SGT 05/17/04

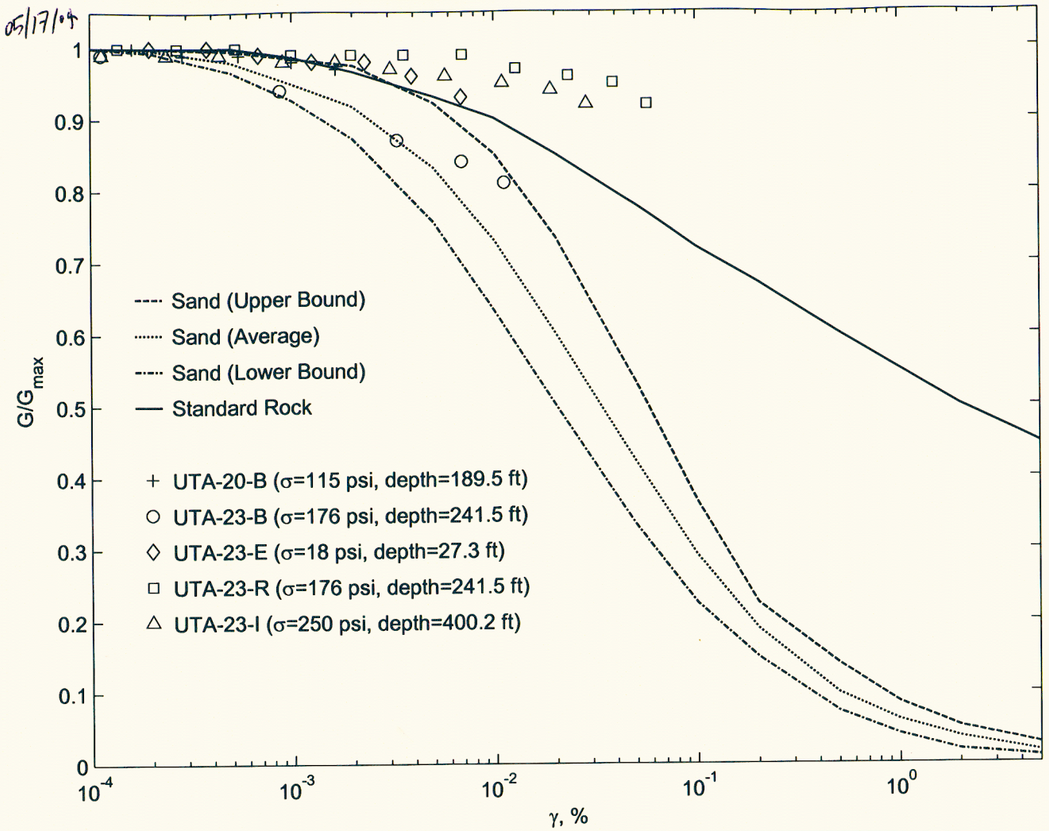

FIGURE 17. NORMALIZED SHEAR MODULUS DATA FOR TPKN TUFF SAMPLES.

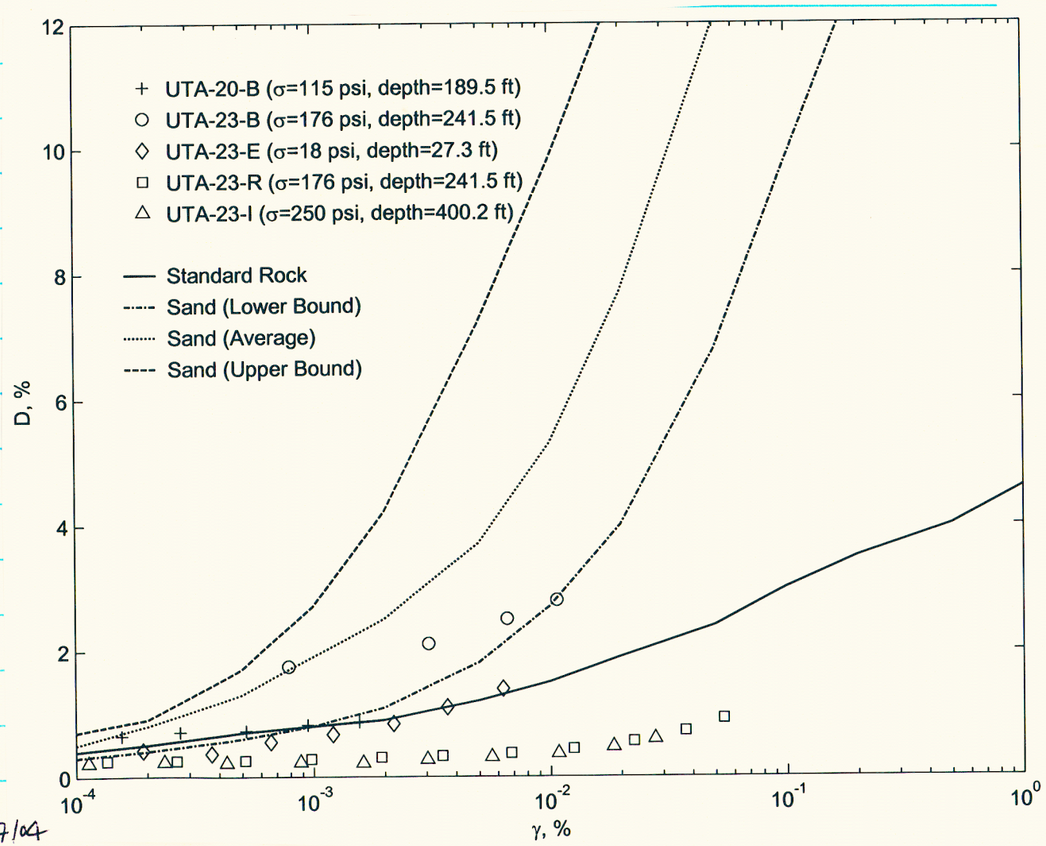

FIGURE 18. DAMPING RATIO DATA FOR TPKN TUFF SAMPLES.

SGT 05/17/04

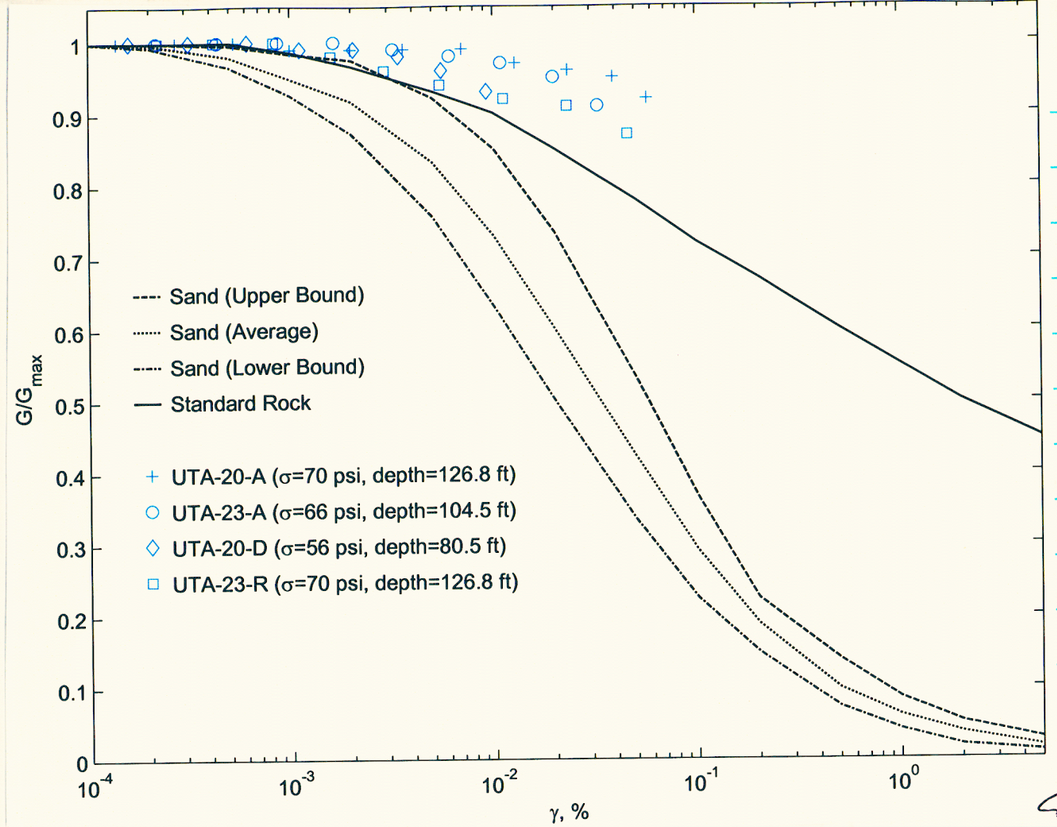

FIGURE 19. NORMALIZED SHEAR MODULUS DATA FOR TPKI TUFF SAMPLES.

SGT 05/17/04

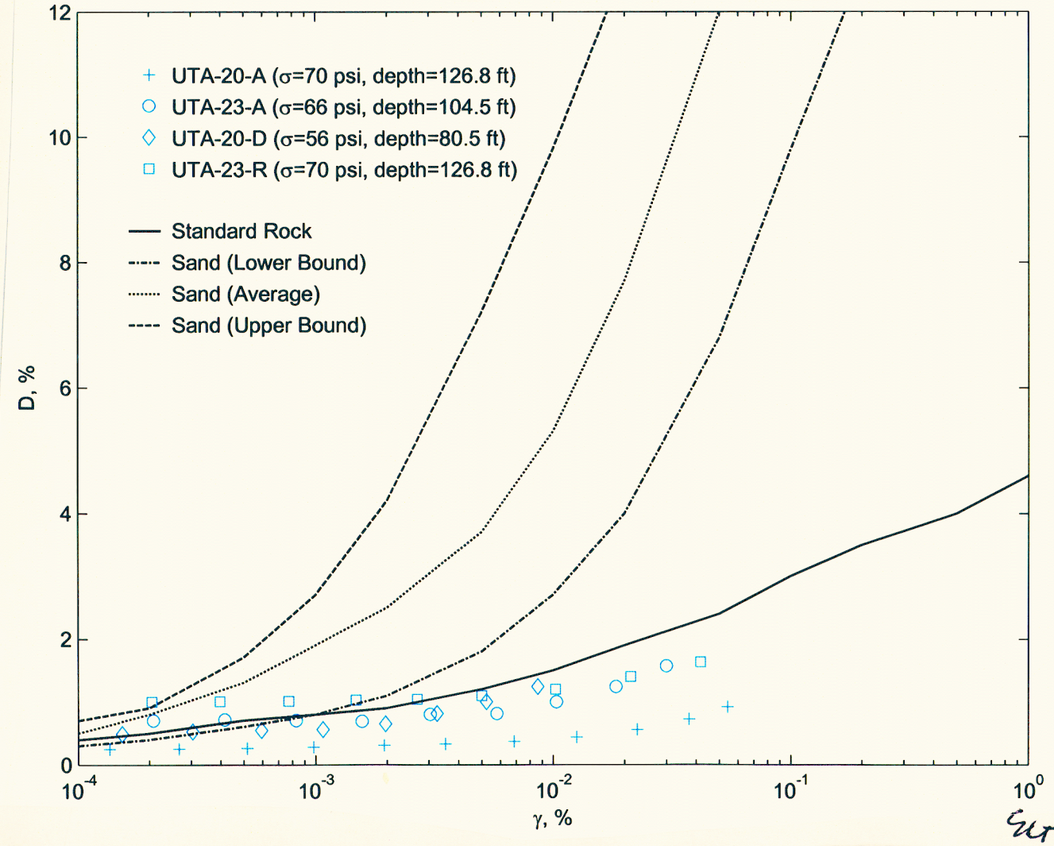

FIGURE 20. DAMPING RATIO DATA FOR TPKI TUFF SAMPLES.

SGT 05/17/04

ENTRY: SARAH GONZALEZ

DATE: 06/16/2004

DYNAMIC MATERIAL PROPERTIES (CONTINUED)

TUFF DATA (CONTINUED):

FIGURES 21 AND 22 SHOW THE SAME DATA THAT IS PLOTTED IN FIGURES 9 AND 10. DATA BELONGING TO TUFF SAMPES OF THE SAME LITHOLOGIC UNIT IS INDICATED BY THE SAME SYMBOL. THE BECHTEL SAIC COMPANY (2002) REPORT DIVIDED THE TUFF SAMPLES INTO 3 GROUPS ACCORDING TO DRY UNIT WEIGHT. IN FIGURES 21 AND 22 TUFF SAMPLES BELONGING TO GROUPS 1, 2 AND 3 ARE SHOWN IN RED, GREEN AND BLUE RESPECTIVELY. THE ABOVE GROUPING WAS CHOSEN BECAUSE OF THE OBSERVED RELATIONSHIP BETWEEN V_s (OBTAINED FROM RC MEASUREMENTS) AND DRY UNIT WEIGHT. VALUES FOR V_s AND DRY UNIT WEIGHT ARE PROVIDED IN TABLE 5. A GENERAL TREND OF INCREASING V_s WITH INCREASING DRY UNIT WEIGHT WAS OBSERVED (BECHTEL SAIC COMPANY, 2002).

GROUP 1 INCLUDES TUFF SPECIMENS WITH A DRY UNIT WEIGHT BETWEEN 133 PCF AND 147 PCF, AND V_s BETWEEN 6900 FT/SEC AND 8800 FT/SEC (REFER TO TABLE 7). THIS GROUP IS PRIMARILY COMPRISED OF THE DENSELY WELDED TUFF UNITS TPCPLN AND TPCPMN, AND THE MODERATELY TO DENSELY WELDED UNIT TPCPUL.

TABLE 9. GROUP 1 TUFF SPECIMENS.

Sample Name	Borehole	Depth (ft)	Unit	Dry Unit Weight (pcf)
UTA-23-C	RF#14	361.0	Tpcpul	133.5
UTA-23-D	RF#14	397.0	Tpcpmn	146.0
UTA-23-G	RF#15	192.5	Tpcpul	144.9
UTA-23-T	RF#15	192.5	Tpcpul	144.5
UTA-23-H	RF#15	322.0	Tpcpln	145.4
UTA-23-J	RF#17	575.6	Tpcpul	140.2

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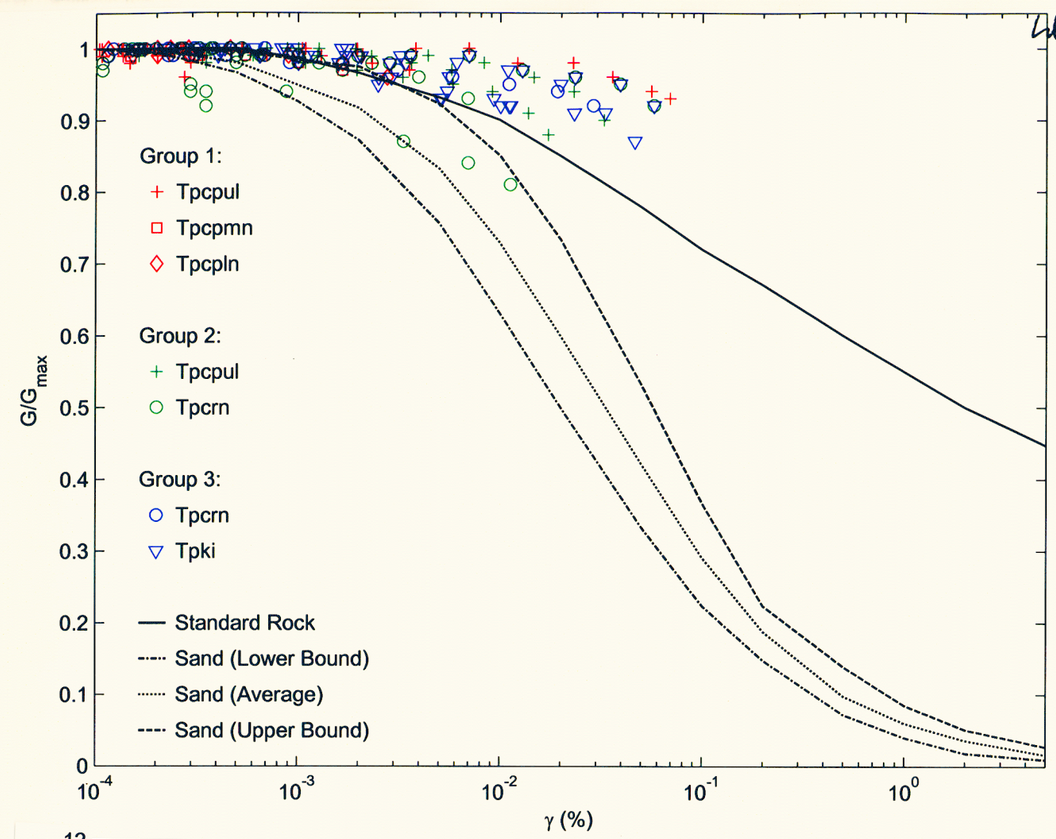

FIGURE 21. NORMALIZED SHEAR MODULUS DATA FOR TUFF SAMPLES GROUPED ACCORDING TO DRY UNIT WEIGHT.

