mass at DCPP ISFSI Using Hoek-Brown Equations		
20	GEO.DCPP.01.20	Development of Strength Envelopes for Shallow Discontinuities at DCPP ISFSI Using Barton Equations	52.27.100.730	
21	GEO.DCPP.01.21	Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPP ISFSI Site	52.27.100.731	
22	GEO.DCPP.01.22	Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site	52.27.100.732	
23	GEO.DCPP.01.23	Pseudostatic Wedge Analyses of DCPP ISFSI Cutslopes (SWEDGE Analysis)	52.27.100.733	
24	GEO.DCPP.01.24	Stability and Yield Acceleration Analysis of Cross Section I-I'	52.27.100.734	
25	GEO.DCPP.01.25	Determination of Seismic Coefficient Time Histories for Potential Siding Masses Above Cut Slopes Behind ISFSI Pad	52.27.100.735	
26	GEO.DCPP.01.26	Determination of Potential Earthquake-Induced Displacements of Potential Sliding Masses on DCPP ISFSI Slope	52.27.100.736	
27	GEO.DCPP.01.27	Cold Machine Shop Retaining Wall Stability	52.27.100.737	
28	GEO.DCPP.01.28	Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI	52.27.100.738	

SUBJECT Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route

MADE BY A. Tafoya AT DATE 12/13/01 CHECKED BY N/A DATE

Cross-Index
(For Information Only)

Item No.	Geoscience Calc. No.	Title	PG&E Calc. No.	Comments
		Transport Route		
29	GEO.DCPP.01.29	Determination of Seismic Coefficient Time Histories for Potential Sliding Masses on DCPP ISFSI Transport Route	52.27.100.739	
30	GEO.DCPP.01.30	Determination of Potential Earthquake-Induced Displacements of Potential Sliding Masses Along DCPP ISFSI Transport Route	52.27.100.740	
31	GEO.DCPP.01.31	Development of Strength Envelopes for Clay Beds at DCPP ISFSI	52.27.100.741	
32	GEO.DCPP.01.32	Verification of Computer Program SPCTLR.EXE	52.27.100.742	
33	GEO.DCPP.01.33	Verification of Program UTEXAS3	52.27.100.743	
34	GEO.DCPP.01.34	Verification of Computer Code - QUAD4M	52.27.100.744	
35	GEO.DCPP.01.35	Verification of Computer Code DEFORMP	52.27.100.745	
36	GEO.DCPP.01.36	Reserved	52.27.100.746	
37	GEO.DCPP.01.37	Development of Freefield Ground Motion Storage Cask Spectra and Time Histories for the Used Fuel Storage Project	52.27.100.747	

FILE No. 077 11/27 '01 16:51 ID:PG&E GEOSCIENCES DEPT 415 973 5778 PAGE 2

PG&E
Geosciences Department
Departmental Calculation Procedure

Number: GEO.001
Revision: 4

Title: Design Calculation Cover Sheet

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number GEO.DCPP.01.28
Revision 0
Date 11/26/2001
Calc Pages: 29
Verification Method: See Summary : A
Verification Pages: See Summary : 2.1 NOT ATTACHED

TITLE: Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route

PREPARED BY: [signature] DATE 11/26/01

Karthik Narayanan
Printed Name

Geomatrix
Organization

VERIFIED BY: [signature] DATE 11/27/01

Christopher Kavanaugh
Printed Name

Geomatrix
Organization

APPROVED BY: [signature] DATE 11/27/01

Lloyd Cluff
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Geosciences
Organization

REGISTERED GEOLOGIST
LLOYD S. CLUFF
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STATE OF CALIFORNIA

Exp. 12/31/02

PG&E
Geosciences Department
Departmental Calculation Procedure

Number: GEO.001
Revision: 4

Title: Design Calculation Cover Sheet

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number GEO.DCPP.01.28
Revision 0
Date 11/26/2001
Calc Pages: 29
Verification Method: See Summary : A
Verification Pages: See Summary : 2

TITLE: Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route

PREPARED BY: [signature] DATE 11/26/01

KARTHIK NARAYANAN — Printed Name
GEOMATRIX — Organization

VERIFIED BY: [signature] DATE 11/27/01

Christopher Krivanec — Printed Name
Geomatrix — Organization

APPROVED BY: ______________ DATE ______________

Printed Name ______________ Organization ______________

Calculation Title: Stability and Yield Acceleration Analysis of Potential Sliding Masses along DCPP ISFSI Transport Route
Calculation No.: GEO.DCPP.01.28
Revision No.: 0
Calculation Author: Karthik Narayanan (Geomatrix Consultants)
Calculation Date: 11/26/01

PURPOSE

The purpose of this calculation is to evaluate the stability and yield acceleration of potential sliding masses along the transport route between Units 1 and 2 and the proposed ISFSI site. The analyses described in this calculation package were conducted in accordance with the Geomatrix Consultants, Inc. Work Plan "Laboratory Testing of Soil and Rock Samples, Slope Stability Analysis, and Excavation design for Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site," Revision 2, dated December 8, 2000.

Potential sliding masses having the lowest factors of safety against sliding are identified in this calculation package. The yield accelerations of these potential sliding masses are used in calculation package GEO.DCPP.01.30 to evaluate their potential for earthquake-induced deformations.

ASSUMPTIONS

The transporter track loads were represented as point loads in the stability and yield acceleration analysis. A plane strain stability analysis model has a unit thickness in the direction perpendicular to the plane of analysis. Hence, the point loads used to model the transporter tracks represent line loads in the direction perpendicular to the plane of the analysis. This assumption results in conservative factors of safety and yield accelerations.

INPUTS

The information required for the slope stability and yield acceleration analyses are the surface topography, soil strengths, and unit weights. The analyses described in this calculation package were conducted for cross sections L-L', D-D', and E-E', shown in Attachment A. Surface topography and subsurface geology were taken from these cross sections.

A summary of properties used for the stability and yield acceleration analyses is shown on Table 1. Soil properties for the colluvium, terrace deposits, and rock were taken from PG&E

(1997) (Attachment B). Properties for the artificial fill were taken to be the same as the colluvium, in accordance with the recommendations presented in Attachment C.

Additional input needed for stability analyses includes the assumed transporter loads. The transporter wheel loads were taken from the recommendations of Attachment D. The transporter loads were modeled as two point loads of 225,000 lb each at a wheel spacing of 182 inches.

METHOD

Slope stability analyses were performed using the computer program UTEXAS3 (Wright, 1990). Spencer's method, a method of slices that satisfies force and moment equilibrium, was used for the analyses. Initially, searches were conducted to identify the circular or wedge-type sliding mass with the lowest factor of safety. If the potential sliding surface identified by the initial search did not intercept or affect the transport route, additional searches were conducted in the vicinity of the transport route to identify potential sliding surfaces that impacted the road. Among the potential sliding masses that included the transport route, the one with the lowest factor of safety was selected as the "critical sliding mass."

Once a critical sliding mass was identified based on its factor of safety and proximity to the transport route, its yield acceleration was calculated using UTEXAS3. The yield accelerations will be used in GEO.DCPP.01.30 for evaluation of earthquake-induced displacements. Horizontal seismic coefficients were incrementally applied to the critical sliding mass, and the yield acceleration was taken to be the horizontal seismic coefficient resulting in a factor of safety of unity. In the above calculations where the transporter load was considered, the transporter load was modeled as two concentrated loads.

SOFTWARE

The calculations of slope stability and yield acceleration were conducted using the program UTEXAS3. This program was verified in GEO.DCPP.01.33.

ANALYSIS

The slope stability and yield acceleration calculations were conducted using UTEXAS3. The input and output files for the calculation of long-term stability and yield acceleration are contained in the compact disc labeled "GEO.DCPP.01.28, Revision 0".

RESULTS

The results of the stability and yield acceleration analyses are summarized on Table 2. The lowest factor of safety for the short-term static stability analysis (including the transporter loads) is 1.60, which was calculated for a circular sliding mass shown on Figure 1. Based on Attachment E, this factor of safety is considered adequate for short-term stability. The corresponding yield acceleration for this critical failure surface is 0.46 (which was used in calculation package GEO.DCPP.01.30 to determine associated deformations).

The computed yield accelerations for the three sections analyzed ranged between 0.37 and 0.76. The lowest calculated yield acceleration was 0.37, corresponding to a wedge type sliding mass (with a factor of safety of 2) along cross section L-L′ (without the transporter load) shown on Figure 2. Yield accelerations are used to estimate earthquake-induced displacements as discussed in calculation package GEO.DCPP.01.30, Revision 0.

REFERENCES

a) Geomatrix Consultants, Inc. Work Plan, Laboratory Testing of Soil and Rock Samples, Slope Stability Analyses, and Excavation Design for Diablo Canyon Power Plant Independent Spent Fuel Storage Installation Site, Revision 2, dated December 8, 2001

b) GEO.DCPP.01.30, Revision 0 -- Determination of Potential Earthquake-Induced Displacements of Potential Sliding Masses along DCPP ISFSI Transport Route.

c) GEO.DCPP.01.33, Revision -- Verification of computer program UTEXAS3

d) Wright, S.G. (1990) -- UTEXAS3, A computer program for slope stability calculations, May 1990, Shinoak Software, Austin, Texas.