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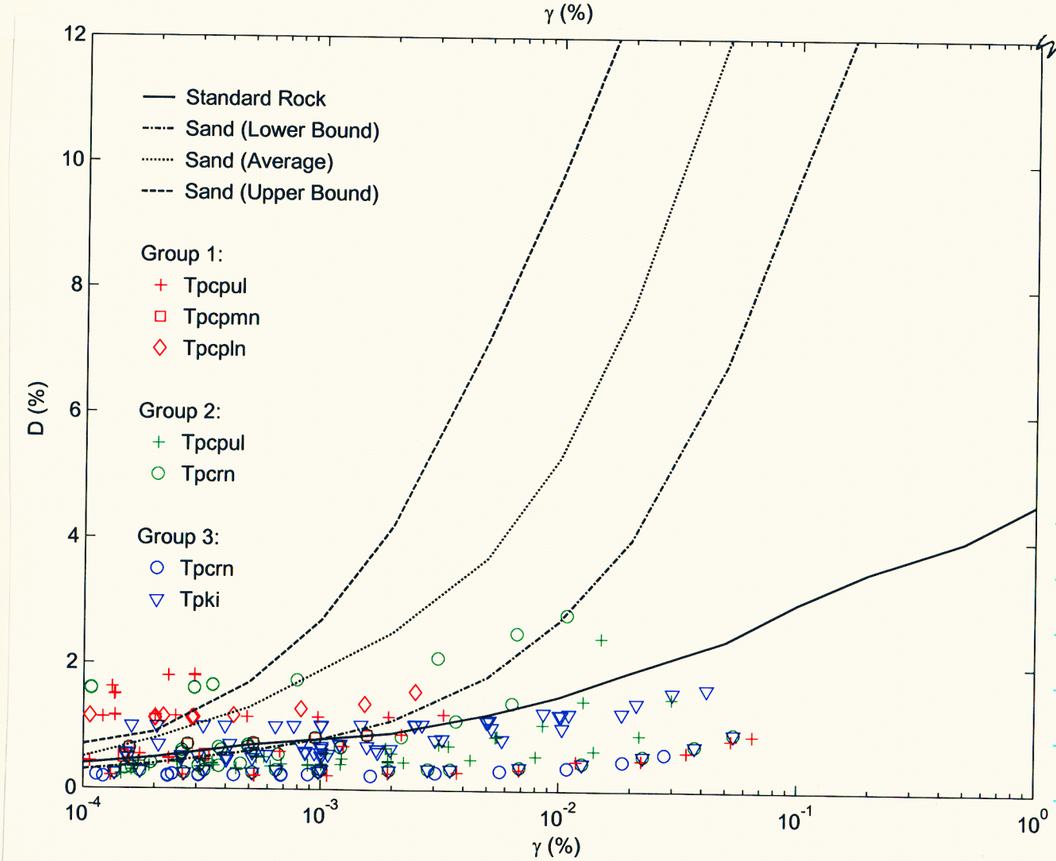

FIGURE 22. DAMPING RATIO DATA FOR TUFF SAMPLES GROUPED ACCORDING TO DRY UNIT WEIGHT.

NO DYNAMIC TESTING WAS PERFORMED ON THE DENSELY WELDED UNIT TPCPLL.

GROUP 2 INCLUDES TUFF SPECIMENS WITH A DRY UNIT WEIGHT BETWEEN 117 PCF AND 132 PCF, AND Vs BETWEEN 5000 FT/SEC AND 6500 FT/SEC. THIS GROUP IS PRIMARILY COMPRISED OF THE MODERATELY TO DENSELY WELDED TUFF UNITS TPCPUL AND TPCRN. REFER TO TABLE 10 FOR THE SAMPLE NAMES AND RESPECTIVE UNITS.

TABLE 10. GROUP 2 TUFF SAMPLES

Sample Name	Borehole	Depth (ft)	Unit	Dry Unit Weight (pcf)
UTA-20-B	RF#16	189.5	Tpcrn	120.9
UTA-20-C	RF#16	253.5	Tpcpul	125.3
UTA-23-B	RF#14	241.5	Tpcrn	124.5
UTA-23-R	RF#14	241.5	Tpcrn	118.2
UTA-23-E	RF#15	27.3	Tpcrn	117.2
UTA-23-F	RF#15	88.7	Tpcpul	131.5
UTA-23-S	RF#15	88.7	Tpcpul	127.4

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GROUP 3 INCLUDES TUFF SPECIMENS WITH A DRY UNIT ~~WEIGHT~~ SLT 06/16/04 WEIGHT BETWEEN 78 PCF AND 94 PCF, AND Vs BETWEEN 3400 FT/SEC AND 4900 FT/SEC. THIS GROUP IS PRIMARILY COMPRISED OF THE NONWELDED TUFF UNIT TPKI, AND ALSO A TPCRN SAMPLE WHICH IS A MODERATELY TO DENSELY WELDED TUFF ~~SAMPLE~~ SLT 06/16/04 UNIT. REFER TO TABLE 11 FOR THE SAMPLE NAMES AND RESPECTIVE UNITS. NO TESTING WAS PERFORMED ON TMBT1 SAMPLES FROM THE WHB SITE, WHICH IS ALSO A NONWELDED TUFF UNIT.

TABLE 11. GROUP 3 TUFF SAMPLES.

Sample Name	Borehole	Depth (ft)	Unit	Dry Unit Weight (pcf)
UTA-20-A	RF#16	126.8	Tpki	80.8
UTA-23-Q	RF#16	126.8	Tpki	78.8
UTA-20-D	RF#16	80.5	Tpki	91.5
UTA-23-A	RF#14	104.5	Tpki	93.5
UTA-23-I	RF#17	400.2	Tpcrn	86.0

SLT 06/16/04

THE TUFF UNITS GENERALLY EXHIBIT MORE LINEAR BEHAVIOR IN COMPARISON TO THE STANDARD SAND AND ROCK CURVES UP TO STRAIN LEVELS OF APPROXIMATELY 0.01 %. BEYOND THESE STRAIN LEVELS THE TUFF DATA APPEAR TO TREND MORE NON-LINEARLY. THERE APPEARS TO BE SOME VARIABILITY IN DYNAMIC BEHAVIOR WITHIN THE DATA AS A WHOLE AS WELL AS ~~WITHIN~~ SLT 06/16/04 BETWEEN SAMPLES FROM THE SAME LITHOLOGIC UNIT. FOR EXAMPLE REFER TO FIGURES 11 AND 12, WHICH PLOT TPCPUL DATA. FIGURES 21 AND 22, HOWEVER, DO NOT REVEAL A STRONG CORRELATION ~~BETEE~~ SLT 06/16/04 BETWEEN THE THREE GROUPS IDENTIFIED IN TERMS OF THEIR DYNAMIC BEHAVIOR.

EVALUATION OF THE DYNAMIC MATERIAL PROPERTY DATA:

THERE IS A LARGE UNCERTAINTY IN THE DYNAMIC BEHAVIOR OF THE TUFF SAMPLES AT STRAIN LEVELS BEYOND APPROXIMATEL 0.1 %. THIS IS A LIMITATION OF THE RCTS TESTING EQUIPMENT WHICH CONDUCTS TESTS ON SPECIMENS OVER A SHEARING-STRAIN RANGE OF ABOUT 10^{-4} % TO SLIGHTLY MORE THAN 10^{1} %. FOR SOME TUFF UNITS, INCLUDING THE DENSELY WELDED UNITS TPCPMN AND TPCPLN, DATA IS LIMITED TO STRAIN LEVELS OF APPROXIMATELY 0.003%. THE LARGE UNCERTAINTY IN DYNAMIC BEHAVIOR BEYOND STRAIN LEVELS OF 0.1% (SLT 06/16/04) MAY BE SIGNIFICANT FOR LARGER EARTHQUAKE MOTIONS WHICH MAY PRODUCE STRAIN LEVELS BEYOND THESE VALUES.

ONLY ONE ALLUVIAL SAMPLE WAS DYNAMICALLY TESTED. IDEALLY THERE SHOULD BE MORE DATA TO BETTER CONSTRAIN THE SHEAR MODULUS AND DAMPING RATIO CURVES.

SLT 06/16/04

REFERENCES:

BSC (BECHTEL SAIC COMPANY), 2002. GEOTECHNICAL DATA FOR A POTENTIAL WASTE HANDLING BUILDING AND FOR GROUND MOTION ANALYSES FOR THE YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT. ANL-MGR-GE-000003 REV 00. LAS VEGAS, NEVADA: BECHTEL SAIC COMPANY. ACC: MOL.20020930.0175.

EDUPRO CIVIL SYSTEMS, 2001. PROSHAKE. VERSION 1.11. SAMMAMISH, WA.

SEED, H.B., WONG, R.T., IDRISS, I.M., AND TOKIMATSU, K., 1986. "MODULI AND DAMPING FACTORS FOR DYNAMIC ANALYSIS OF COHESIONLESS SOILS." JOURNAL OF GEOTECHNICAL ENGINEERING, ASCE, VOL. 112, NO. 11, PP. 1016-1032.

ADDITIONAL NOTES:

FIGURES 7 TO 22 WERE PLOTTED IN MATLAB (VERSION 6.5.1, RELEASE 13). THE MATLAB PLOTTING ROUTINES allwv.m AND tuff.m WERE USED TO READ AND PLOT THE DATA IN TABLES 2, 3, 4, 6, 7 AND 8. THESE MATLAB FILES ARE ON THE ATTACHED CD.

SGT 06/16/04

ENTRY: 6/18/04 BY JOHN STAMATAKOS

PURPOSE: REVIEW OF VELOCITY DATA PROVIDED BY DOE IN THE DATA REPORT ENTITLED "GEOTECHNICAL DATA FOR A POTENTIAL WASTE HANDLING BUILDING AND FOR GROUND MOTION ANALYSES FOR THE YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT."

THIS REPORT WAS PRODUCED BY BECHTEL SAIC COMPANY, LLC IN SEPTEMBER, 2002.

RESULTS OF OUR REVIEW AND EVALUATION ARE DOCUMENTED IN AN INTERMEDIATE MILESTONE ENTITLED "PRELIMINARY EVALUATION AND ANALYSES OF THE U.S. DEPARTMENT OF ENERGY GEOTECHNICAL DATA AT THE WASTE HANDLING BUILDING SITE, YUCCA MOUNTAIN, NEVADA." BY S. GONZALEZ, J. STAMATAKOS, K. MURPHY, AND H.L. MCKAGUE (TIM 422 : 06002.01.102.422).

IN THE DOE GEOTECHNICAL REPORT, SHEAR-WAVE (V_s) AND COMPRESSION-WAVE (V_p) VELOCITY DATA WAS COLLECTED IN SEVERAL WAYS.

1. CONVENTIONAL DOWNHOLE LOGGING IN WHICH GEOPHONES WERE MOVED UP AND DOWN BOREHOLES AS SOURCE WAVES WERE GENERATED AT THE SURFACE. SOURCES WERE EITHER SLEDGE HAMMER BLOWS TO A STEEL PLATE (P-WAVES) OR TO A WOOD BEAM (S-WAVES) COUPLED TO THE GROUND BY PARKING A TRUCK ON TOP OF IT. JS

2. DOWNHOLE SUSPENSION SURVEYS IN WHICH THE DOWNHOLE TOOL WAS MOVED UP AND DOWN THE BOREHOLES AS SOURCES WERE GENERATED WITHIN THE TOOL ITSELF. TWO SETS OF RECIVERS ARE INCLUDED IN THIS TOOL SO THAT V_s AND V_p CAN BE MEASURED

BETWEEN SOURCE AND RECIEVER OR FROM ONE RECEIVER TO ANOTHER.

3. SPECTRAL ANALYSIS OF SURFACE WAVES (SASW) WHICH USES DISPERSIVE CHARACTERISTICS OF RAYLEIGH WAVES AS THEY PROPAGATE THROUGH A LAYERED MEDIUM BECAUSE OF CHANGES IN LAYERED MEDIUM PROPERTIES. FORWARD MODELING IS USED TO DEVELOP ONE-DIMENSIONAL MODELS OF SOIL AND ROCK PROPERTIES THAT WOULD PRODUCED THE OBSERVED DISPERSION OF SURFACE WAVES.

OF THE THREE METHODS WE FOCUSED ON THE SOURCE-TO-RECIEVER DATA FROM THE SUSPENSION SURVEYS. WE DID THIS BECAUSE THIS DATA WAS THE MOST COMPLETE AND LENDED ITSELF TO OUR APPROACH OF LINKING V_S AND V_P WITH LITHOLOGY. THIS WAS DEEMED APPROPRIATE BECAUSE THE THREE METHODS PRODUCED COMPARIBLE RESULTS.

TO SHOW SIMILARITY IN RESULTS FROM THE VARIOUS METHODS, I PLOTTED DATA FROM BOREHOLE RF#15. AND NEARBY SAWS LINE "PROFILE 2" IN FIGURE 23.

- CONVENTION V_S & V_P DATA ARE FROM TABLES 8 AND 9 OF BECHTEL SAIC COMPANY, LLC (2002) AND FROM FIGURE 6 OF BECHTEL SAIC COMPANY, LLC (2002).
- SUSPENSION V_S & V_P DATA WERE SCANNED FROM FIGURE VII-3 OF BECTEL SAIC COMPANY, LLC (2002).
- SASW DATA FROM FIGURE 93 OF BECHTEL SAIC COMPANY, LLC (2002).