TABLE OF CONTENTS

ATTACHMENTS

Attachment A -11/12/01, PG&E Geosciences, Robert K. White, Re: Forwarding of approved plan and cross-sections D-D′, E-E′, and L-L′ for DCPP ISFSI transport route stability analyses

Attachment B - PG&E, 1997, Assessment of slope stability near the Diablo Canyon Power Plant, Response to NRC request of January 31, 1997.

Attachment C - 11/19/01, PG&E Geosciences, Robert K. White, Re: Transmittal of additional inputs for DCPP ISFSI transport route analysis.

Attachment D - Letter from Robert White to Faiz Makdisi (November 15, 2001) subject: Forwarding of Cold Machine Shop Retaining Wall Calculation Inputs from Project Engineer. Partial enclosure: Klimczak, Richard L. (2001) Letter to Robert White, PG&E Geosciences, Subject: Diablo Canyon Units 1 and 2, Transmittal of Information on the Transporter Movement Along the Transport Route. Dated October 19, 2001.

Attachment E – ASCE Standard N725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures

ENCLOSURES

Compact disc labeled "GEO.DCPP.01.28, Revision 0" containing the input and output files for the calculation of long-term stability and yield acceleration.

TABLE 1

SOIL PARAMETERS FOR STABILITY ANALYSIS
SLOPE SECTIONS A-A' AND C-C'
DIABLO CANYON POWER PLANT SITE
(From PG&E, 1997)

Geologic Unit	Description	Density In-Place (pcf)	Shear Strength Parameters
Topsoil	Organic CLAY, silty (CH) (section B-B' only)	115	S_u = 1200 psf
Qc	Young colluvium, soft to stiff CLAY, silty and sandy (CH-CL)	115	S_u = 1500 psf
Qpf[1]	Pleistocene colluvial fan deposits, CLAY to SILT, gravelly and sandy	115	S_u = 3000 psf
Qptm	Pleistocene marine terrace deposits, poorly graded SAND to GRAVEL	130	c = 0; ϕ = 40°
Tof_b	Miocene Obispo Formation, sandy siltstone and silty sandstone, local chert, blocky, Bedrock	140	C = 4000 psf; ϕ = 35°

[1] Properties for colluvium were applied to artificial fill per Attachment B.

TABLE 2

FACTORS OF SAFETY AND YIELD ACCELERATIONS COMPUTED FOR POTENTIAL SLIDING MASSES

Cross Section	With Transporter?	Description	FS	k_y (g)	Figure	Files[1] input = *.dat output = *.out
L-L'	Yes	Circular	1.60	0.46	1	stacir, dyncir
L-L'	No	Wedge	1.99	0.37	2	stawed2, dynwed2
E-E'	Yes	Circular	3.38	0.57	3	stacirwt, dyncirwt
E-E'	No	Circular	4.98	0.76	4	stacirnt, dyncirnt
D-D'	Yes	Circular	2.33	0.45	5	stacirwt, dyncirwt
D-D'	No	Circular	2.21	0.45	6	stacirnt, dyncirnt

[1] Files are in organized in directories by their respective cross section

FS = 1.60 ky =0.46
SECTION L-L'