06/18/04

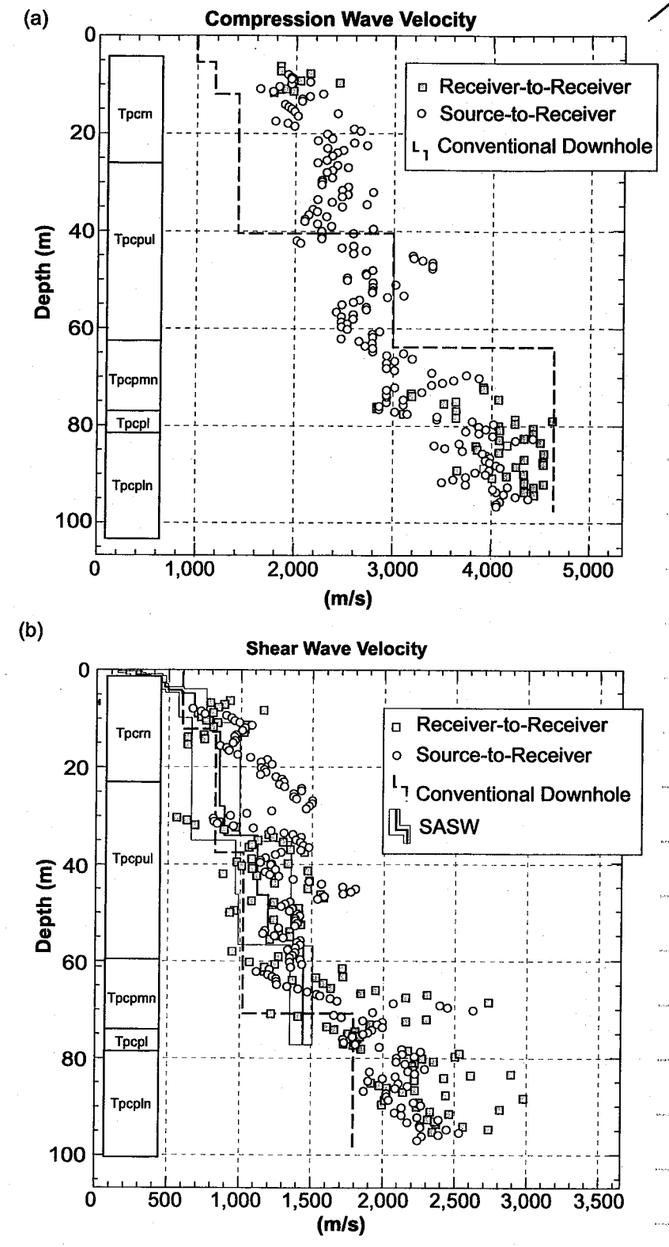

FIGURE 23. COMPARISON OF V_S (b) AND V_P (a) DATA FOR BOREHOLE RF#15

FOR THESE PLOTS, DATA WAS EITHER SCANNED OR TYPED INTO EXCEL SPREADSHEET. KALEIDAGRAPH VERSION 3.09 WAS USED TO PLOT NUMERIC DATA. SCANNED IMAGES AND PLOTS FROM KALEIDAGRAPH WERE IMPORTED INTO ADOBE ILLUSTRATOR. THIS SOFTWARE WAS USED TO GENERATE FINAL PLOTS AND GRAPHS.

I NOTE THAT THE VELOCITY STEPS IN THE CONVENTIONAL DOWNHOLE DATA ARE SOMEWHAT SUBJECTIVE. FIGURE 24 SHOWS THE V_s AND V_p DATA FROM BOREHOLE RF #15 ALONG WITH THE PICKS OF CHANGE IN SLOPE USED TO DEFINE LAYER BOUNDARIES. WHILE THE PICKS PROVIDED IN THE BECHTEL SAIC COMPANY, LLC (2002) REPORT DO NOT CORRESPOND WITH LITHOLOGY, IT IS EASY TO SEE THAT EQUALLY VALID PICKS COULD BE MADE AT LITHOLOGIC BOUNDARIES. FOR EXAMPLE THE DOE VELOCITY (V_s) LAYER BOUNDARY AT 70 M COULD ACTUALLY BE CLOSER TO 60 M DEPTH AND THUS CORRESPOND TO THE CONTACT BETWEEN THE TIVA CANYON UPPER LITHOPHYSAL ZONE AND THE MIDDLE NON LITHOPHYSAL ZONE OF THE TIVA CANYON TUFF.

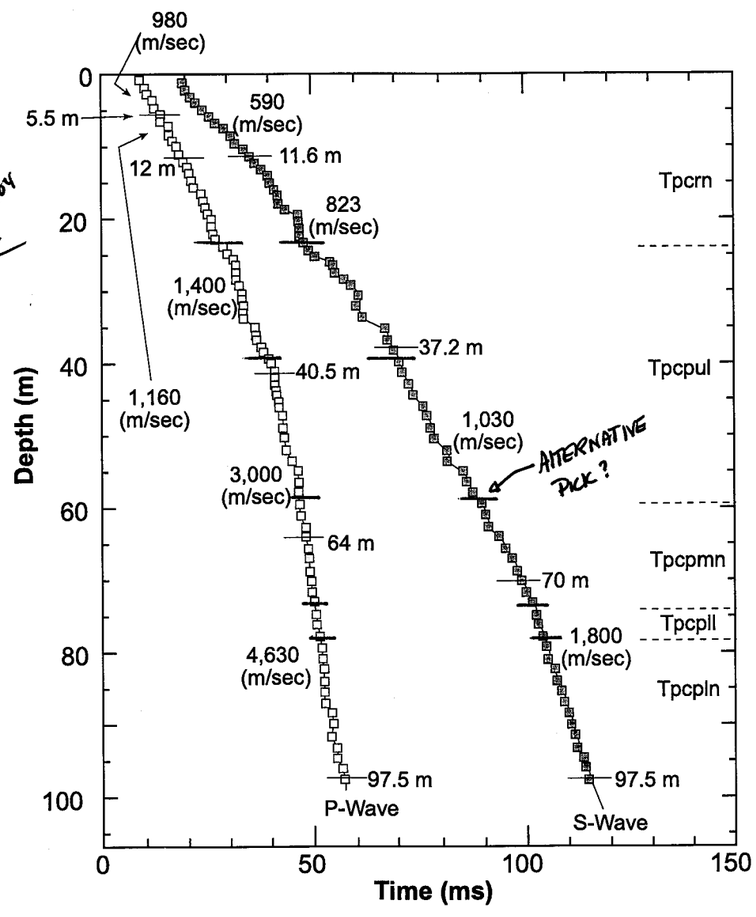

FIGURE 24

CONVENTION V_s AN V_p DATA FOR RF#15. LITHOLOGY IS ALSO SHOWN FOR COMPARISON. PICKS (SUCH AS −37.2 M) ARE DOE CONTRACTOR'S PICKS FOR VELOCITY LAYER BOUNDARIES.

CORRELATION OF V_s AND V_p WITH LITHOLOGY VS. DOE INTERPRETION THAT V_s, V_p CORRELATE WITH DEPTH

THE IMPLICATION IN BECHTEL COMPANY REPORT IS THAT V_s AND V_p DO NOT DEPEND ON LITHOLOGY, BUT ARE ONLY RELATED TO DEPTH. DOE COMPOSITE VELOCITY PROFILES, THAT ARE CONSIDERED TO REPRESENT THE SITE, ARE PLOTTED WITH V_s OR V_p AS A FUNCTION OF DEPTH NOT LITHOLOGY. IN THE FORTHCOMING DOE REPORT ENTITLED "DEVELOPMENT OF EARTHQUAKE GROUND MOTIONS FOR PRECLOSURE SEISMIC DESIGN AND POSTCLOSURE PERFORMANCE ASSESSMENT AT YUCCA MOUNTAIN, NV." THE DOE CONCLUDES THAT "BOUNDARY LAYERS BETWEEN VELOCITY LAYERS DO NOT CORRELATE STRONGLY WITH LITHOLOGIC UNITS SUGGESTING THAT CHANGES IN DENSITY CONTROL THESE CHANGES RATHER THAN MATERIAL TYPE." [WE REVIEWED A DRAFT OF THIS DOE REPORT IN THE OR OFFICE IN LAS VEGAS IN JANUARY AND AGAIN IN APRIL OF 2004].

TO TEST THIS APPROACH, WE DEVELOPED VELOCITY PROFILES THAT ACCOUNTED FOR LITHOLOGY. WE USED THE DOE V_s AND V_p DATA FROM THE SUSPENSION SURVEYS (SOURCE-TO-RECEIVER) BECAUSE THIS DATA WAS SORTED BY LITHOLOGIC UNIT IN THE GEOTECHNICAL REPORT, AND BECAUSE THIS METHOD PRODUCED SUFFICIENT AMOUNT OF DATA TO ALLOW US TO DEVELOP STATISTICS ON THE RESULTS.

WE TOOK V_s AND V_p DATA FROM TABLES VII-2 AND VII-3 FROM BECHTEL SAIC COMPANY, LLC (2002). THE DATA WERE SORTED BY LITHOLOGIC UNIT AND BOREHOLE AND PUT INTO AN EXCEL SPREADSHEET (EXCEL 97 SR-2). THIS SPREADSHEET IS ATTACHED TO THIS NOTEBOOK - CD FILE "VELOCITY_DENSITY_PROFILES_DATA.XLS"

TABLE 12 ON THE NEXT PAGE SHOWS AN EXAMPLE OF THE INPUT DATA AND STATISTICAL CALCULATIONS PERFORMED ON THE DATA.

Qal	Borehole	Mean Vel. (ft/sec)	StDev	n	StError	Hi	Low		WMean	Sum X^2
	13.0									
	14.0	5450	632.7	31	113.6	5563.6	5336.4		168950	9.33E+08
	15.0									
	16.0	5060	427.3	30	78.0	5138.0	4982.0		151800	7.74E+08
	17.0	5120	342.8	24	70.0	5190.0	5050.0		122880	6.32E+08
	18.0	6280	368.8	16	92.2	6372.2	6187.8		100480	6.33E+08
	19.0	4250	962.5	52	133.5	4383.5	4116.5		221000	9.87E+08
	20.0	4680	813.8	43	124.1	4804.1	4555.9		201240	9.7E+08
	21.0	4280	609.4	58	80.0	4360.0	4200.0		248240	1.08E+09
	22.0									
	23.0	4320	1200.4	39	192.2	4512.2	4127.8		168480	7.84E+08
	24.0	5390		1						
	25.0									
	26.0	4340	1171.2	33	203.9	4543.9	4136.1		143220	6.67E+08
	28.0									
	29.0	4430	524.7	36	87.5	4517.5	4342.6		159480	7.16E+08
	Ave.	4872.7	705.4	11	212.7	5085.4	4660.1			
				sum n		5857.8	3887.698		E(X)	E(x2)
				363					4643.994	22536968
		Sig-Mu	651.077							
		Sig-Sig	317.825							
		sum sigs	968.903							
							Mean	4872.727		
							Var.	970283.45		
							StDev	985.02967		

Tmbt1	Borehole	Mean Vel.	StDev	n	StError	Hi	Low		WMean	Sum X^2
	13.0									
	14.0									
	15.0									
	16.0									
	17.0	6070	483.7	118	44.5	6114.5	6025.5		716260	4.38E+09
	18.0	5960	57.7	3	33.3	5993.3	5926.7		17880	1.07E+08
	19.0	6710	736.1	98	74.4	6784.4	6635.6		657580	4.47E+09
	20.0									
	21.0									
	22.0	6780	522.8	51	73.2	6853.2	6706.8		345780	2.36E+09
	23.0									
	24.0									
	25.0									
	26.0									
	28.0									
	29.0	7530	1593.9	119	146.1	7676.1	7383.9		896070	7.05E+09
	Ave.	6610.0	678.8	11	204.7	6814.7	6405.3			
				sum n		7772.7	5447.320		E(X)	E(x2)
				389					6770.103	47186118
		Sig-Mu	632.337							
		Sig-Sig	567.639							
		sum sigs	1199.976							
							Mean	6610.000		
							Var.	1351825.3		
							StDev	1162.6802		

TABLE 12 EXAMPLE OF V_P DATA IN EXCEL SPREADSHEET

EXPLANATION OF SPREADSHEET CALCULATIONS

UNIT NAMES
- Qal - QUATERNARY ALLUVIUM
- Tmbt1 - PRE-RAINIER MESA BEDDED TUFF
- Tpki - "TUFF X" (COMB PEAK IGNIMBRITE)
- Tpbts - POST TIVA BEDDED TUFF
- TpCrn - TIVA CANYON TUFF, CRYSTAL RICH NON LITHOPHYSAL
- TpCPul - TIVA CANYON TUFF, UPPER LITHOPHYSAL ZONE
- TpCPmn - TIVA CANYON TUFF, MIDDLE NON LITHOPHYSAL ZONE
- TpCPll - TIVA CANYON TUFF, LOWER LITHOPHYSAL ZONE.
- TpCPln - TIVA CANYON TUFF, LOWER NON LITHOPHYSAL ZONE

MEAN VEL, STDEV, AND n ARE FROM TABLES VII-2 AND VIII-3 IN BECHTEL SAIC COMPANY, LLC (2002)

STERROR IS THE STANDARD ERROR OF THE MEAN = $\frac{\text{STDEV}}{\sqrt{n}}$. HI AND LOW ARE MEAN ± STERROR. THIS WAS NOT USED IN OUR LETTER REPORT.

WMEAN IS THE WEIGHTED MEAN = MEAN VEL * n

SUM $X^{\wedge 2}$ IS THE SUM WEIGHTED MEAN SQUARED = $\left[(\text{MEAN VEL}^2) + (\text{STDEV}^2)\right] * n$

SUM n IS THE TOTAL NUMBER OF MEASUREMENTS = SUM of Column

SIG-MU IS THE STANDARD DEVIATION OF THE AVERAGE OF MEAN VEL VALUES
SIG-SIG IS THE STANDARD DEVIATION OF THE AVERAGE OF STDEV VALUES
SUM SIGS IS THE SUM OF SIG-MU + SIG-SIG.
THESE WERE NOT USED IN OUR LETTER REPORT

MEAN. IS THE AVERAGE OF WELL MEAN VEL VALUES.

VAR IS THE VARIANCE = $\cancel{\text{SUM}(\text{WMEAN})}$ $\text{SUM}\left(\frac{\text{SUM } X^{\wedge 2}}{\text{SUM } n}\right) - \left[\frac{\text{SUM}(\text{WMEAN})}{\text{SUM } n}\right]^2$

THESE FORMULA CAN BE OBTAINED FROM THE ATTACHED SPREADSHEET "Velocity_Density_Profiles.xls"

THIS SPREADSHEET PROVIDES STATISTICAL VALUES USED IN FIGURE 25, WHICH SHOWS BOTH THE INDIVIDUAL WELL DATA AND STANDARD DEVIATIONS AS WELL AS WEIGHTED MEAN AND ITS STANDARD DEVIATION. NOTE THAT I CONVERTED FT/SEC TO M/SEC USING 1 m = 3.28 ft.

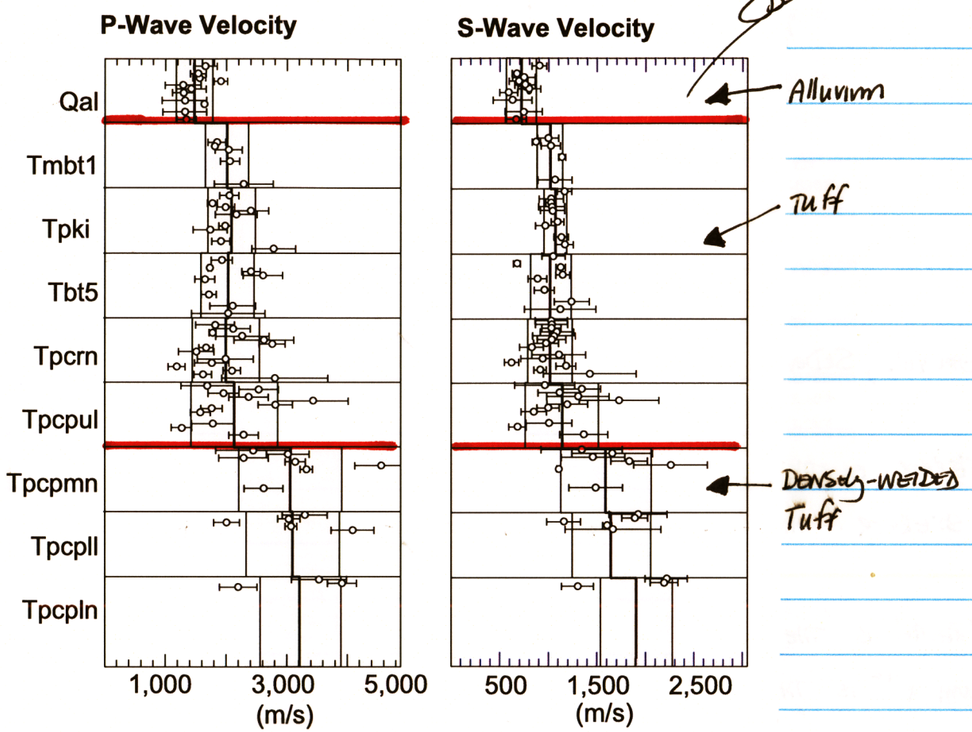

FIGURE 25. V_P AND V_S FOR EACH LITHOLOGIC UNIT

THE DATA SHOW TWO DISTINCT BREAKS IN SLOPE; ONE AT QAL/TMBT1 CONTACT AND ONE AT TPCPUL/TPCPMN CONTACT. THESE ARE IMPORTANT CONTACTS; ONE SEPARATES ALLUVIUM FROM TUFF AND THE OTHER MODERATELY WELDED TUFF FROM DENSELY-WELDED TUFF.