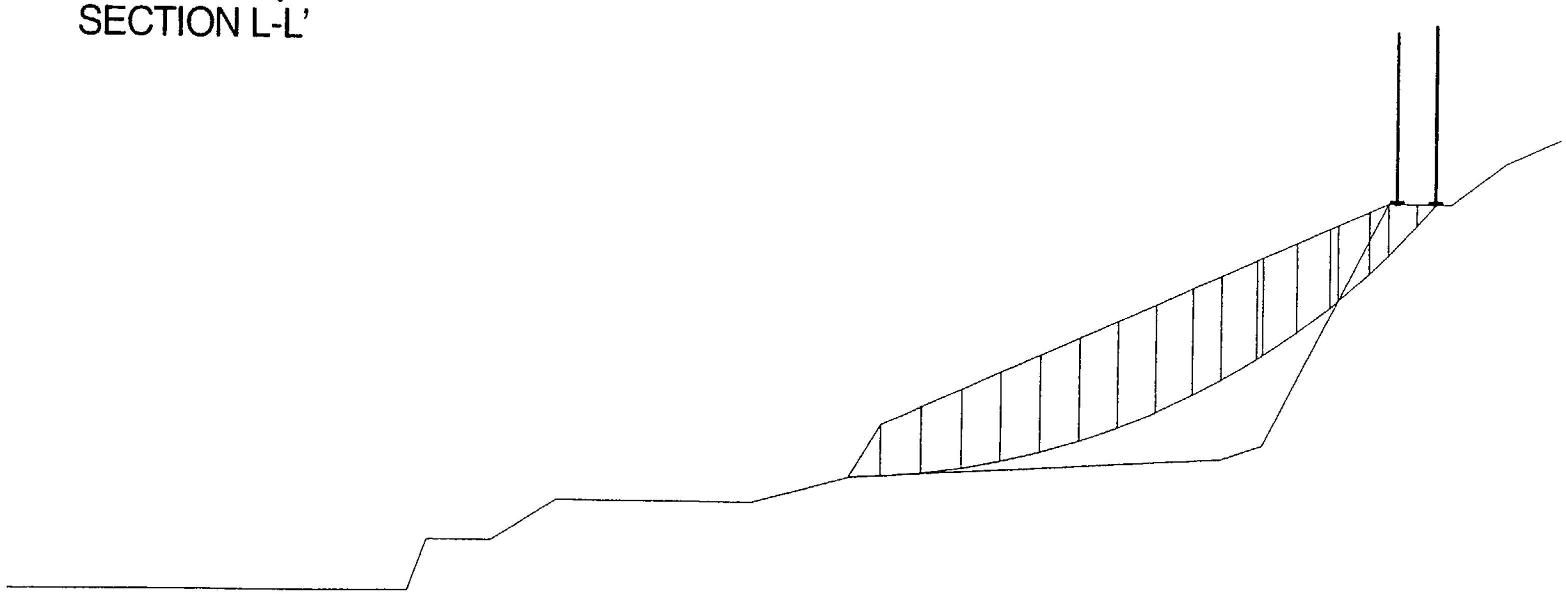

FIGURE 1 - Critical circular surface; cross section L-L'; with transporter

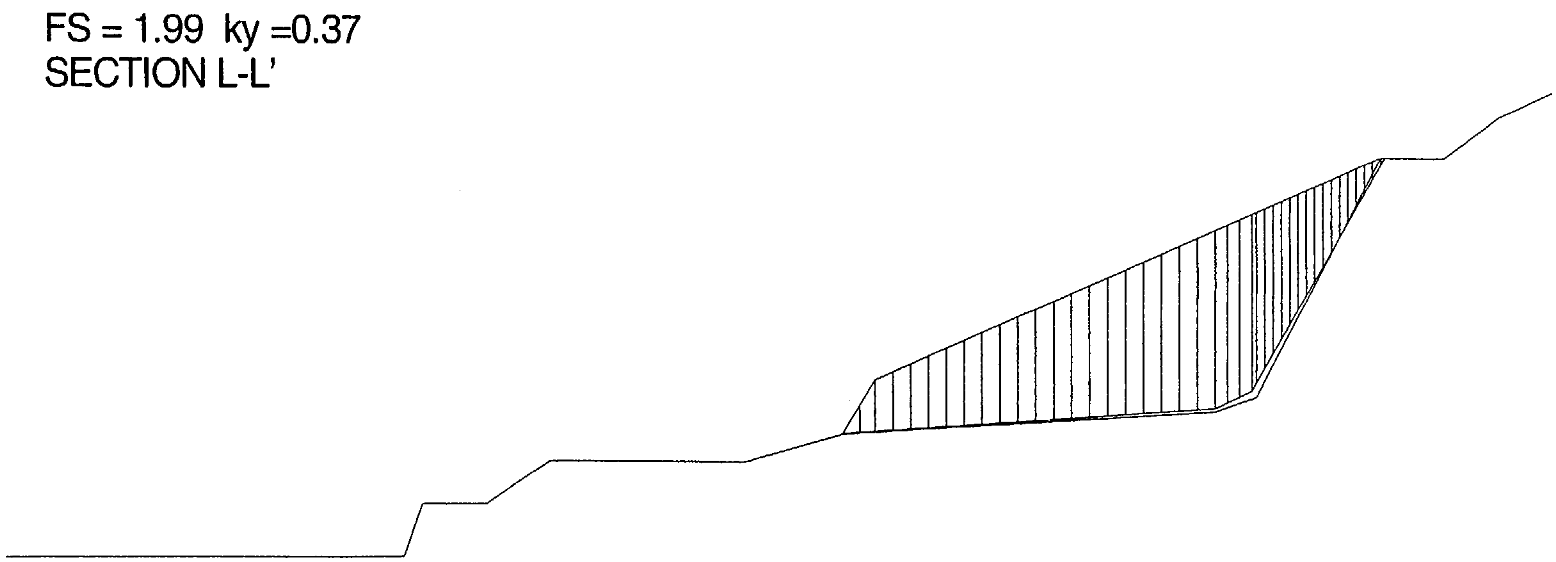

FIGURE 2 - Critical wedge; cross section L-L'; no transporter

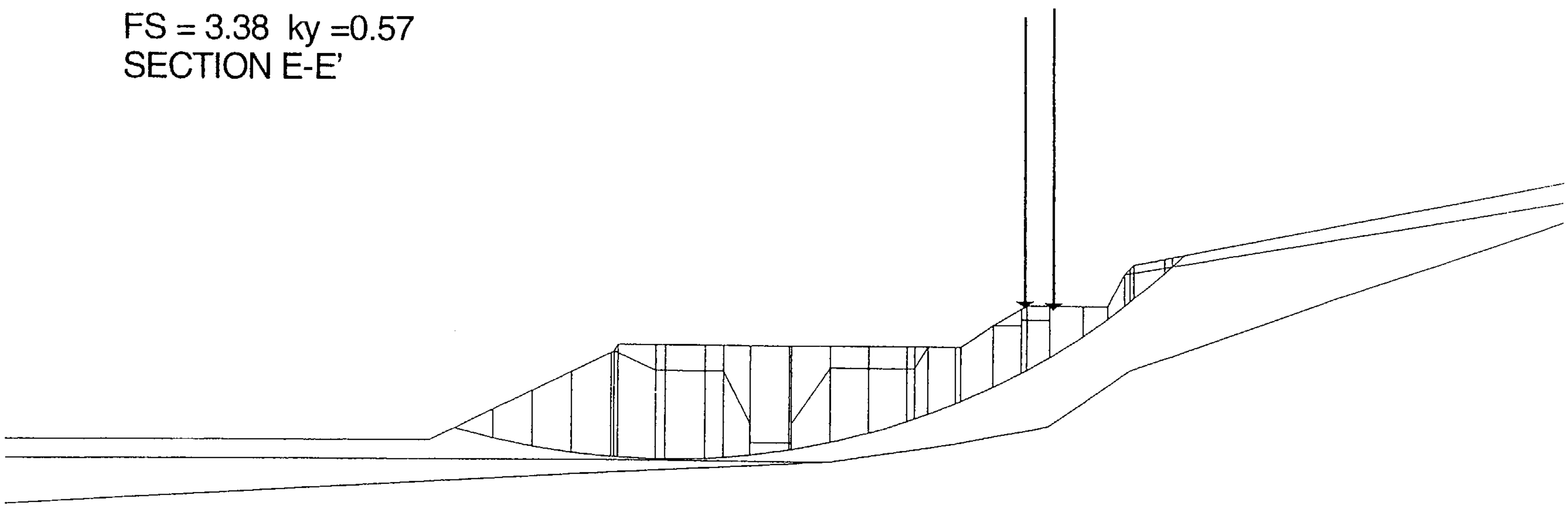

FIGURE 3 - Critical circle; cross section E-E'; with transporter

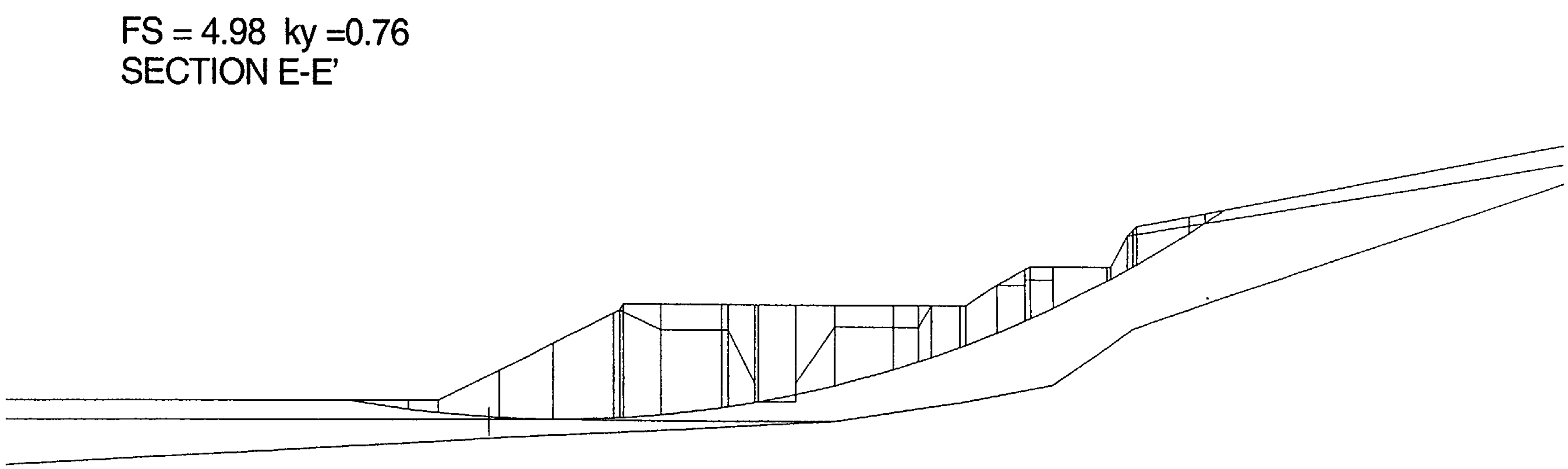

FIGURE 4 - Critical circle; cross section E-E'; no transporter

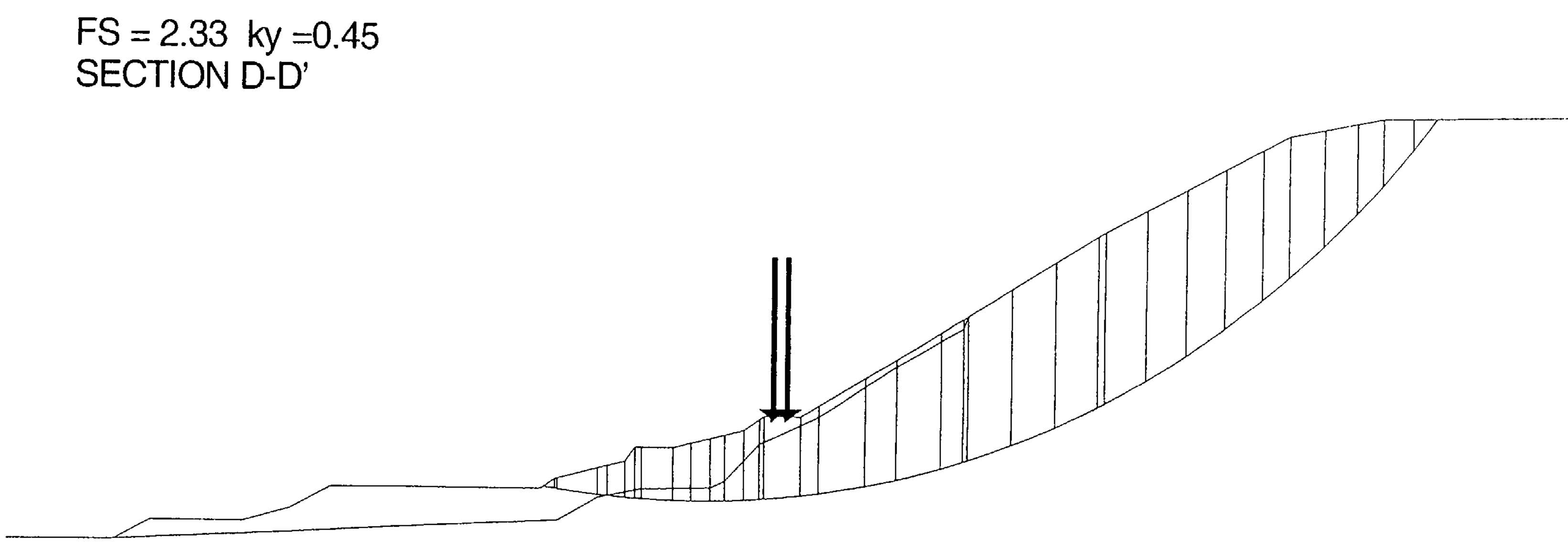

FIGURE 5 - Critical circle; cross section D-D'; with transporter

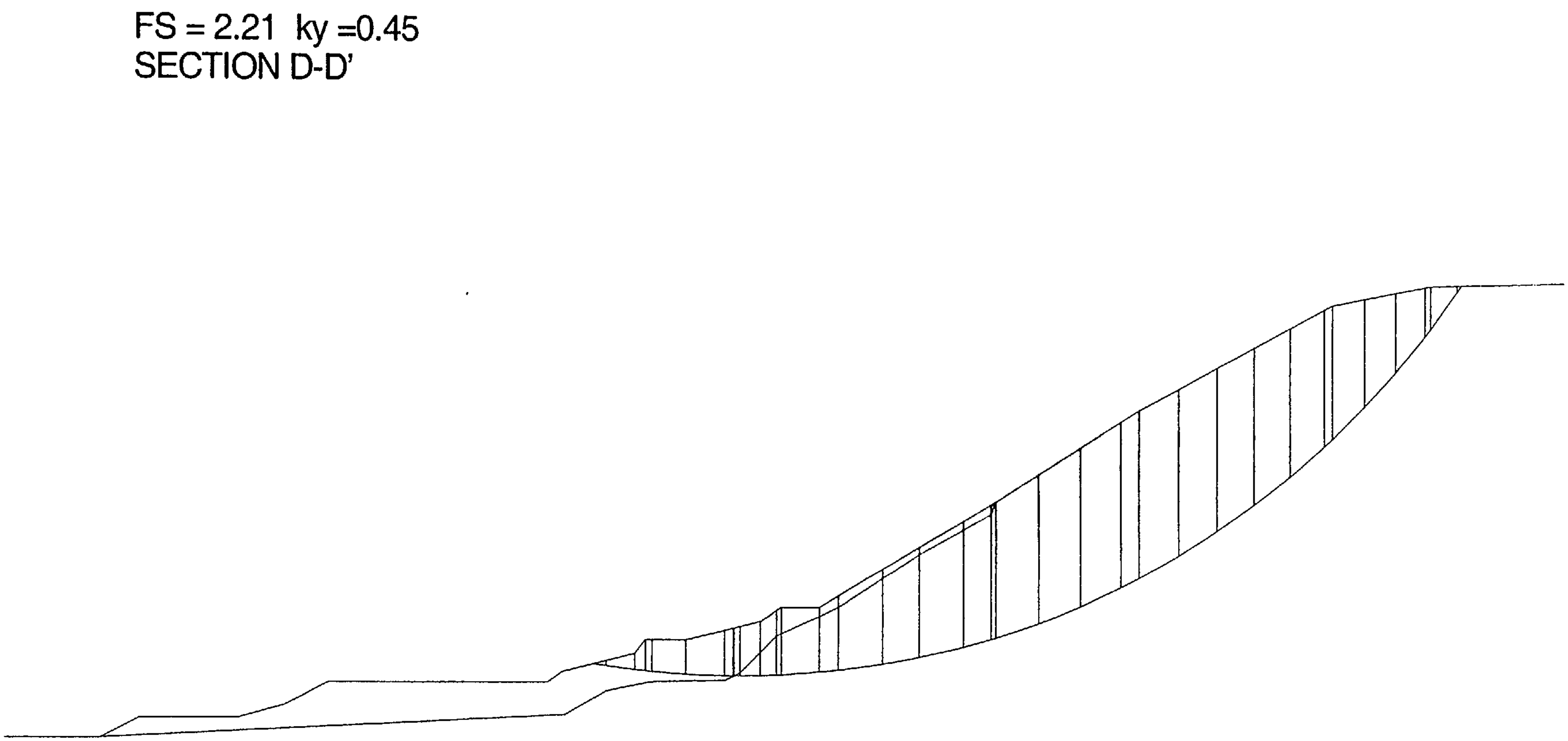

FIGURE 6 - Critical circle; cross section D-D'; no transporter

Pacific Gas and Electric Company

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DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

November 12, 2001

Re: Forwarding of Approved Plan and Cross Sections D-D', E-E', and L-L' for DCPP ISFSI Transport Route Stability Analyses

DR. MAKDISI:

Please find enclosed the following approved plan and cross sections from Geosciences Calculation GEO.DCPP.01.21, rev. 1:

Figure 21-3, Geologic Map of the ISFSI Site and Transport Route Vicinity
Figure 21-17a, Cross Section D-D' through Patton Cove Landslide
Figure 21-18a, Cross Section E-E'
Figure 21-25, Cross Section L-L'

for your use in DCPP ISFSI transport route stability analyses. These figures supersede those transmitted to you in draft form by Rich Koehler of William Lettis Associates on October 25, 2001.

Also for your use, we have determined the azimuth of each section from Figure 21-3, as follows:

Section D-D': 38 degrees
Section E-E': 34 degrees
Section L-L': 67 degrees

If you have any questions regarding this information, please call.

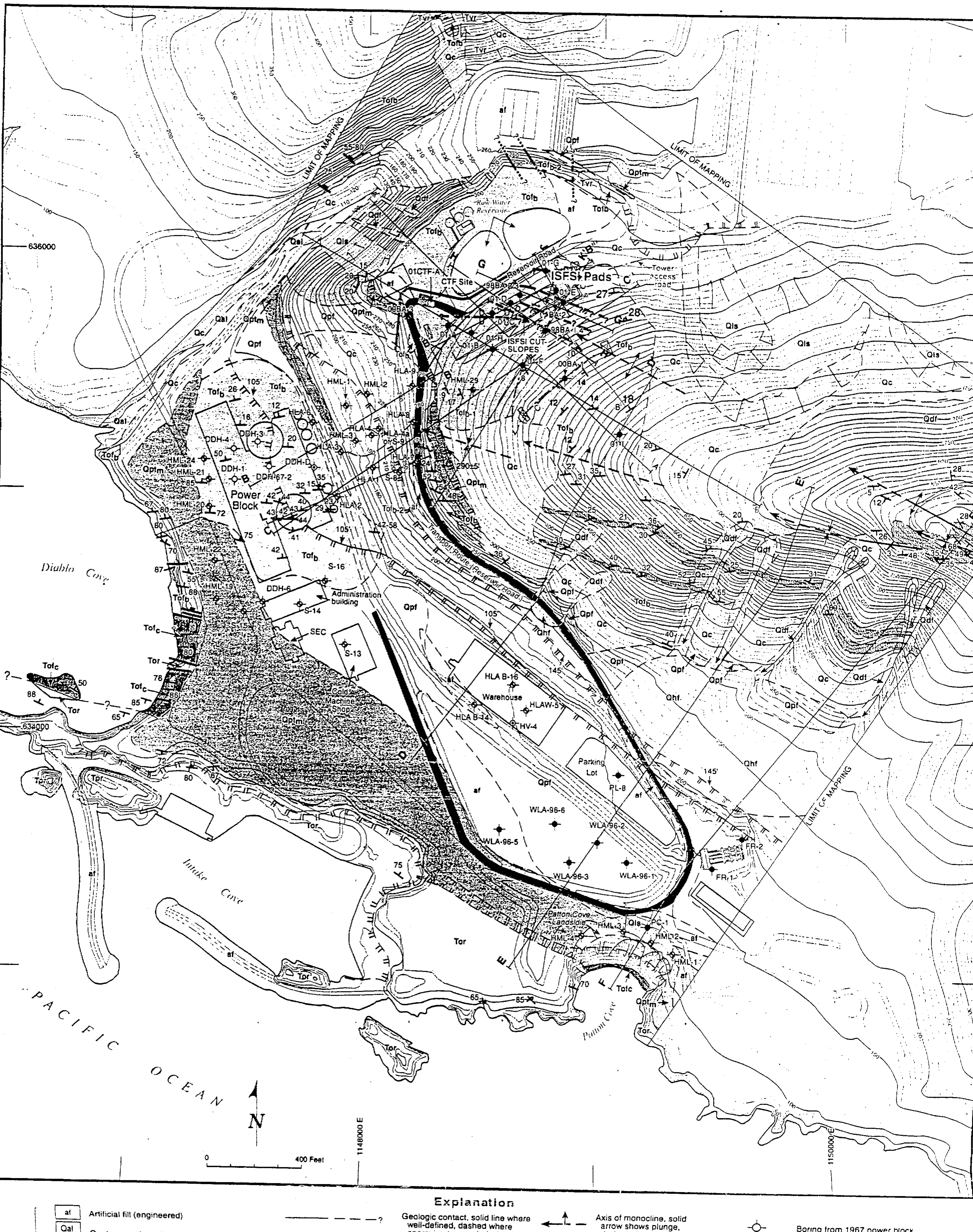
Rob White

ROBERT K. WHITE

Enclosures

GEO. DCPP.01.28
ATTACHMENT A
REV. 0

ltr2fm6.doc:rkw:11/12/01



Explanation

Quaternary

- af — Artificial fill (engineered)
- Qal, Qdf, Qc, Qls, Qhf — Quaternary deposits - alluvium, debris flow, colluvium, landslide, Holocene colluvial fan

  NOTE: Only surficial deposits greater than about 5 feet thick shown
- Qpf — Pleistocene colluvial fan
- Qptm — Pleistocene marine terrace deposit (inferred)

Tertiary

- Tvr — Volcanic rock (middle Miocene), diabase intrusive sills and dikes.

Obispo Formation (lower and middle Miocene)

- Tofb (Prominent outcrops) — Member Tof, Unit b - sandstone, dolomitic sandstone, dolomite and minor limestone; gray, yellow-brown, brown, and bluish gray; medium to very thick bedding, some units massive; moderately hard to hard; medium density; calcite and quartz veins; very blocky to blocky.
- Tofc — Member Tof, Unit c - siliceous claystone and siltstone, with lesser sandstone
- Tor — Member Tor - volcanic rock, zeolitized and silicified tuff

Symbols:

- Geologic contact, solid line where well-defined, dashed where approximate, queried where uncertain.
- Landslides, arrows indicate direction of movement, hachures define head scarp region
- Qdf — Debris flow path
- Axis of syncline, solid arrow shows plunge, dashed where approximate
- Axis of anticline, solid arrow shows plunge, dashed where approximate
- Axis of monocline, solid arrow shows plunge, dashed where approximate
- 290' — Buried shoreline, angle of marine terrace wave cut platform; elevation indicated
- Footprint of 500 kV tower
- 85 — Strike and dip of fault
- 10 — Strike and dip of bedding
- Horizontal bedding
- 60 ? — Bedrock fault with attitude; dashed where approximate, dotted where covered, queried where uncertain.
- Boring from 1967 power block study
- 1977 boring DDH-D at power block
- Boring from previous HLA and HLM studies
- Boring for ISFSI investigations, WLA 1996 to 2001
- B — B' Geologic cross section
- Transport route

NOTES:

1. This topographic map predates construction of Diablo Canyon Power Plant and facilities are only approximately located.
2. Topography southeast of power plant reflects, in part, pre-construction ground surface(ISFSI cut slope is schematic).
3. The ISFSI, CTF, and Transport Route are located by placing them as closely as possible to topographic and cultural features and are not considered precise.