THESE RESULTS (AND PLOTS IN FIGURE 25) SUGGEST TO US THAT LITHOLOGY MAY BE IMPORTANT FACTOR IN DEVELOPING GROUND RESPONSE PROFILES.

DENSITY DATA

DENSITY MEASUREMENTS WERE OBTAINED BY DOE USING CALIPER AND GAMMA-GAMMA WIRELINE LOG. MEASUREMENT WERE FROM 7 OF THE BOREHOLES (RF# 16, 18, 20, 21, 22, 24, & 28). THIS IS A STANDARD APPROACH AND ONE USED A LOT ACROSS THE NTS FOR DOWNHOLE DENSITY MEASUREMENTS (L. MCKAGUE PERSONAL COMM.).

WE TREATED DENSITY IN A SIMILAR WAY AS THE VELOCITY DATA ANALYSIS. TABLE 13 IS AN EXAMPLE OF THE DATA, DATA ANALYSIS, AND STATISTICS WE ~~SUSE~~ USED IN THE LETTER REPORT. THE INPUTS (BOREHOLE #, MEAN DENSITY AND STDEV, AND n ARE TAKE FROM TABLE 12 OF BECHTEL SAIC COMPANY, LLC (2002). WE CONVERTED DENSITY IN (lbm/cft) TO METRIC (Mg/m^3) USING $1\ Mg/m^3 = 62.42796\ lbm/ft^3$. OTHER STATISTICAL MEASURES ARE THE SAME AS THOSE DESCRIBED ON PREVIOUS PAGES OF THIS SCIENTIFIC NOTEBOOK.

TABLE 13. EXAMPLE DENSITY DATA FROM SPREADSHEET

Qal	Borehole	Mean (lbm/cuft)	Mean (mg/m^3)	StDev	n	StError	Hi	Low		WMean	Sum X^2
	16.000	114.130	1.828	4.510	107	0.436	114.566	116.394		12211.91	1395921.679
	18.000	117.430	1.881	5.340	106	0.519	117.949	116.911		12447.58	1464741.973
	20.000	118.710	1.902	3.610	139	0.306	119.016	118.404		16500.69	1960608.372
	21.000	111.240	1.782	9.510	217	0.646	111.886	110.594		24139.08	2704856.761
	22.000	119.510	1.914	3.800	147	0.313	119.823	119.197		17567.97	2101670.775
	24.000	118.200	1.893	2.700	41	0.422	118.622	117.778		4846.2	573119.73
	28.000	110.120	1.764	8.760	21	1.912	112.032	108.208		2312.52	256266.192
	Averages	115.620	1.852	5.461	111	0.650	116.270	115.355			
					sum n					E(X)	E(x2)
		Sig-Mu	3.792		778					115.7146	13441.11244
		Sig-Sig	2.646					Mean	115.620		
		sum sigs	6.438					Var.	51.24641		
								StDev	7.15866		

Tmbt1	Borehole	Mean (lbm/cuft)	Mean (mg/m^3)	StDev	n	StError	Hi	Low		WMean	Sum X^2
	16.000										
	18.000	117.130	1.876	5.620	10	1.777	118.907	120.783		1171.3	137510.213
	20.000										
	21.000										
	22.000	109.670	1.757	5.320	476	0.244	109.914	111.671		52202.92	5738566.179
	24.000										
	28.000										
	Averages	113.400	1.816	5.470	243	1.011	114.411	116.227			
					sum n					E(X)	E(x2)
		Sig-Mu	5.275		486					109.8235	12090.69216
		Sig-Sig	0.212					Mean	113.400		
		sum sigs	5.487					Var.	29.49146		
								StDev	5.430604		

THIS DATA LOCATED IN ATTACHED EXCEL FILE "VELOCITY - DENSITY - PROFILES.XLS"

FIGURE 26 SHOWS THE MEAN VELOCITY DATA FOR EACH LITHOLOGIC UNIT. THE BEDDED (AIRFALL) IGNIMBRITE UNIT Tpki HAS LOWEST DENSITY AND THE DENSELY WELDED TIVA CANYON TUFF HAS THE HIGHEST DENSITY.

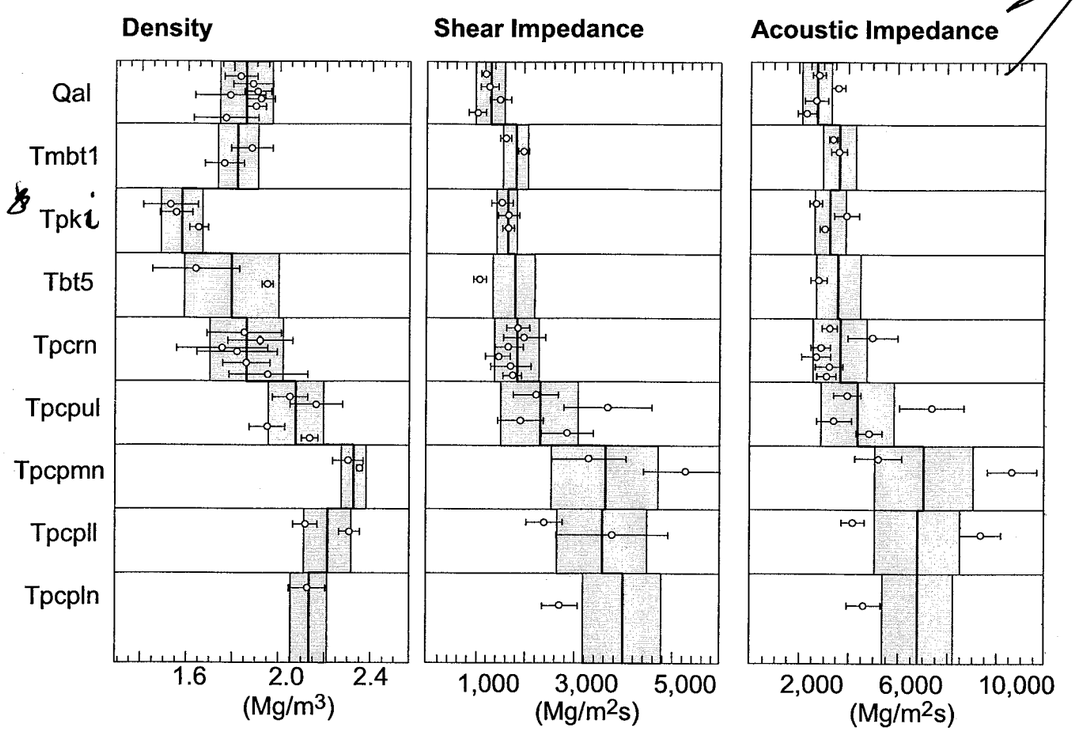

FIGURE 26. DENSITY DATA SORTED BY LITHOLOGIC UNIT. SHEAR IMPEDANCE AND ACOUSTIC IMPEDANCE WHICH ARE CALCULATED BY DENSITY × V_S AND DENSITY × V_P.

FIGURE 26 ALSO SHOWS IMPEDANCE PROFILES. THESE WERE OBTAINED BY MULTIPLYING THE DENSITY TIMES V_S (SHEAR IMPEDANCE) AND DENSITY TIME V_P (ACOUSTIC IMPEDANCE). NOTE THE SHARP IMPEDANCE CONTRASTS ACROSS THE Tpcpmn/Tpcpul AND TMBT1/QAL INTERFACES.

AS A FINAL TEST OF THE DATA I GENERATED TWO MORE PLOTS (SHOWN IN FIGURE 27). IN THE FIRST PLOT DENSITY AND VELOCITY (V_S FROM SOURCE-TO-RECIEVER SUSPENSION SURVEYS) WERE PLOTTED AS A FUNCTION OF DEPTH. THE ERROR BARS IN THIS PLOT ARE EITHER THE REPORTED 1-SIGMA VALUES OR THE DEPTH RANGE OVER WHICH V_S AND DENSITY WERE AVERAGED. CONTRARY TO THE DOE ASSERTION MENTIONED ON PAGE 39, WE DO NOT SEE A STRONG CORRELATION BETWEEN DENSITY AND V_S AND DEPTH. FOR DEPTHS SHALLOWER THAN 100 M, DENSITY AND V_S APPEAR TO BE INDEPENDENT OF DEPTH. AT DEEPER DEPTHS THE HIGHER DENSITY AND LARGER V_S VALUES REFLECT THE PRESENCE OF DENSELY-WELDED TIVA CANYON TUFF. DATA AND PLOT ARE STORED AS KALEIDAGRAPH FILES AND ARE ATTACHED TO THIS NOTEBOOK AS GEOTECH_DATA_EVALUATION.QDA AND DENSITY_V_S_aafb_Depth.QPC. THE SECOND PLOT SHOWS THAT DENSITY IS ALSO RELATIVELY INDEPENDENT FROM V_S. LARGER V_S VALUES (ABOVE 1500 M/S) EXIST ONLY IN SAMPLES WITH LARGER DENSITY - WHICH ARE SAMPLES OF DENSELY-WELDED TIVA CANYON TUFF. THUS, CONTRARY TO THE DOE CONCLUSION, WE SUGGEST THAT LITHOLOGY IS THE BEST PREDICTOR OF V_S AND DENSITY.

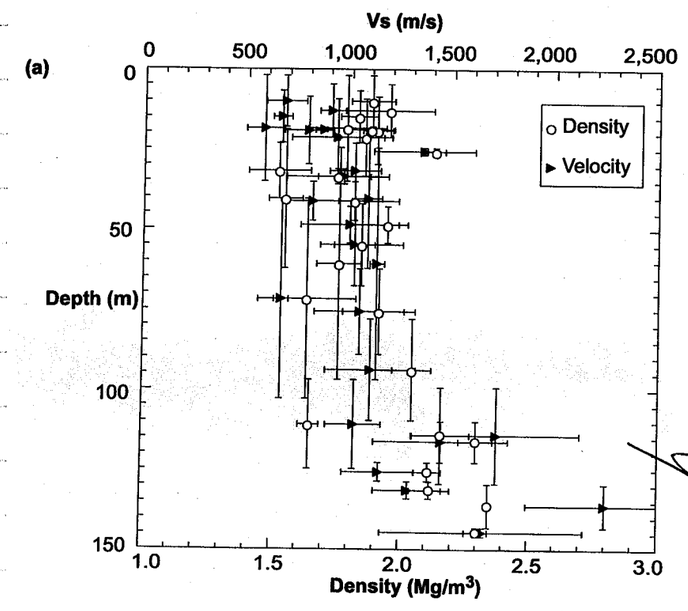

FIGURE 27. DENSITY AND V_S PLOTTED AS A FUNCTION OF DEPTH. ONLY THOSE DATA FROM BOREHOLES WITH BOTH DENSITY MEASUREMENTS AND V_S ARE PLOTTED.

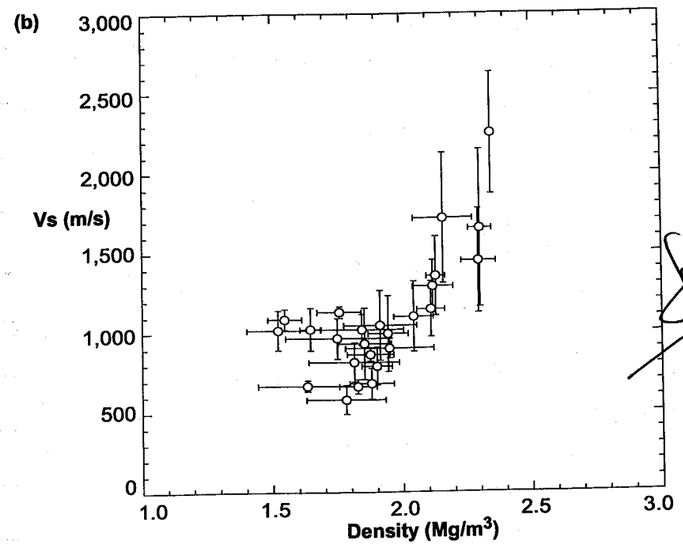

FIGURE 27 CONT.

NOTE THAT NOT ALL V_S DATA ARE PLOTTED IN FIGURE 27. WE ONLY USED DATA FROM BOREHOLES THAT HAD BOTH DENSITY AND V_S REPORTED. THIS WAS DONE TO BE CONSISTENT IN THE COMPARISONS OF THESE DATA.

DEVELOPMENT OF PROFILES FOR GROUND RESPONSE MODELS

KATHERINE MURPHY PROVIDED ME WITH FIVE INDEPENDENT GEOLOGIC PROFILES, BASED ON THE LAYERS IN THE 3D EARTHVISION MODEL OF THE WASTE HANDLING BUILDING SITE. THESE DATA ARE ALSO STORED IN THE ATTACHED SPREADSHEET "VELOCITY_DENSITY_PROFILE_DATA.XLS" AN EXAMPLE OF THE PROFILE DATA IS PROVIDED IN TABLE 14.

Profile 5 E551245 N4078568

Unit	Thickness	Depth	Mean Vel. ft/sec	High Vel. (+1 sigma)	Low Vel. (-1 sigma)	Mean Den. lbm/ft3	High Den. (+1 sigma)	Low Den (-1 sigma)
Qal	25	25	2336	2838.3	1833.7	115.62	122.78	108.46
Tpki	11	36	3488.9	3872.7	3105.1	98.157	103.85	92.467
Tpbt5	3	39	3335	4016.7	2653.3	111.71	124.58	98.845
Tpcrn	18	57	3312.9	4062.8	2563	115.77	125.71	105.83
Tpcpul	31	88	3712.7	4941.7	2483.7	129.19	136.65	121.73
Tpcpmn	14	102	5192.9	6719.9	3665.9	144.91	148.25	141.57
Tpcpll	5	107	5378	6706	4050	137.75	144.18	131.32
Tpcpln	5	112	6213.3	7414.8	5011.8	132.75	137.65	127.85

TABLE 14. EXAMPLE OF PROFILE DATA THAT IS USED AS INPUT TO GROUND RESPONSE MODELS

IN THE SPREADSHEET, THICKNESS WAS OBTAINED FROM THE EARTHVISION MODEL. MEAN VEL AND MEAN DEN. ARE VALUES OBTAINED FROM PREVIOUS CALCULATIONS DESCRIBED ON PAGES 41 AND 43. NOTE THE LOCATION OF EACH PROFILE IS PROVIDED AS UTM COORDINATES (ZONE 11).

ENTRY 6/18/94 BY JOHN STAMATAKOS

PURPOSE: DOCUMENT SELECTION OF INPUT TIME HISTORIES FOR GROUND RESPONSE MODELING.