DIABLO CANYON ISFSI

FIGURE 21-3
GEOLOGIC MAP OF THE ISFSI SITE AND TRANSPORT ROUTE VICINITY

Calculation 52.27.100.738, Rev. 0, Attachment A, Pg. 17 of 31

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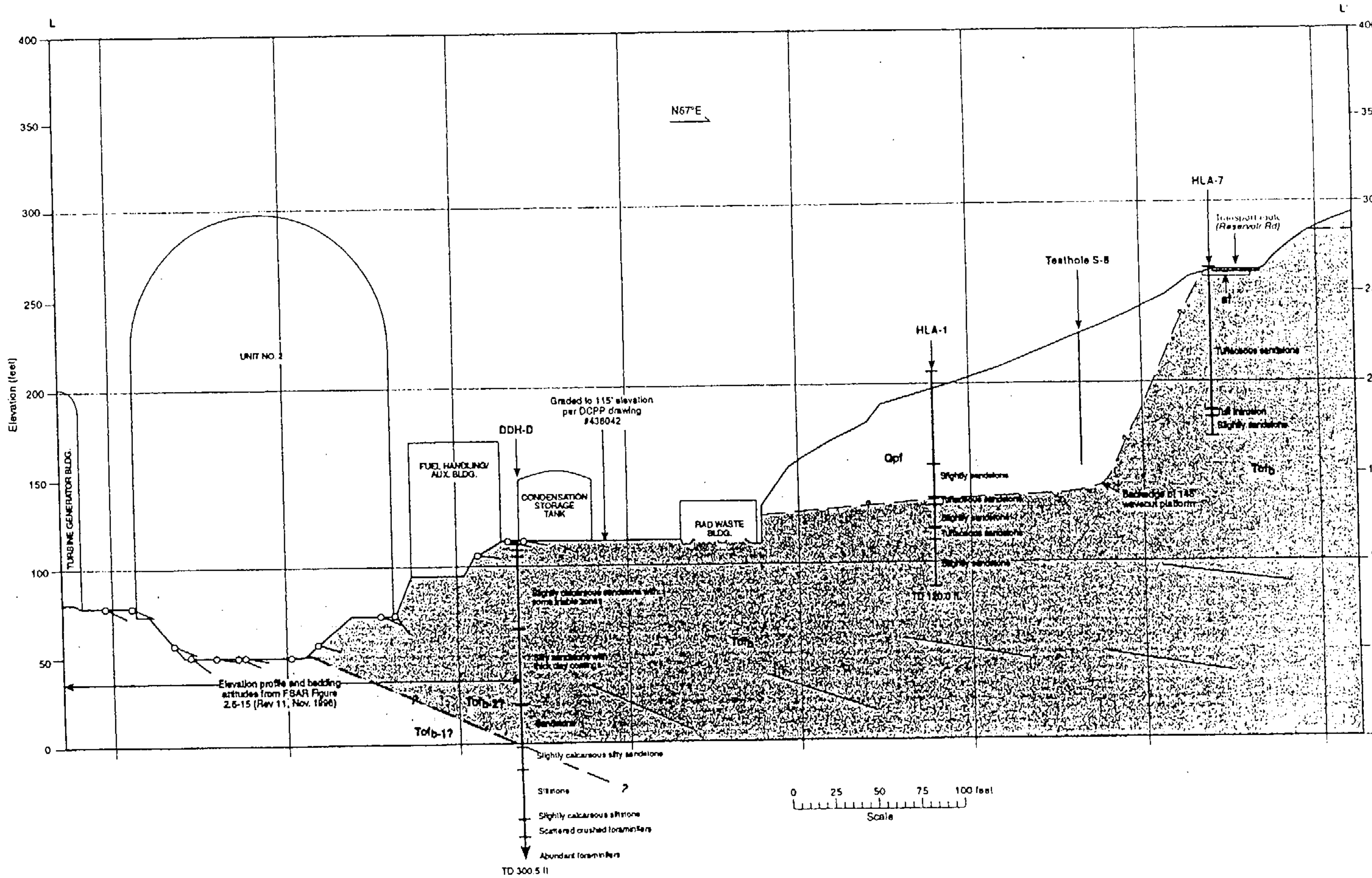

GEO.DCPP.01.28
ATTACHMENT A
REVISION 0
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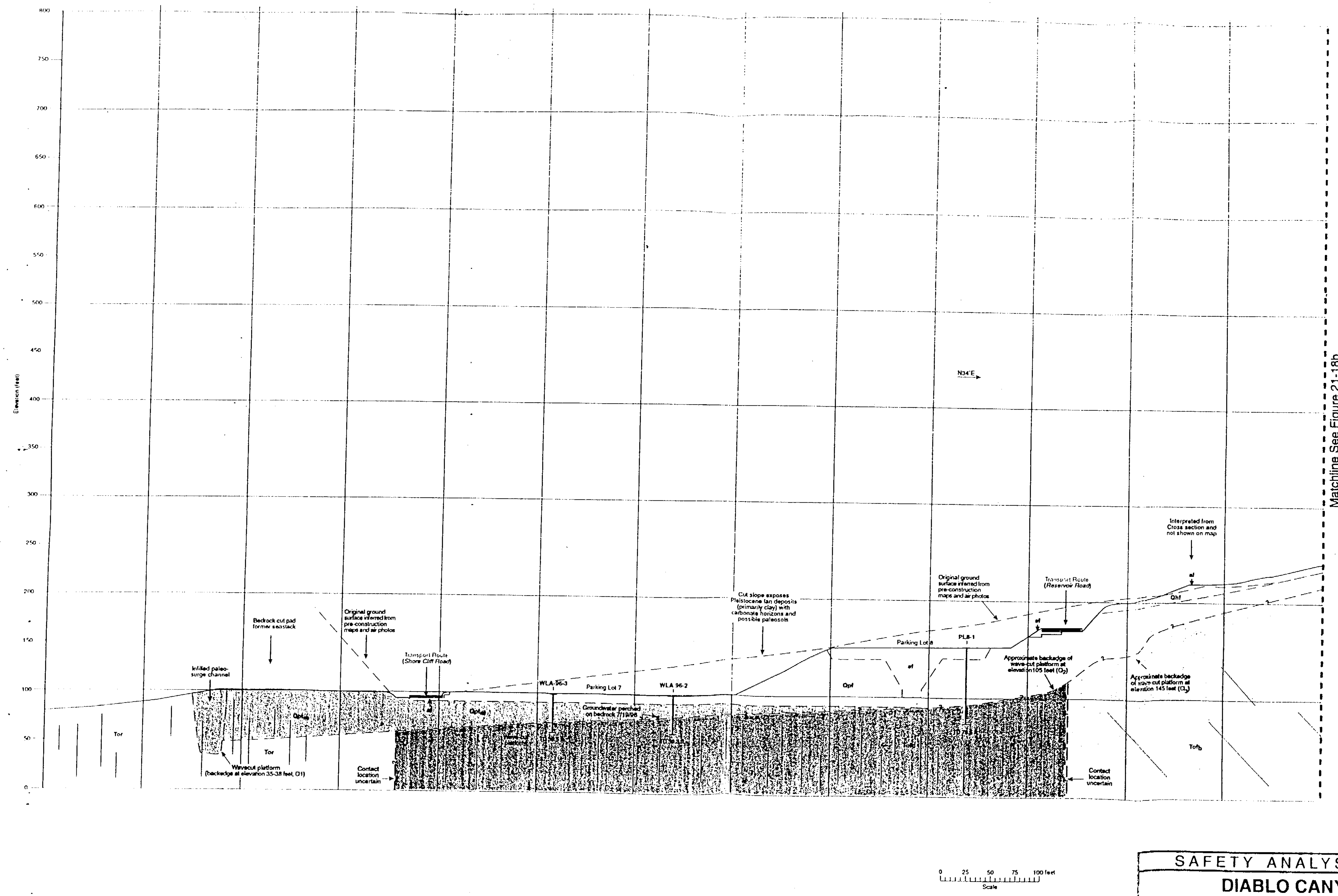
DIABLO CANYON ISFSI

FIGURE 21-25
CROSS SECTION L-L'