FOR PRECLOSURE ANALYSIS, DOE DEAGGREGATION OF THE YUCCA MOUNTAIN PSHA INDICATES THAT $M_W = 6$ TO $M_W = 6.5$ AT CLOSE DISTANCE DOMINATES THE HAZARD. THUS, FOR OUR PRELIMINARY EVALUATION WE SELECTED INPUT TIME HISTORIES THAT MET THESE CRITERIA. THE NEARBY FAULT SOURCES ARE NORMAL FAULTS AND THE INPUT TIME HISTORIES WILL BE FOR ROCK CONDITIONS WITH $V_S > 6000$ ft/sec.

WE SEARCHED THE EUROPEAN DATA BASE AT HTTP://WWW.ISESD.CV.IC.AC.UK/ESD/FRAMESET.HTM WE LOOKED FOR RECENT EARTHQUAKE RECORDS BASED ON THE FOLLOWING CRITERIA

M_W 6 to 6.8
STATIONS RECORDING ON ROCK CONDITIONS
EPICENTRAL DISTANCE $\leq$ 30 KM
NORMAL FAULT EARTHQUAKES

THE EUROPEAN DATABASE RETURNED SEVEN CHOICES (5 WITH AVAILABLE RECORDS). OF THESE WE CHOSE KOZANI-PREFECTURE AND UMBRIA NOCERA. THESE TWO RECORDS WERE CLOSEST TO THEIR RESPECTIVE EPICENTERS.

THE SUMMARY OF EARTHQUAKE RECORDS IN THE EUROPEAN DATABASE IS SHOWN IN TABLE 15.

DETAILS OF THE UMBRIA AND KOZANI TIME HISTORIES IS SHOWN IN FIGURES 28 AND 29.

DATABASE

Information potentially subject to copyright protection was redacted from this location. The redacted material is from the information listed below.

TABLE 15. WEBSITE PAGE SHOWN EUROPEAN EARTHQUAKE DATA THAT MET OUR INPUT CRITERIA.

Information potentially subject to copyright protection was redacted from these pages. The redacted material is from the following reference:

Ambraseys, N., P. Smith, R. Sigbjornsson, P. Suhadolc, and B. Margaris. Internet-Site for European Strong-Motion Data. <http://www.isesd.cv.ic.ac.uk> EVR1-CT-1999-40008, European Commission, Directorate-General XII, Environmental and Climate Programme, Bruxelles, Belgium. 2001.

FIGURE 28. PRINTOUT of TIME HISTORIES FOR UMBRIA EARTHQUAKE RECORD

FIGURE 29. PRINTOUT of TIME HISTORIES FOR KOZANI EARTHQUAKE RECORD.

WE ALSO SELECTED TWO TIME HISTORIES FROM THE NORTHRIDGE EARTHQUAKE BECAUSE WE KNOW FROM REVIEWING THE DOE DOCUMENT ENTITED "DEVELOPING EARTHQUAKE GROUND MOTIONS FOR PRECLOSURE SEISMIC DESIGN AND POST CLOSURE PERFORMANCE ASSESSMENT AT YUCCA MOUNTAIN, NV," THAT THE DOE WILL RELY ON SCALED TIME HISTORIES FROM THIS EARTHQUAKE IN ITS ASSESSMENTS.

FOR THIS ANALYSIS WE SELECTED TWO RECORDS FROM THE COSMOS VIRTUAL DATA CENTER

- DUARTE - VALLEY VIEW ELEM SCHOOL - 237 MEL CANYON ROAD
- JENSEN FILTRATION PLANT GENERATOR BUILDING

THESE RECORDS WERE SELECTED BECAUSE THEY ARE ON ROCK OR VERY FIRM SOIL SITES AND BECAUSE THE CAPTURE A LARGE RANGE IN INPUT MOTION. PGA VALUES FOR THE DUARTE RECORD ARE LESS THAN 0.1g. PGA VALUES FOR THE JENSEN RECORDS ARE NEARLY 1.0 g.

FIGURES 30 AND 31 SHOW THE 3 COMPONENT ACCELERATION TIME HISTORIES FOR THESE TWO RECORDS.

COSMOS VIRTUAL DATA CENTER

Consortium of Organizations for Strong-Motion Observation Systems

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Acceleration

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FIGURE 30. DUARTE TIME HISTORY RECORD

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Acceleration

Information potentially subject to copyright protection was redacted from this location. The redacted material is from the information listed above.

FIGURE 31. JENSEN FILTRATION PLANT RECORD

ENTRY: SARAH GONZALEZ

DATE: 06/21/2004

SLG 06/21/04

GROUND RESPONSE CALCULATIONS

The data in Bechtel SAIC Company (2002) will be used as inputs to develop representative Postclosure and Preclosure time histories for Point B, as well as and Preclosure time histories for Points D and E (refer to Figure 32). These time histories are not yet available and Bechtel SAIC Company (2002) does not contain any of these calculations.

Preliminary ground response calculations were conducted in order to help quantify the effects of data uncertainty on ground motion amplification. These calculations were performed using the program ProShake (EduPro Civil Systems, 2001) which calculates the response of a semi-infinite horizontally layered soil deposit overlying a uniform half-space subjected to vertically propagating shear waves (Schnabel et al., 1972). An equivalent linear procedure is used to account for the nonlinearity of the soil (Idriss and Seed, 1968).

SLG 06/21/04

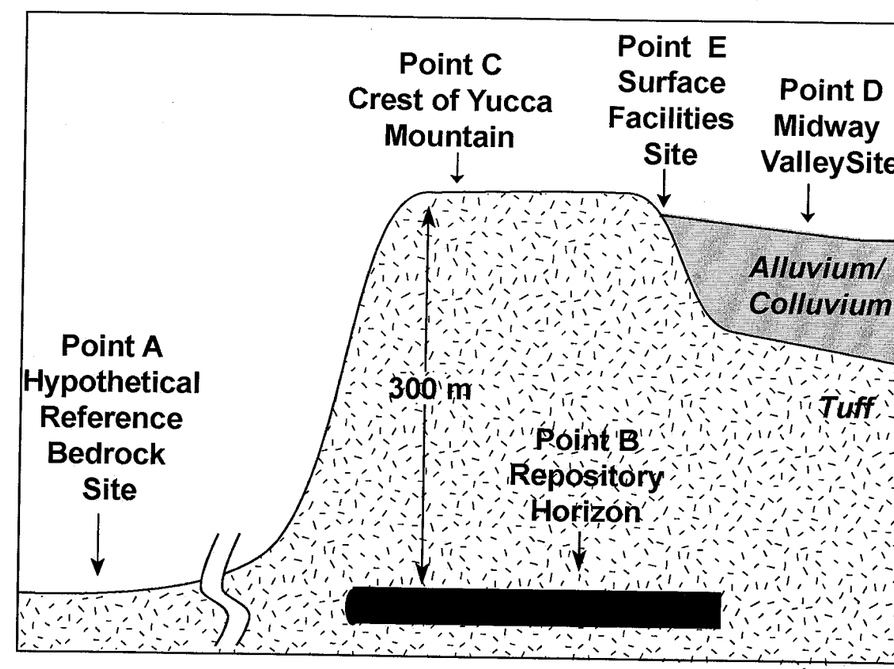

FIGURE 32. SCHEMATIC OF THE SEISMIC REFERENCE POINTS AT YUCCA MOUNTAIN (MODIFIED FROM STEPP ET A., 2001)

SK 06/21/04

Inputs to the Ground Response Calculations

Inputs to the ProShake model include developing a soil column and assigning a velocity, density and thickness to each layer in the column, including the half-space. Each layer is also assigned a damping and shear modulus reduction curve. In addition an input time history needs to be specified at the top of any layer within the soil profile, or at the corresponding outcrop.

Time History Inputs

Four different time histories were selected as inputs (Figure 33). Response spectra for these time histories are provided in Figure 34. These events were selected because they are similar to events that are representative of the 10^{-4} annual probability of exceedance at the Yucca Mountain site Point A (refer to Figure 32). Deaggregation of the mean hazard for an annual probability of exceedance of 10^{-4} at the Yucca Mountain site shows that at intermediate frequencies (5 to 10 Hz), the ground hazard is dominated by earthquakes smaller than Mw 6.5 at distances less than 15 km (Stepp et al., 2001). The sources of these earthquakes are the Paintbrush Canyon, Stagecoach Road and Solitario Canyon faults (Stepp et al., 2001). All three faults are normal faults.

Two of the input time histories were generated from normal faulting events (Kozani and Nocera), and were recorded on hard rock sites. These recordings are also from European earthquakes. The remaining time histories (Sylmar and Duarte) were recorded from the Northridge, California earthquake, which was a thrust faulting event. Each time history (horizontal component) is input at the base of the soil profile as rock outcropping motions, which corresponds to Point A in Figure 32. Refer to the entry on pages 48 to 54 by John Stamatakos for more details regarding these time histories.

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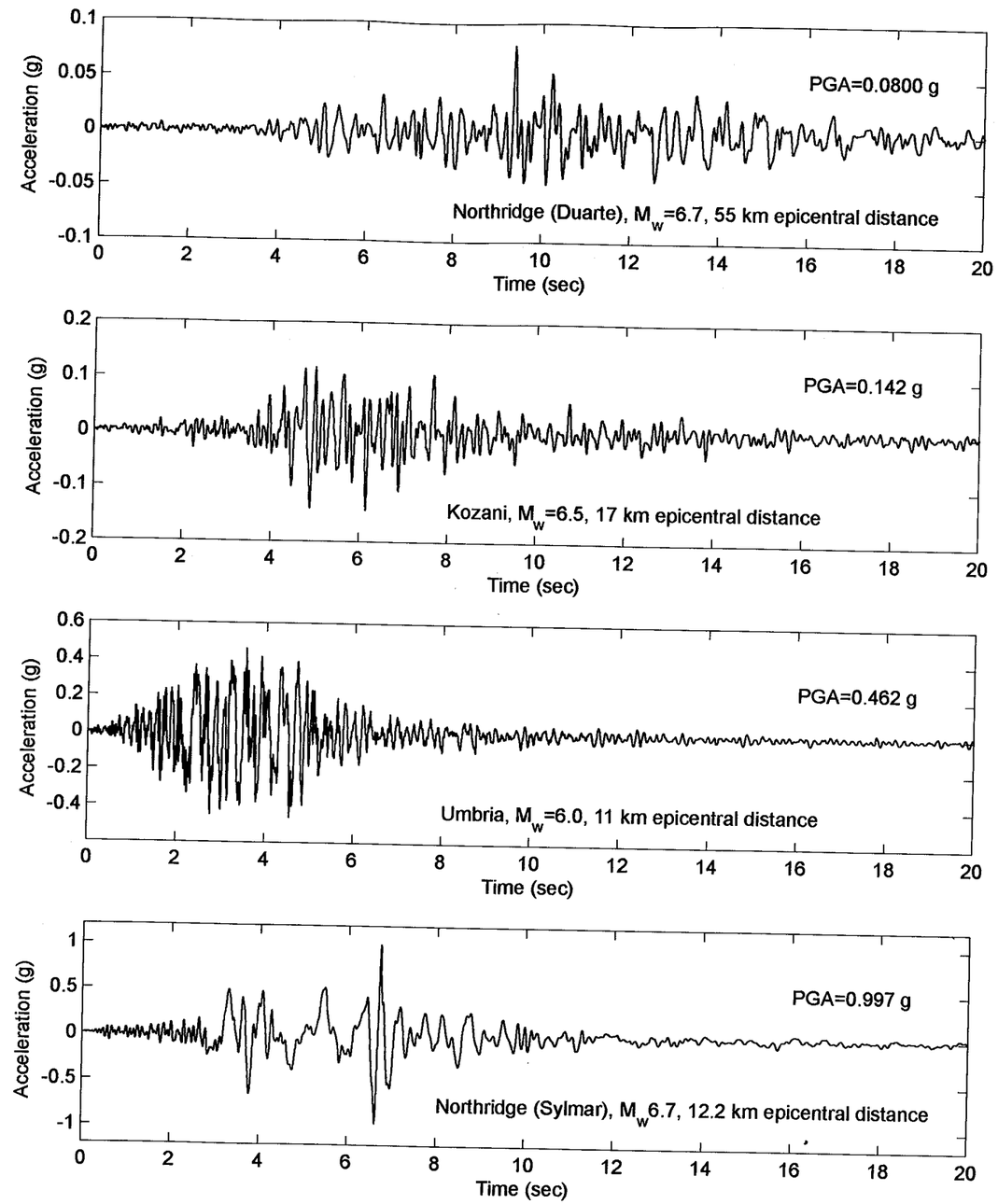

FIGURE 33. TIME HISTORY INPUTS USED IN THE GROUND RESPONSE CALCULATIONS.

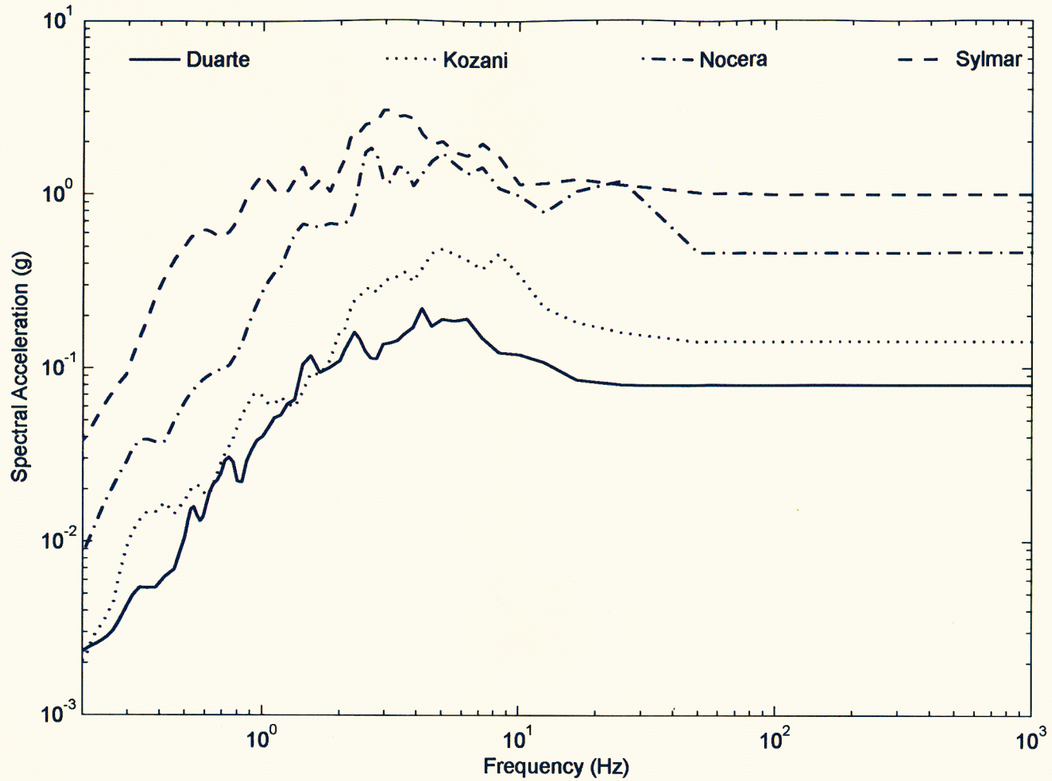

FIGURE 34. RESPONSE SPECTRA (5% DAMPED) OF INPUT TIME HISTORIES USED IN THE GROUND RESPONSE CALCULATIONS.

Layer Thickness Inputs

The layer thickness inputs used in the ground response calculations are shown in Figures 35 to 39. These layer thickness inputs correspond to lithologic profiles which were obtained from the three-dimensional EarthVision model. These profiles were selected to represent the variable geologic conditions at the WHB Site. Refer to the entry on page 47 by John Stamatakos for more information regarding the generation of the profiles.