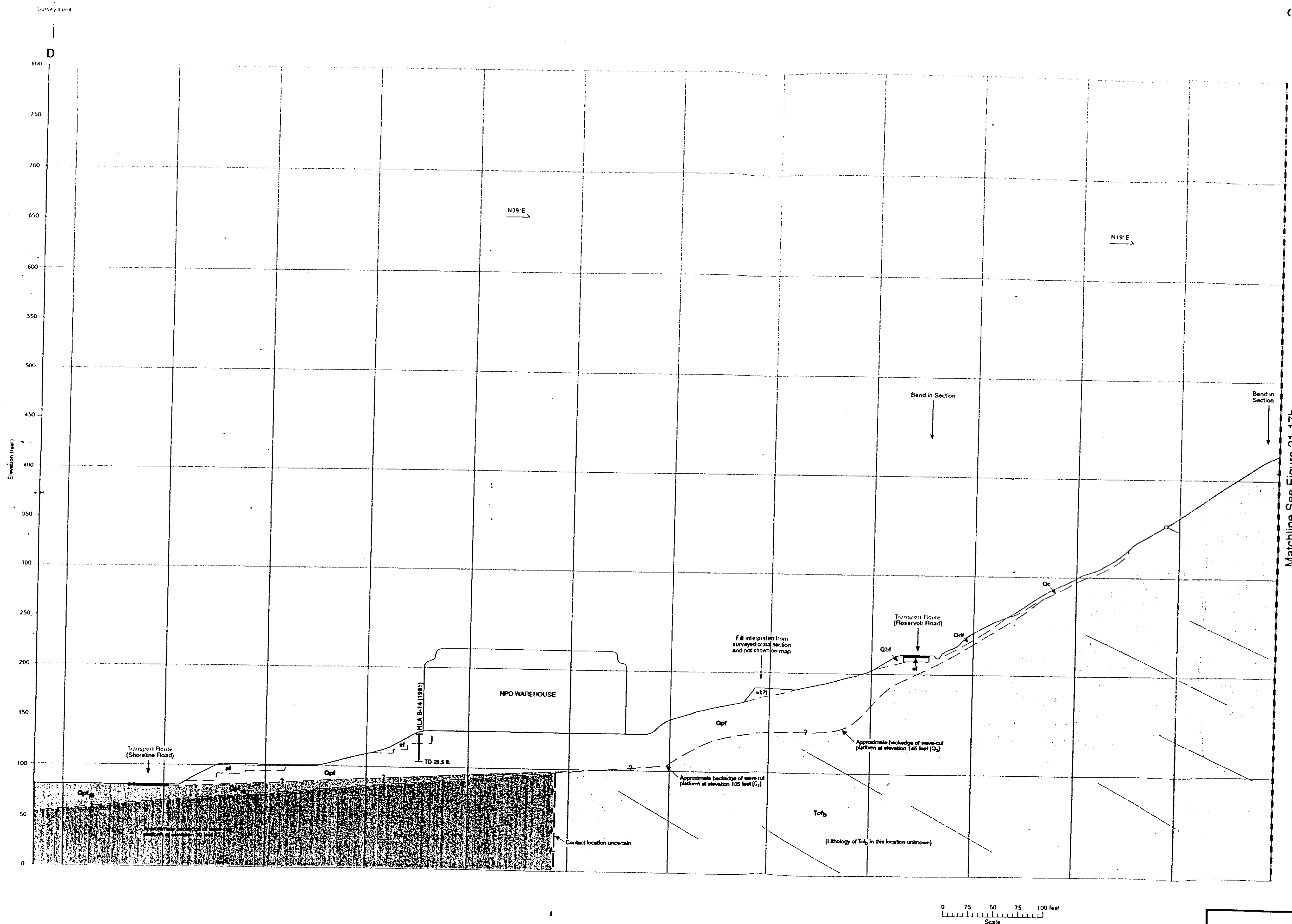


GEO.DCPP.01.28
ATTACHMENT A
REV 0
P. 16/29

SAFETY ANALYSIS REPORT

DIABLO CANYON ISFSI

FIGURE 21-18a
CROSS SECTION E-E'



GEO.DCPP.01.28
ATTACHMENT A
REV 0

DIABLO CANYON ISFSI

FIGURE 21-17a
CROSS SECTION D-D'
THROUGH PATTON COVE LANDSLIDE

GEO.DCPP.01.28
ATTACHMENT P
REVISION 0
P. 18/29

SSESSMENT OF

lope Stability Near The iablo Canyon Power Plant

esponse to NRC Request of January 31, 1997

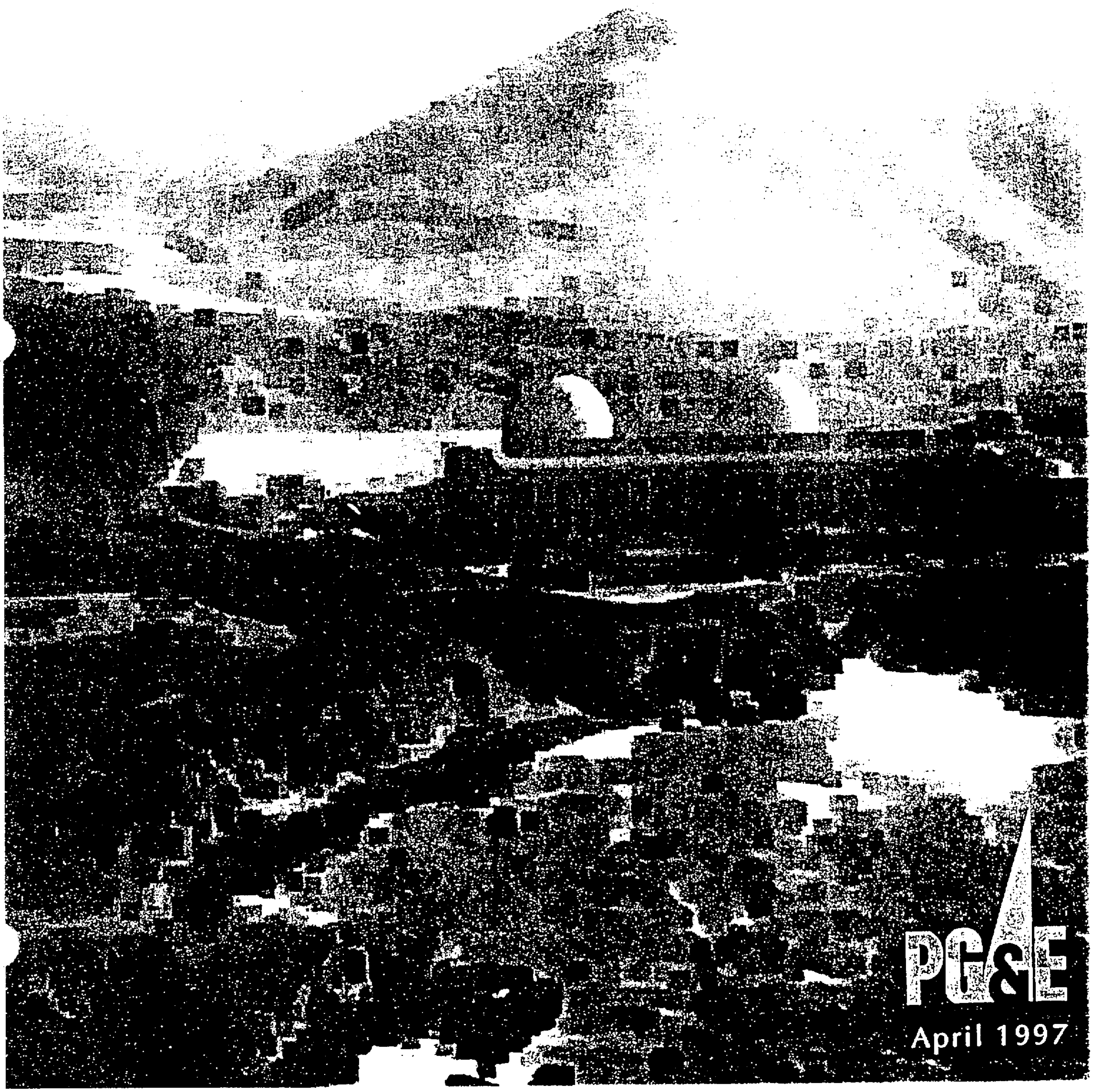


TABLE 1

SOIL PARAMETERS FOR STABILITY ANALYSIS
SLOPE SECTIONS A-A' AND B-B'

Geologic Unit	Description	Density In-Place (pcf)	Shear Strength Parameters
Topsoil	Organic CLAY, silty (CH) (section B-B' only)	115	S_u = 1200 psf
Qc	Young colluvium, soft to stiff CLAY, silty and sandy (CH-CL)	115	S_u = 1500 psf
Qpf	Pleistocene colluvial fan deposits, CLAY to SILT, gravelly and sandy	115	S_u = 3000 psf
Qptm	Pleistocene marine terrace deposits, poorly graded, SAND to GRAVEL	130	c = 0; ϕ = 40°
Tof_b	Miocene Obispo Formation, sandy siltstone and silty sandstone, local chert, blocky, BEDROCK	140	c = 4000 psf; ϕ = 35°

slope material (or the reduced strength due to earthquake shaking), and the location of the potential slip surface.

- The peak, or maximum, acceleration, k_{max}, induced within a potential sliding mass (average of the peak acceleration over the mass) is estimated. The average earthquake-induced acceleration, also known as the average seismic coefficient, can be estimated using dynamic response analyses.

- For a specified potential sliding mass, the induced acceleration is compared with the yield acceleration. When the induced acceleration exceeds the yield acceleration, downslope movements will occur along the direction of the assumed failure plane. The movement will stop after the time when the induced acceleration level drops below the yield acceleration and when the velocity drops to zero. The magnitude of the potential displacement can be calculated by simple double integration of the induced acceleration time history for the specified potential sliding mass.

Yield Acceleration

The yield acceleration for the cut slope east of Unit 2 was estimated using the computer program SLOPE/W (GEO-SLOPE, 1995) and the Modified Bishop method. A cross section of the profile analyzed showing the slip surface having the lowest computed factor

1/19/01 10:39 FAX

ATTACHMENT C

Pacific Gas and Electric Company

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245 Market Street, Room 418B
Mail Code N4C
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DR. FAIZ MAKDISI
GEOMATRIX CONSULTANTS
2101 WEBSTER STREET
OAKLAND, CA 94612

November 19, 2001

Re: Transmittal of additional inputs for DCPP ISFSI Transport Route Analysis

DR. MAKDISI:

As part of the scope of your analysis of the stability of the transport route for the DCPP ISFSI, you are assessing stability of the route at various sections using both unreduced ground motions previously transmitted to you (reference my October 31 2001 letter to you) and reduced ground motions based on incorporating results of a probabilistic seismic hazard analysis and the estimated exposure interval of the transporter on the route. A probabilistically reduced peak bedrock ground acceleration of 0.15g has been derived in calculation GEO.DCPP.01.02, and this value has been approved for further analyses. Accordingly, please scale the peak acceleration of the unreduced ground motions to this level for your transport route analyses.

In addition, you are assessing the stability of transport route road fill wedges at reduced ground motion levels and with the transporter load previously transmitted to you (reference my November 5 2001 letter to you). The exact subsurface configuration of any fill wedges along the access road is currently unknown, and is shown in only a general way on sections provided to you (reference my November 12 2001 letter to you) based on general descriptions provided in the road construction specification. However, given that the density of any compacted fill derived from the native material is likely to be at or above the density of underlying native material, fill strength is likely to be comparable to the native material, and the exact configuration of the fill is therefore not of consequence. Please proceed with near-surface stability analyses with this assumption.

If you have any questions regarding this information, please call.

Rob White

ROBERT K. WHITE

ltr2fm10.doc:rkw:11/19/01

GEO.DCPP.01.28
REVISION 0
ATTACHMENT C
P. 20/29

Pacific Gas and Electric Company

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DR. FAIZ MAKDISI
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OAKLAND, CA 94612

November 5, 2001

Re: Forwarding of Cold Machine Shop Retaining Wall Calculation Inputs from Project Engineer

DR. MAKDISI:

Inputs to the calculation checking the stability of the DCPP Cold Machine Shop Retaining Wall under proposed ISFSI transporter loads have been provided to Geosciences from Richard Klimczak, Project Engineer for the ISFSI project. I am forwarding these inputs to you formally, as required by Geosciences Calculation Procedure GEO.001, rev. 4. Please incorporate these into your calculation in place of previous inputs provided to you informally, and complete the calculation as required by Geosciences Work Plan GEO 2001-03, rev. 1, Appendix H. A description of the inputs follows. A copy of the Work Plan is also enclosed for distribution to those on your staff who are responsible for performing the calculation. Please have them sign the Work Plan Attachment acknowledging their review and forward copies to me.

Letter to Robert White from Richard Klimczak, dated October 3, 2001. Subject: Transmittal of Information on the Transporter Movement Along the Transport Route.

The reference letter contains a copy of PG&E calculation 52.27.14.01, pages RLOC 02553 1215 through 1255 (42 pages). These calculation pages are enclosed in this forwarding letter. The reference letter also contains 11x17 copies of drawings 516992 and 516993. These drawings are also enclosed in this forwarding letter. The reference letter also lists applicable criteria for the transporter. These criteria have been superseded by the following letter, and should not be used in your calculation.

GEO.DCPP.01.28
ATTACHMENT D
REVISION 0

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Letter to Robert White from Richard Klimczak, dated October 19, 2001. Subject: Transmittal of Information on the Transporter Movement Along the Transport Route.

This reference letter contains modified transporter criteria and should be used in place of those criteria in the 10/3/01 letter above.

If you have any questions regarding this information, please call.

Rob White

ROBERT K. WHITE

Enclosures

GFO.DCPP.01.28
ATTACHMENT D
REVISION 0
P 22/29

Memorandum

Date: October 3, 2001 File #: 72.10.05

To: Robert White Phone: (415) 973-0544
PG&E Geosciences Dept

From: Richard L. Klimczak, Project Engineer

Subject: Diablo Canyon Units 1 and 2
Transmittal of Information on the Transporter Movement Along the Transport Route

PG&E Pacific Gas and Electric Company

Dear Rob,

This memorandum provides criteria for movement of the loaded Transporter from the Auxiliary/Fuel Handling Building (Power Plant) to the Cask Transfer Facility (CTF). Information provided herein is applicable to Calculations GEO.DCPP.01.02 and GE0.DCPP.01.27 and other evaluations of Transport Route stability.

Estimate of Total Yearly Travel Time of A Loaded Transporter Along the Transport Route: (Ref. Calculation GEO.DCPP.01.02)

Holtec Calculation HI-2002563, Rev. 3, Pg. K-2 shows 1.5 hours to travel between the Power Plant and the CTF. This calculation also conservatively assumes movement of 8 casks per year. Accordingly, we estimate 8 trips at 1.5 hours per trip for a total travel time of 12 hours along the transport route each year.

Transporter for HI-STORM 100 Transfer Cask: (Reference Calculation GEO.DCPP.01.27)

The following criteria applies to movement of the loaded Transporter from the Power Plant to the CTF and along the Transport Route:

1) Cask Transporter Weights:

Transporter weight	170,000 lbs.
Payload weight	275,000 lbs
Total weight:	445,000 lbs

2) Track Contact Surface Area:

Dimensions for each of two tracks	294 inches x 29.5 inches
Total effective contact area for two tracks	10,000 sq. inches
Estimated contact surface pressure	44.5 psi

3) Center to center spacing between tracks: 182 inches

The basis for this information is a 9/28/01 memorandum to the file, "Cask Transporter Track Contact Surface Area Estimate," prepared by Rich Hagler of the UFSP for static, level contact surface bearing pressures and the referenced HI-2002501, "Functional Specification for the Diablo Canyon Cask Transporter," Revision 4, July 30, 2001.

Evaluation of Stability of the Retaining Wall Located Adjacent to the Unit 2 Cold Machine Shop: (Reference Calculation GEO.DCPP.01.27)

The attached PG&E calculation and drawings apply to the evaluation of the retaining wall located adjacent to and to the east of the Unit 2 Cold Machine Shop

1) A copy of PG&E calculation 52.27.14.01, "Cold Machine Shop, Retaining Wall and Stairs," 42 pages, RLOC 02553 1215 thru 1255.

2) 11" x 17" copies of the following PG&E Drawings:

Drawing Number	Revision	Title
516992	8	Finish Grading Plan Cold Machine Shop
516993	3	Yard Facilities & Details Cold Machine Shop

This transmittal is per requirements of DCPP Procedure CF3.ID17.

If you have questions please contact me at (805) 595-6320 or A. Tafoya at (805) 595-6392.

Richard L. Klimczak
Project Engineer
Diablo Canyon Used Fuel Storage Project

Attachments: As listed

cc: JStrickland SLO B3 w/o
BHPatton SLO BB w/o
AFTafoya SLO B10 w/o
CEHartz SL0 B0 w/o
RDHagler SLO B13
[redacted] 245 Market N4C, 422B w/o

RKWhite 245 Market N4C, 418B w/o
JISun 245 Market N4C, 422A w/o
JCYoung 245 Market N4C, 413C w/o
DCPP Chronological File
DCPP RMS DCPP 119/1
DCPP File No. 72.10.05

GEO.DCPP.01.28
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ATTACHMENT D
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FILE No. 071 11 26 '01 15:07 ID:PG&E GEOSCIENCES DEPT 415 973 5778 PAGE

Jul 24 01 02:22p PG&E Used Fuel Storage (805)595-6402 p.2

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ANSI/ASCE 1-82
ANSI Approved
November 5, 1986

ASCE STANDARD

N725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures

APRIL 1982

AMERICAN SOCIETY OF CIVIL ENGINEERS

GEO.DCPP.01.28 ATTACH. E
REV 0 P.25/29

quate source and its associated quality. In general, Section 4.3 material selection requirements are equally applicable to site protection structures.

5.4 Design. Parameters to be established for the design and safety evaluation of dams, dikes, breakwaters, seawalls, revetments are generally the same as those given in Section 4.4.

5.4.1 Operating Conditions. Design conditions for site protection structures are generally those associated with extreme hydrological phenomena. However, normal operating conditions (which include erosion, weathering seepage or other normal operating phenomena that would affect performance of the protective structure) shall be considered in design.

5.4.2 Static Loading Conditions. The following conditions shall be considered for protective structures:

(1) During construction
(2) End of construction
(3) Design maximum flood evaluation as a hydrostatic load
(4) Load case where maximum design surcharge is present and water level is at its design minimum elevation.

5.4.3 Static Stability and Performance. Factors of safety for structural capacity should be based upon the ratio of available strength to applied stress or other load effects. The minimum factors safety for the static loading condition listed in Paragraph 5.4.2 shall be as follows:

Condition	Minimum Factor of Safety
1	1.1
2	1.3
3	1.2
4	1.5

In using these minimum recommended safety margins the Geotechnical Engineer should have a high degree of confidence in the reliability of values used for the following parameters:

(a) type and gradation of material
(b) thoroughness and completeness of field exploration and laboratory testing
(c) certainty of loading conditions
(d) degree of control and workmanship that can be assured.

5.4.4 Dynamic Loading Conditions. The dynamic force applicable to site protection structures are the same as those considered in Section 4.4.5.

5.5 Analytical Methods. The analytical methods applicable to ultimate heat sink structures are also applicable to site protection structures.

6.0 Site Contour Earth Structures—Retaining Walls, Natural Slopes, Cuts and Fills

6.1 Scope.

6.1.1 Purpose. The purpose of this Section is to describe criteria to be used as a guide in the design, evaluation and construction of those site contour control structures such as retaining walls, slopes, cuts and fills (classified as Seismic Category I). This standard is intended to identify factors to be considered in construction of those structures and should in no way limit the investigation and analysis deemed necessary for determination of the suitability of such a structure—or the effect such an earth structure would have on other nuclear plant structures.