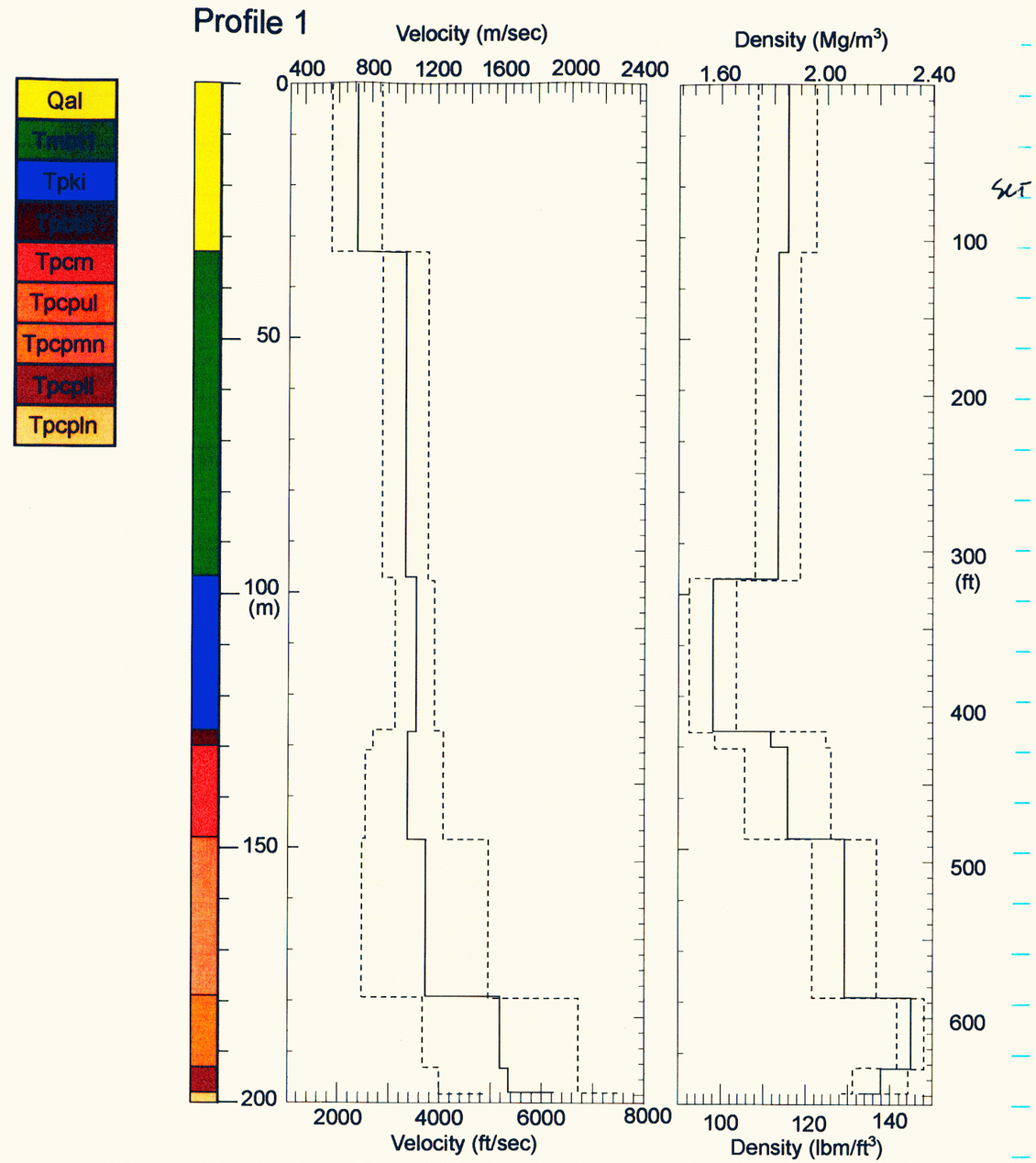

FIGURE 35. THICKNESS, VELOCITY AND DENSITY PROFILE 1 USED IN THE GROUND RESPONSE CALCULATIONS.

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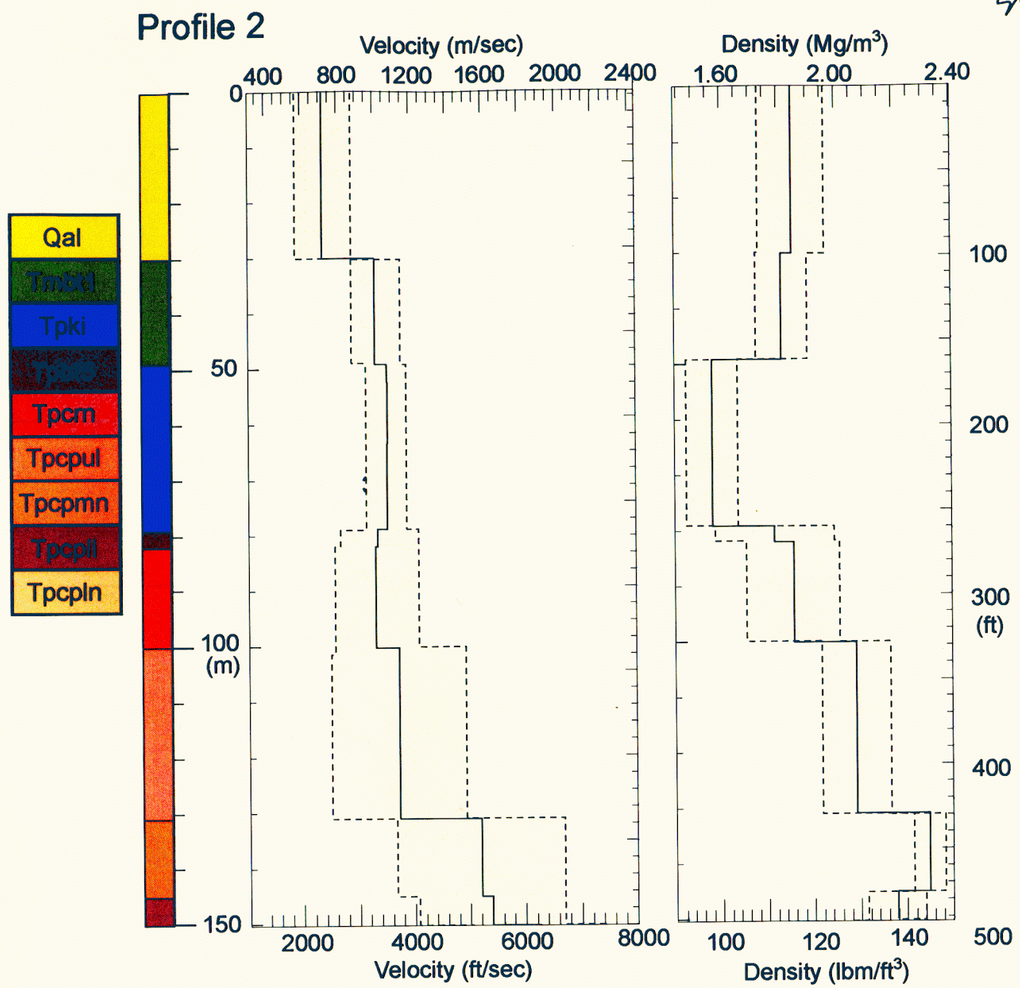

FIGURE 36. THICKNESS, VELOCITY AND DENSITY PROFILE 2 USED IN THE GROUND RESPONSE CALCULATIONS.

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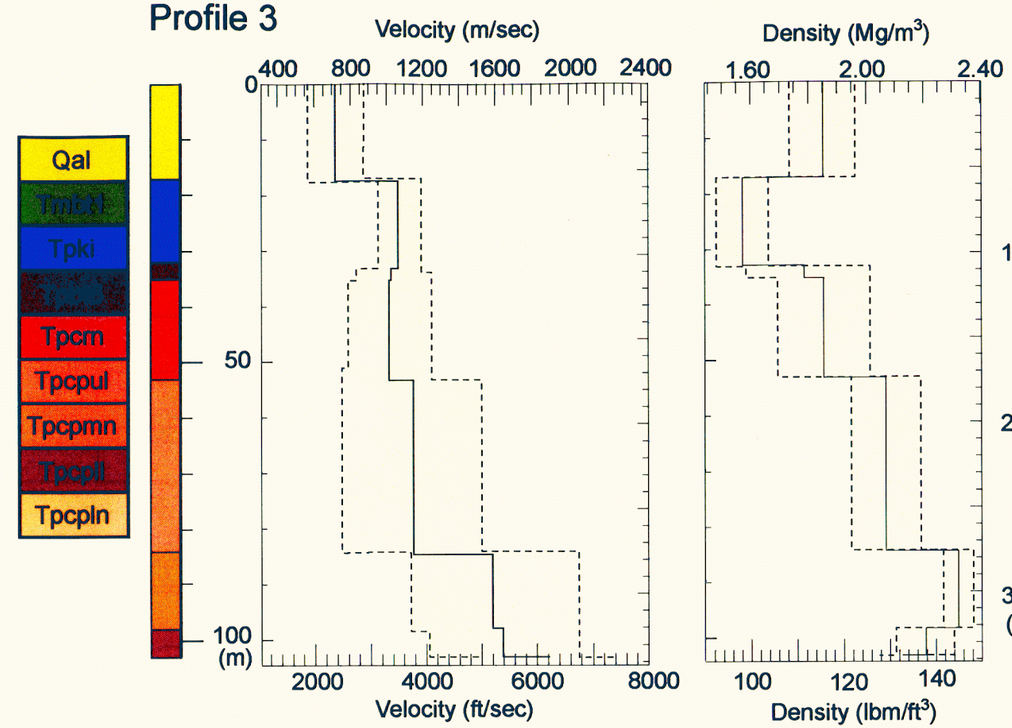

FIGURE 37. THICKNESS, VELOCITY AND DENSITY PROFILE 3 USED IN THE GROUND RESPONSE CALCULATIONS.

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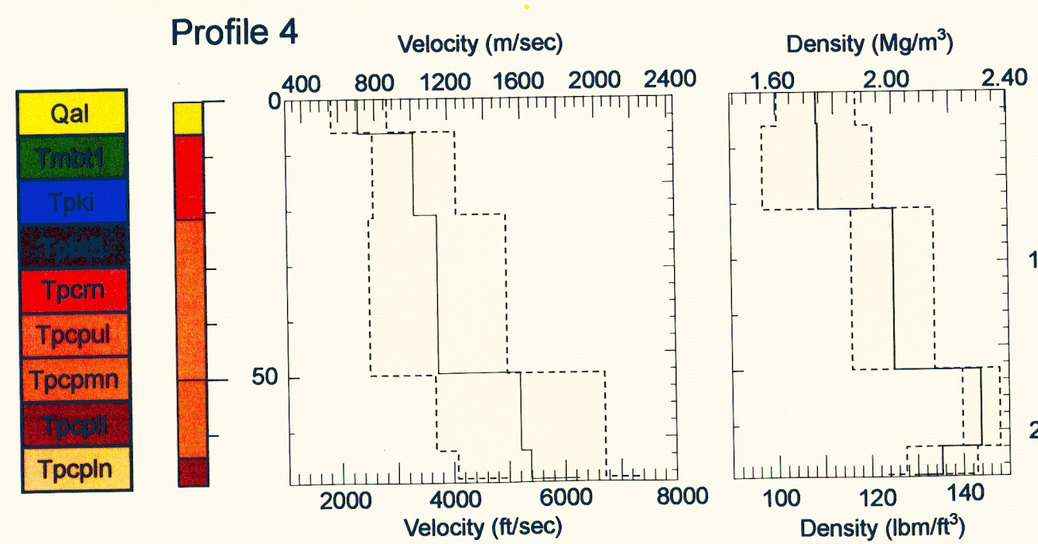

FIGURE 38. THICKNESS, VELOCITY AND DENSITY PROFILE 4 USED IN THE GROUND RESPONSE CALCULATIONS.

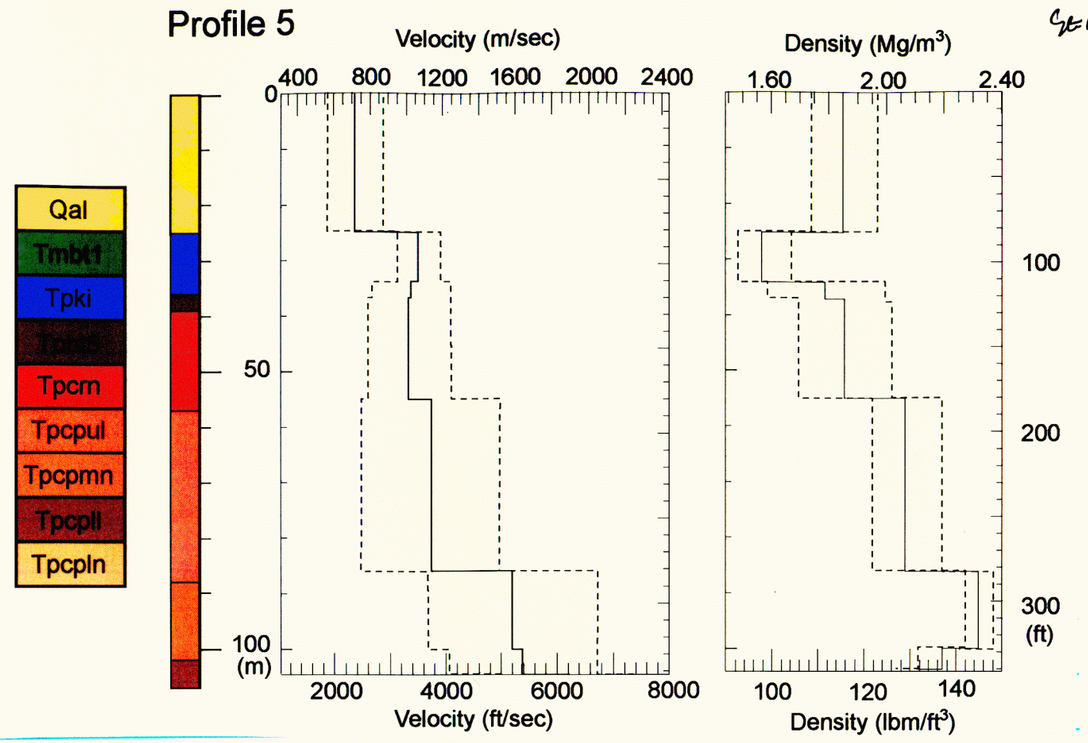

FIGURE 39. THICKNESS, VELOCITY AND DENSITY PROFILE 5 USED IN THE GROUND RESPONSE CALCULATIONS.

Velocity and Density Inputs

The various V_s profiles used in the ground response response calculations were correlated with lithology and are shown in Figures 35 to 39. Large V_s contrasts are observed at two lithologic interfaces: between the Qal and Tmbt1 units and between the Tcpcpul and Tpcpmn units. The mean V_s values were used. Three additional profiles, shown in Figure 40, were also developed to accentuate variations across the Qal/Tmbt1 and Tcpcpul/Tpcpmn layer, based on the 1-sigma error limits. Refer to the entry on page 47 by John Stamatakos for more information regarding the generation of these velocity profiles.

The density profiles were also correlated with lithology and are shown in Figures 35 to 39. Large density contrasts at the interface between the Qal and Tmbt1 units and between the Tcpcpul and Tpcpmn units. The mean values velocity values in Figures 35 to 39 were used. Three additional density profiles, shown in Figure 41, were developed to accentuate variations in the density within Tpki unit (tuff unit "x") and across the Tcpcpul/Tpcpmn interface. Refer to the entry on page 47 by John Stamatakos for more information regarding the generation of these density profiles.