6.1.2 Use and Type of Structure

6.1.2.1 Retaining Walls. A retaining wall is any permanent structural element built to support an earth bank that cannot support itself. It is used primarily to control site contours and may have specific application to construction of elevated or depressed roadways, erosion protection facilities, bridge abutments and retaining potentially unstable hillsides. Principal types of retaining walls considered in this standard include gravity walls, semigravity walls, cantilever walls, counterfort walls, buttressed walls, crib and bin walls, reinforced earth walls and anchored (or tie back) walls. The emphasis in this Section is on the design of earth structures used as retaining walls, and determination of loads on walls made of other materials.

6.1.2.2 Natural Slopes, Cuts and Fills. Natural slopes considered in this section are any landforms existing on, or adjacent to, the proposed site. A cut slope is any slope resulting from the excavation of in situ soils. Manmade fills are provided to maintain site grade. Slopes, cuts and fills covered by this specification are provided primarily to maintain site contours (and whose failure would adversely affect the function of any safety related nuclear plant structure).

6.2 Site Investigation. A general discussion of site investigation applicable to all earth structures is presented in Section 3.0.

6.2.1 Seismology and Geology. General seismic geology siting criteria are given in 10 CFR 100, Appendix A.[3] Various other references provide useful information on requirements that must be satisfied by a thorough seismologic and geologic investigation.[9, 10]

6.2.2 Hydrology. Earth structures used as retaining walls, slopes, cuts and fills are particularly sensitive to surface water erosion and groundwater level and movement. Such structures shall be designed to withstand historical and design basis flooding and precipitation in accordance with ANSI N 170.[11]

6.2.3 Geotechnical. In the construction of earth structures it is imperative that the structure cross-section, materials of construction and their gradation, zoning and placement be consistent with site geology and foundation conditions. Investigations shall be undertaken and sufficient information obtained so that the engineer can, with confidence, design a structure meeting those requirements. References discussing the required geotechnical investigations in considerable detail should be consulted.[11, 12, 13, 14, 15, 16, 17, 18]

Since natural slopes and cuts consider the use of in situ materials, available literature and information concerning the foundation geology of the soils (and of rocks on the site) shall be consulted. Past records of construction in the area and old well logs shall also be examined. Air-photo interpretation and site reconnaissance should be completed to reveal old slide scarps or other evidence of slope movements. Cross-sections and profiles of the slope should be made in sufficient quantity and detail to represent the slope and foundation conditions.

6.3 Materials. Section 4.3 material selection requirements are equally applicable to retaining walls, slopes and fills.

6.4 Design

6.4.1 Design Parameters. Parameters to be established for the design and safety evaluation of retaining walls, natural slopes, cuts and fills shall include the following:

(a) a geotechnical profile along the entire length and across the structure at intervals not to exceed 250 feet, which is adequate to serve as a basis for design
(b) the potential for ground surface rupture or displacement due to geological factors
(c) ground surface acceleration value for the SSE
(d) properties of available cast shapes, rubble, stone, rock, in situ and filter materials used for construction of the structure
(e) cross-sections showing structure geometry and composition of materials
(f) liquefaction potential of the earth structure and its foundation under (a) the SSE and (b) hydrodynamic changes in effective stress caused by the maximum design event
(g) stability of the structure and its foundation under hydrodynamic and surcharge force systems associated with maximum design event
(h) hydrological parameters shall be in accordance with ANSI N 170.[11]

6.4.2 Operating Conditions. Operating conditions for contour control structures will vary according to the purpose, location and other conditions unique to the plant being considered. These conditions may influence the design of ancillary facilities. The Geotechnical Engineer shall consider all normal operating conditions in design of the structure, as well as anticipated transients, abnormal and extreme environmental conditions considered as design basis during the life of the structure.

6.4.3 Static Loading Conditions. The following conditions shall be considered for contour control structures:

(1) During construction
(2) End of construction
(3) Maximum design surcharge to include any loading above grade by earth, material, structure, equipment and vehicles for design against sliding
(4) Load condition 3 coincident with most disadvantageous ground water design level
(5) Maximum design surcharge to include any loading above grade by earth, material, structure, equipment and vehicles for design against overturning
(6) Load condition 5 coincident with most disadvantageous ground water design level
(7) Design maximum flood and precipitation as a hydrostatic load.

6.4.4 Static Stability and Performance. Factors of safety for slope stability studies should be based upon the rate of available strength to applied stress or other load effects. The minimum factors of safety for the static load conditions listed in Section 6.4.3 shall be as follows:

Condition	Minimum Factor of Safety
1	1.3
2	2.0
3	1.5
4	1.3
5	2.0*
6	1.8
7	1.0

*For foundation failure by bearing in clay use a F.S. of 3.0. In using these minimum recommended safety margins the Geotechnical Engineer should have a high degree of confidence in the reliability of the values used for the following parameters:

(a) type and gradation of material
(b) thoroughness and completeness of field exploration and laboratory testing
(c) certainty of loading conditions
(d) degree of control and workmanship that can be assured.

6.4.5 Dynamic Loading Condition. The effects of earthquake-induced forces, dynamic surcharge loadings and the dynamic effects of the Design Maximum Flood and Precipitation[11] must be considered. The postulated loading conditions due to dynamic loads to be evaluated are as follows:

(1) Failure due to disruption of structure by major differential fault movement due to a SSE
(2) Slope failure induced by SSE vibratory ground motion
(3) Sliding of the earth structure on weak foundation materials or materials whose strength may be reduced by liquefaction
(4) Failure due to dynamic surcharge load effects if any
(5) Failure due to dynamic loads associated with the Maximum Design Flood or Precipitation.

6.4.6 Dynamic Stability and Performance. During an earthquake, or in response to other dynamic load phenomena, large cyclic forces may be induced in a slope or fill. These forces may be sufficiently large and may occur with a sufficient number of cycles to produce excess pore water pressures or reduction in shear strength of certain types of materials used in construction of an earth structure. Depending on the severity of the ground vibratory motions and the types of embankment materials, small to large permanent deformations of the embankment could occur during or after an earthquake. In loose saturated cohesionless soils complete loss of strength may occur, leading to failure of an earth structure. This same phenomena could also result from the effects of dynamic wave action although the dynamic frequency characteristics of wave action make it a much less likely occurrence. Structures containing cohesive materials or well-compacted and graded materials generally suffered little or no damage as a result of strong ground shaking.[22]

In assessing the safety of an earth structure during and after an earthquake—or other dynamic loading—the following factors should be considered:

(1) The magnitude and type of anticipated loading
(2) The degree of confidence in the method of analysis used and in the definition of material and design parameters.

The following minimum factor of safety is specified for the dynamic load conditions listed in Section 6.4.5:

Condition	Minimum Factor of Safety
1	Precluded by Siting Criteria*
2	1.3
3	1.3
4	1.3
5	1.2 (general)
	1.0 (local)

*Must evaluate based on the impact of a failure

6.4.7 *Other Design Considerations.* Other considerations that may affect the design shall be investigated as necessary:

(1) Removal of lateral support including action of:
   (a) erosion by streams, rivers, etc.
   (b) waves and longshore tidal currents
   (c) subaerial weathering, wetting and drying and frost action.
(2) Removal or creation of new slope by rock fall, slide or subsidence (faulting).
(3) Subterranean erosion, solution carbonates, salt, gypsum, and collapse of caverns, subsidence of mine areas, dispersive soils.
(4) Overloading of weak underlying soil layer(s) by fill.
(5) Overloading of sloping bedding planes.
(6) Oversteepening of cuts in unstable soil or rock and undercutting of steeply adverse dipping bedding planes.

6.4.8 *Performance Criteria.* The performance of any slope must be judged on the following basis:

(1) Downslope Movements. Downslope movements, whether for natural or manmade slopes, shall not interfere with the ability of the plant to perform its safety functions. This necessitates consideration of the proximity of the slope to Class I structures and the specific function of the slope, if any. (The definition of slope failure is dependent on these conditions).
(2) Erosion and Undercutting. Erosion and undercutting of the toe of the slope shall be controlled so that they will not affect the overall stability or function of the slope.
(3) Creep. If the plant and/or adjoining facilities are sited on a slope, creep movements of sufficient magnitude can constitute a failure, as well as general massive instability of the slope. The potential for creep and the magnitude that can be tolerated shall be evaluated.

6.5 *Analytical Methods and Procedures*

6.5.1 *Retaining Walls.* Once the soil types and design parameters have been established, the type of retaining structure can be selected. Generally the foundation conditions, the height of wall, or the expected lateral load narrows the selection process considerably. Typical dimensions and guidelines for sizing the proportions of retaining structures are given in various foundation texts.[81, 4, 4] The structural adequacy of the individual members should be determined by the Geotechnical Engineer or Engineer based on the imposed loads, using applicable Standards.

6.5.1.1 *Earth Pressure Computation.* As defined previously, earth pressures acting on the wall are computed using appropriate soil properties (usually strength) and available earth pressure theories. The design magnitude and distribution of these pressures should also take into consideration the type of backfill and its characteristics and drainage provisions, and the method and direction of compaction. Clayey soils can produce high earth pressures and should be avoided if possible. Free draining clean granular soils generally result in lower horizontal earth loadings.

For conventional retaining walls, convenient empirically established design charts are available for different types of backfill.[64] These curves have also been reproduced in most geotechnical