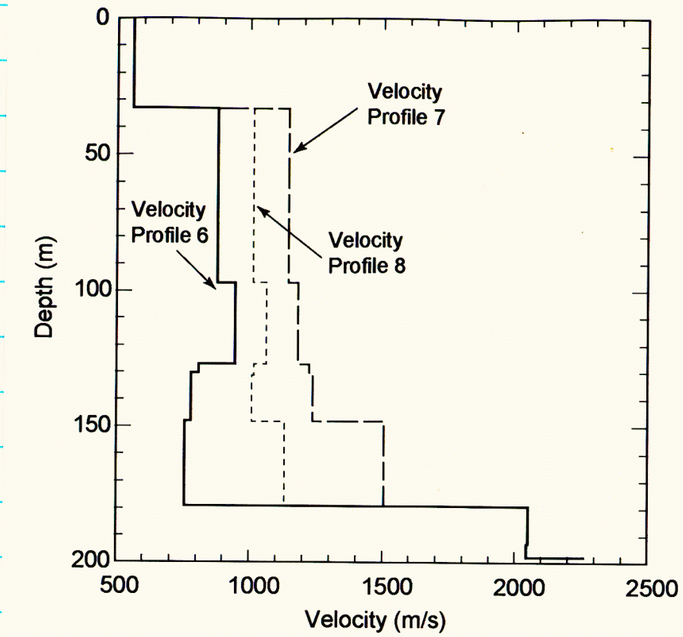

FIGURE 40. Vs PROFILES 6, 7 AND 8 USED IN THE GROUND RESPONSE CALCULATIONS.

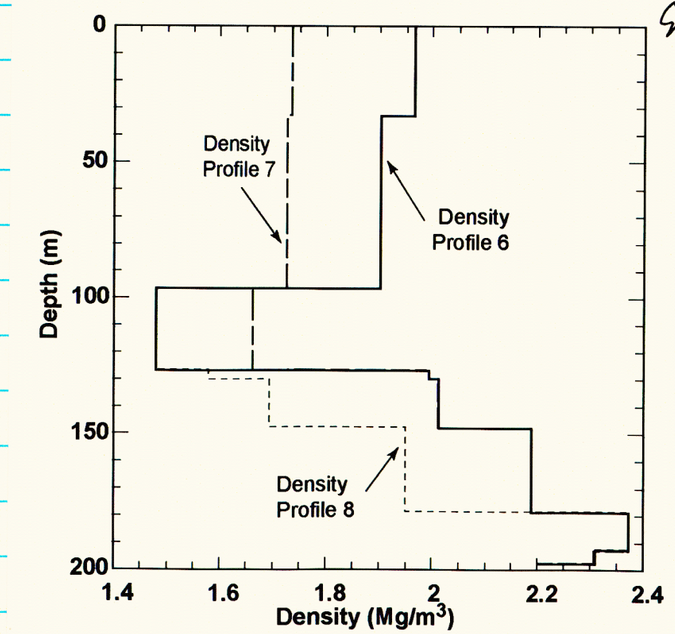

FIGURE 41. DENSITY PROFILES 6, 7 AND 8 USED IN THE GROUND RESPONSE CALCULATIONS.

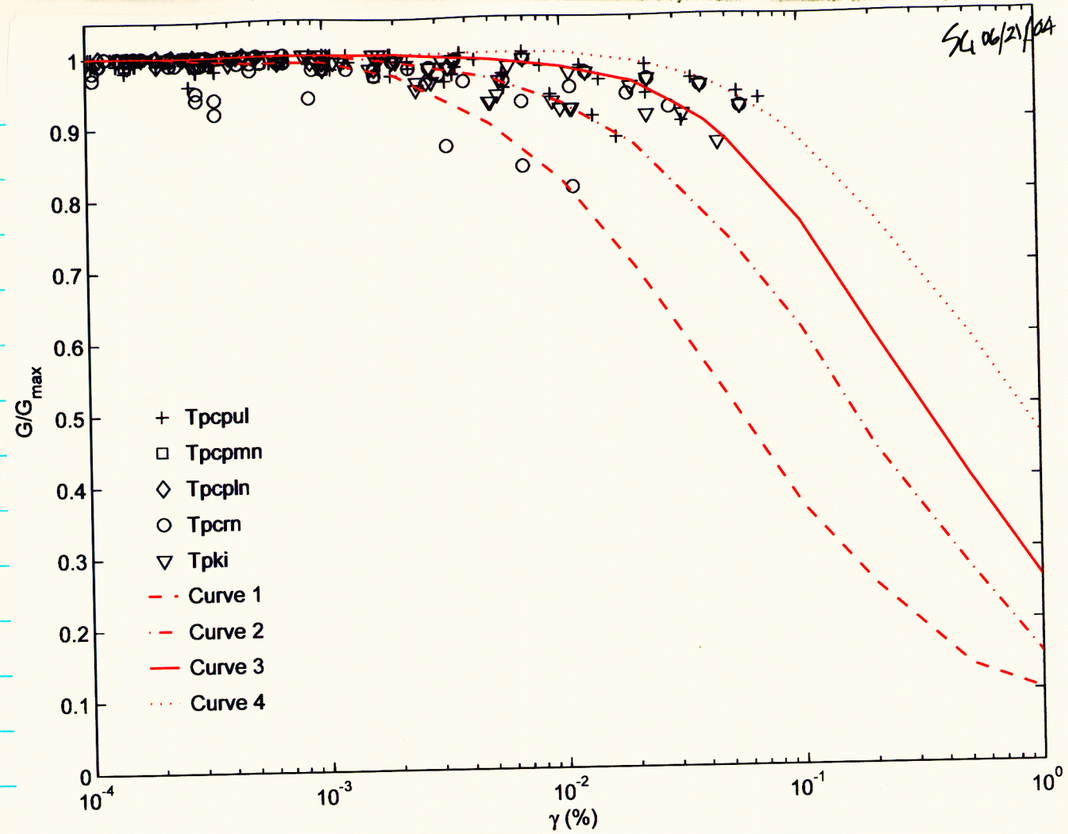

FIGURE 42. RANGE OF TUFF SHEAR MODULUS CURVES USED FOR GROUND RESPONSE CALCULATIONS.

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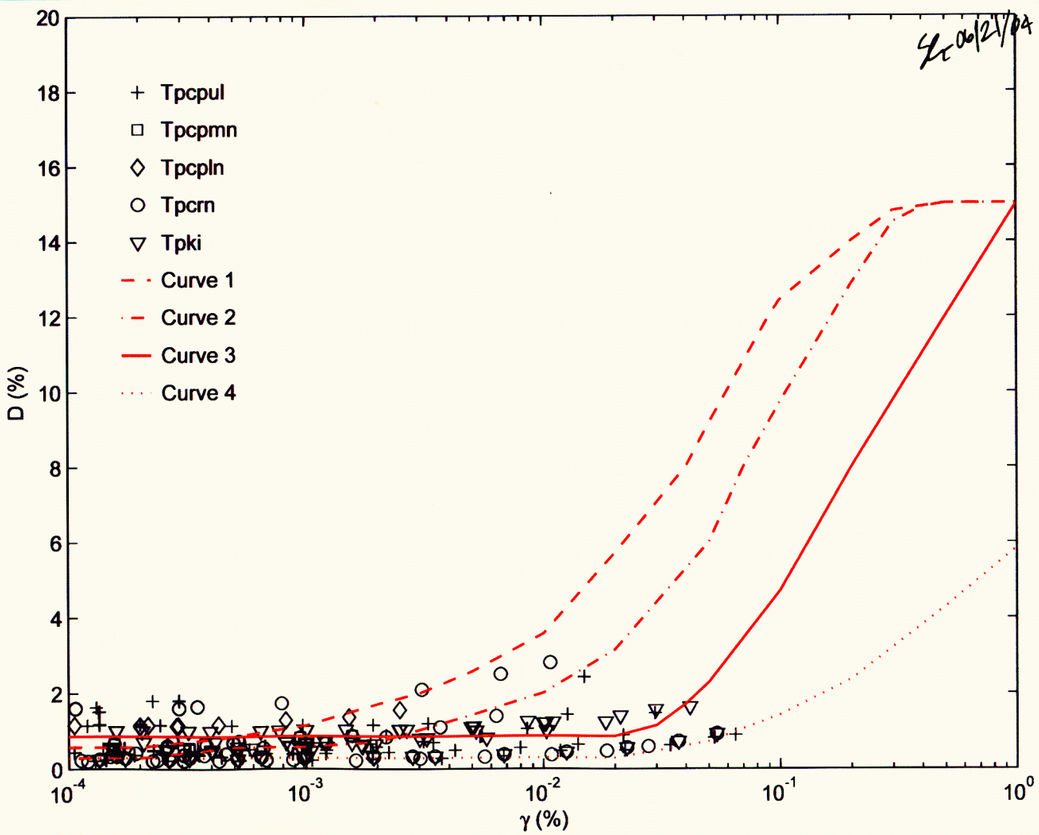

FIGURE 43. RANGE OF TUFF DAMPING CURVES USED FOR GROUND RESPONSE CALCULATIONS.

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Dynamic Material Property Inputs

The alluvium was assigned the average sand shear modulus reduction curve (Seed et al., 1986) shown in Figure 7 and average sand damping curve (Seed et al., 1986) shown in Figure 8. No distinctions were observed between dynamic data for the different tuff units. For this reason all tuff units were assigned identical modulus and damping curves. The various shear modulus and damping ratio curves used in the ground response modeling are shown in Figures 42 and 43 respectively. These curves represent only a select range of dynamic behavior that is possible within the observed tuff data set. These curves are based on the base case tuff curves which appear in the forthcoming DOE report entitled "Development of Earthquake Ground Motions For Preclosure Seismic Design and Postclosure Performance Assessment At Yucca Mountain, NV". We reviewed a draft of this report in the OR office in Las Vegas in January and April of 2004. Selected values were hand picked from the mean normalized shear modulus and material damping curves contained this report. These values are in the file ***curves.xls*** which is on the attached CD. These curves are shown in Figures 42 and 43 which were plotted in Matlab using the m-file ***tuff_curves***.m and is also on the attached CD.

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Results of the Ground Response Calculations

The results for ground response calculations are given by transfer functions, which are defined here as the ratio of the soil surface amplitude to the rock outcrop amplitude. Transfer functions for Models 1 to 5 are provided in Figure 44. Peak amplitudes and the corresponding frequency are also provided in Table 16. Models 1 to 5 consist of the V_s, density and thickness profiles of Figures 35 to 39 respectively. The average shear modulus and damping curves for sand (Seed et al, 1986) were used for the alluvium. All of the tuff units were assigned linear material properties with 2% damping. The results show that there is significant variability in ground amplification within the WHB Site. Generally peak amplitudes are within the range of 2.2 to 2.7 (with the exception of Model 4). However, the corresponding frequencies of these peak amplification factors range from 1.5 Hz to 4.3 Hz which may be significant.

Models 6, 7 and 8 have inputs that are identical to Model 1 (which based on profile 1 in Figure 35) with the exception of density. The density profiles used instead are those from Figure 41 which accentuate variations in the density within Tpki unit (tuff unit "x") and across the Tcpcpul/Tpcpmn interface. The results of these calculations are shown in Figure 45 and Table 17, and show little sensitivity to the modified density inputs. Results are very similar to those of Model 1. In comparison ground response calculations are very sensitive to V_s. Models 9, 10 and 11 have inputs that are also identical to Model 1 with the exception of V_s. The alternative V_s profiles from Figure 40, which accentuate variations across the Qal/Tmbt1 and Tcpcpul/Tpcpmn layer, are used instead of the mean values. The results of these calculations are shown in Figure 46 and Table 18. Amplification factors are significantly higher than Model 1.

Models 12 to 15 are identical to Model 1, with the exception of the tuff dynamic property inputs. The tuff units in Models 12 through 15 were assigned the shear modulus and damping Curves 1 (exhibits the most nonlinear behavior) through 4 (exhibits the most linear behavior) respectively (from Figures 42 and 43). The results are shown in Figure 47 and Table 19. Overall there is not a significant difference between results for the range of input curves. There is a small decrease in amplification, as more nonlinear dynamic property curves (i.e Curve 1 in Model 12) are used. As expected, this effect is most noticeable in the larger time history inputs Sylmar and Nocera, which produce the largest shear strains. The maximum strain levels were produced by the Sylmar record. In these ground response calculations, maximum strain levels generally fall below 0.2 % (ranging from 0.12% to 0.19 %). The maximum strain levels for the other records are significantly lower. At these lower strain levels the different modulus and damping curves (i.e. Curves 1 to 4) have similar values. The sensitivity of the ground response calculations to input dynamic property curves may be more apparent if larger ground motions are used, as strain levels may become large enough where the modulus and damping curves in Figures 42 and 43 diverge from one another. This needs further investigation.

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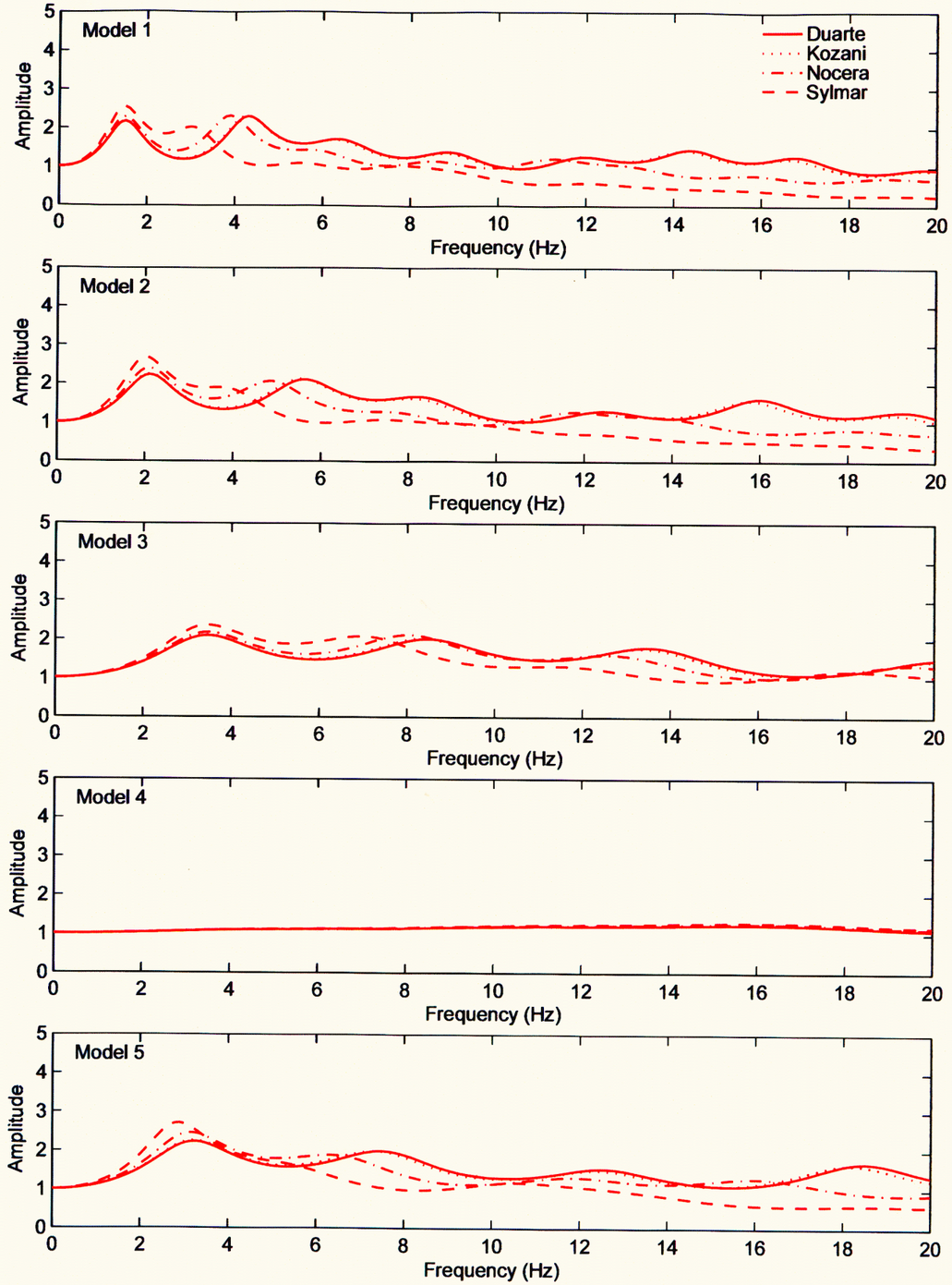


FIGURE 44. TRANSFER FUNCTIONS FOR MODELS 1 TO 5.

SL 06/21/04

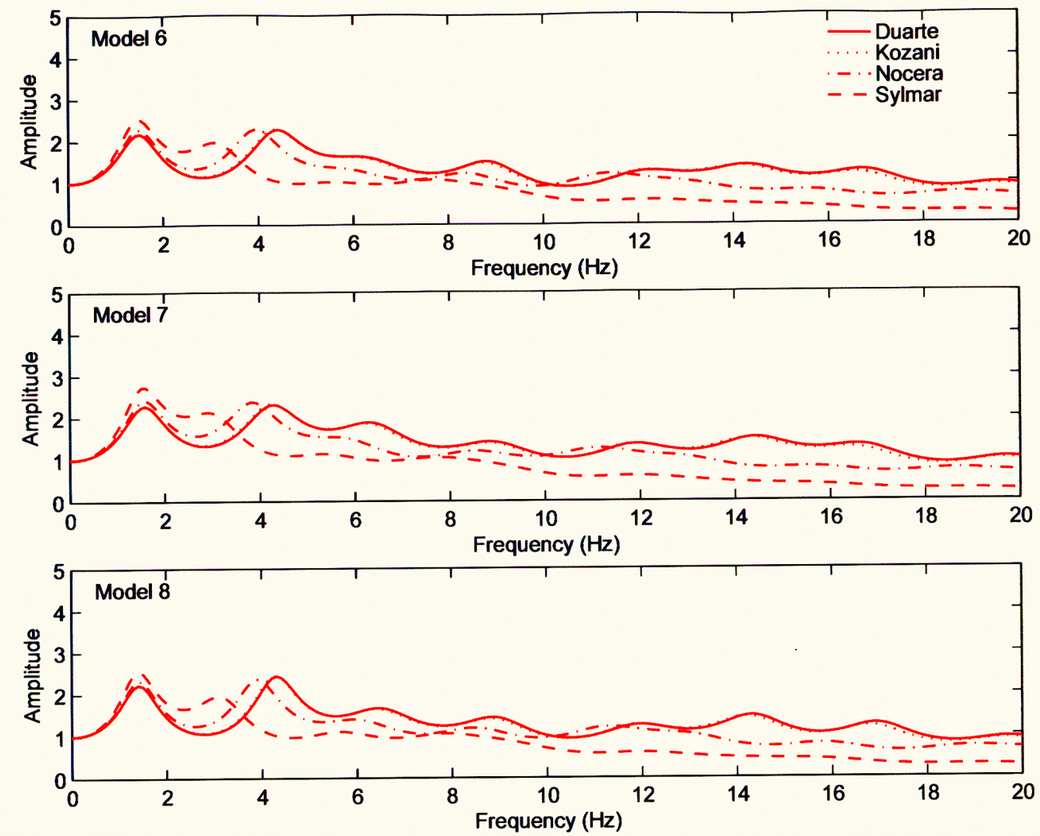
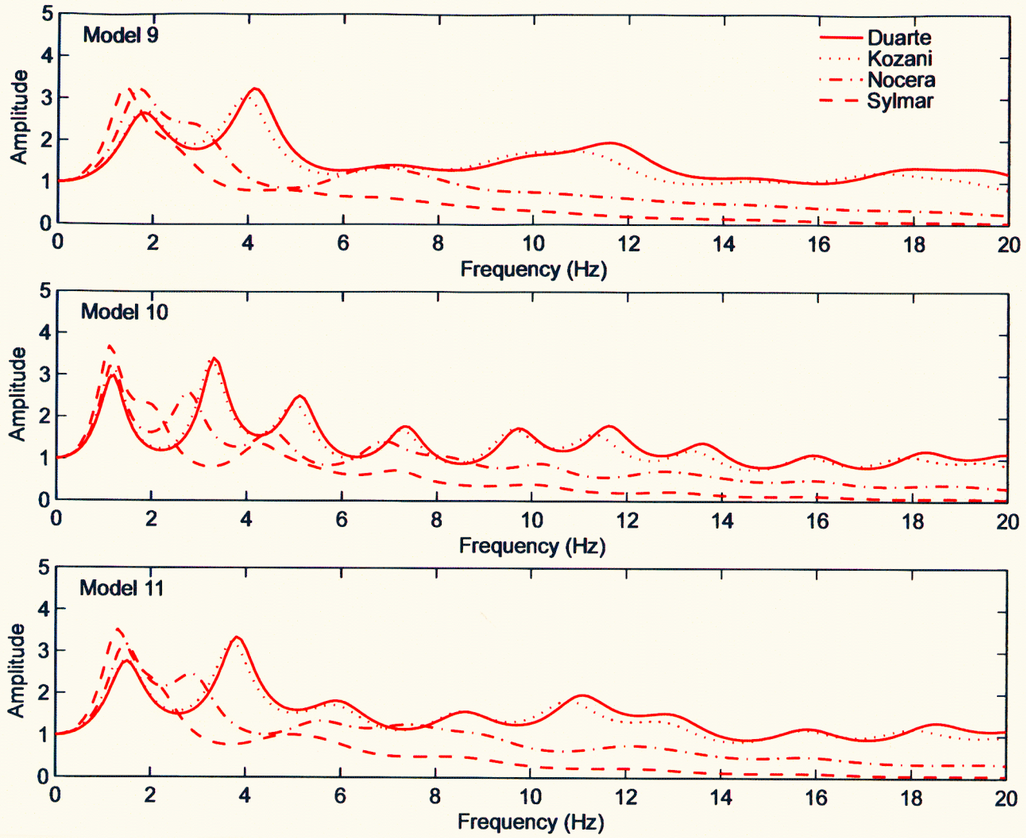


FIGURE 45. TRANSFER FUNCTIONS FOR MODELS 6 TO 8.

SL 06/21/04



SCT 06/21/04

FIGURE 46. TRANSFER FUNCTIONS FOR MODELS 9 TO 11.

SCT 06/21/04

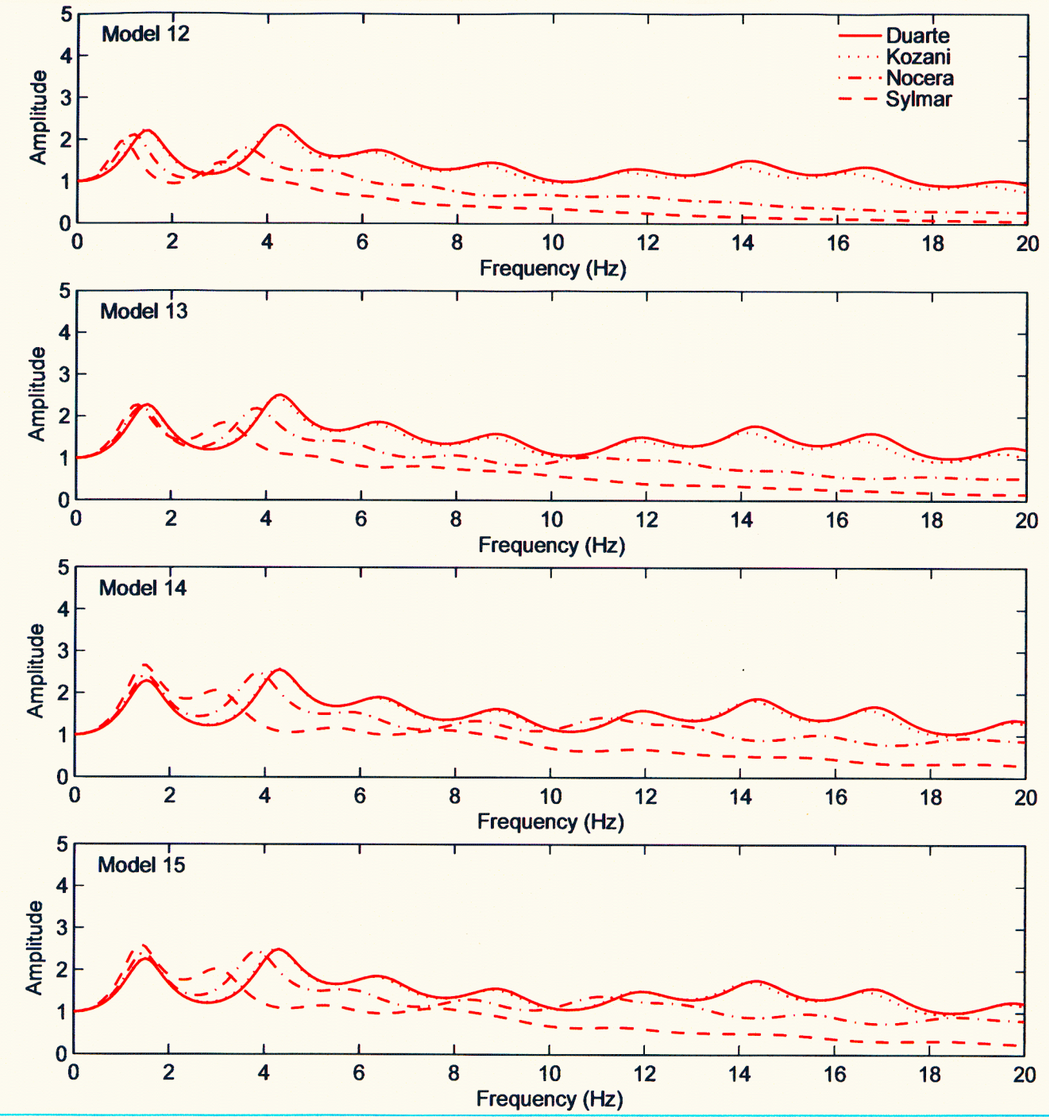


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FIGURE 47. TRANSFER FUNCTIONS FOR MODELS 12 TO 15.

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TABLE 16. MAXIMUM SPECTRAL AMPLIFICATION FACTORS FOR MODELS 1 TO 5.

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EQ Record	Model1		Model 2		Model 3		Model 4		Model 5	
	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)
Duarte	2.31	4.30	2.24	2.10	2.10	3.50	1.24	16.00	2.23	3.20
Kozani	2.33	4.30	2.26	2.10	2.11	3.50	1.25	16.00	2.26	3.20
Nocera	2.32	3.90	2.41	2.10	2.18	3.50	1.27	16.00	2.45	3.10
Sylmar	2.55	1.50	2.69	2.00	2.36	3.50	1.30	16.10	2.71	2.90

TABLE 17. MAXIMUM SPECTRAL AMPLIFICATION FACTORS FOR MODELS 6 TO 8.

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EQ Record	Model 6		Model 7		Model 8	
	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)
Duarte	2.27	4.40	2.31	4.30	2.44	4.30
Kozani	2.29	4.40	2.34	4.20	2.45	4.30
Nocera	2.29	1.50	2.42	1.60	2.36	3.90
Sylmar	2.54	1.50	2.73	1.50	2.55	1.40

TABLE 18. MAXIMUM SPECTRAL AMPLIFICATION FACTORS FOR MODELS 9 TO 11.

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EQ Record	Model 9		Model 10		Model 11	
	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)
Duarte	3.23	4.10	3.41	3.30	3.34	3.80
Kozani	3.04	3.90	3.33	3.30	3.24	3.70
Nocera	3.23	1.70	3.22	1.20	3.16	1.50
Sylmar	3.28	1.40	3.68	1.10	3.52	1.30

TABLE 19. MAXIMUM SPECTRAL AMPLIFICATION FACTORS FOR MODELS 12 TO 15.

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EQ Record	Model 12		Model 13		Model 14		Model 15	
	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)	SAF_{max}	f (Hz)
Duarte	2.34	4.20	2.51	4.30	2.56	4.30	2.50	4.30
Kozani	2.27	4.20	2.45	4.20	2.57	4.30	2.51	4.30
Nocera	2.11	1.20	2.21	1.40	2.48	3.80	2.45	3.80
Sylmar	1.97	1.00	2.26	1.30	2.65	1.40	2.61	1.40

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References

BSC (Bechtel SAIC Company) 2002. Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analyses for the Yucca Mountain Site Characterization Project. ANL-MGR-GE-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020923.0175.

EduPro Civil Systems, 2001. ProShake. Version 1.11. Sammamish, WA.

Idriss, I.M. and Seed, H.B. 1968. "Seismic Response of Horizontal Soil Layers." Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 94, No. SM4,July.

Schnabel, P.B., Lysmer, J. And Seed, H.B. 1972. "SHAKE: A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites", Report No. UCB/EERC-72/12, Earthquake Engineering Research Center, University of California, Berkeley, December, 102p.

Seed, H.B., Wong, R.T., Idriss, I.M., and Tokimatsu, k. 1986. "Moduli and damping factors for dynamic analysis of cohesionless soils." Journal of Geotechnical Engineering, ASCE, Vol. 112, No. 11, pp. 1016-1032.

Stepp, J.C., Wong, I., Whitney, J., Quittmeyer, R., Abrahamson, N., Toro, G., Youngs, R., Coppersmith, K., Savy, J., Sullivan, T. and Yucca Mountain PSHA Project Members. 2001. "Probabilistic Seismic Hazard Analyses for Ground Motions and Fault Displacement at Yucca Mountain, Nevada." Earthquake Spectra, Vol. 17, No. 1, pp. 113-151.

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Additional Notes

Figures 33 and 34 were plotted in Matlab using the m-file ***plot_input.m*** which is on the attached CD in the directory ***Model 1***. The transfer functions shown in Figure 44 to 47 were also plotted in Matlab using the m-file ***plot_output.m***. In addition, this m-file saves the maximum amplification factors which are given in Table 16 to 19.

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ENTRY: SARAH GONZALEZ

DATE: 06/22/2004

LIST OF FILES ON ATTACHED CD

THE FILES LISTED IN THIS SCIENTIFIC NOTEBOOK ARE CONTAINED ON THE CD ATTACHED TO THE BACK COVER. TABLE 20 ALSO PROVIDES A LIST OF THESE FILES.

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TABLE 20. LIST OF FILES CONTAINED ON ATTACHED CD.

DIRECTORY NAME	FILE NAME	FILE DESCRIPTION
	Velocity_Density_Profile_data.xls	This Excel spreadsheet file contains subset of velocity and density data from the geotechnical report plus statistical analyses of the data and inputs to the profiles developed for sensitivity studies.
	Geotech_data_evaluation.QDA	Kaleidagraph data file containing statistical data - VS, VP, density, impedance, and unit thickness that were derived from the the Excel file Velocity_Denisty_Profile_data.xls.
	Density_Velocity_aafo_depth	Kaleidagraph plot file in which Vs and Density are plotted as a function of depth.
	tuff_RC.xls	Tuff data obtained from RC testing. Sheet 2 gives normalized shear modulus data for each test specimen (in columns). Corresponding shear strain values are given in Sheet 1.Sheet 4 gives damping data for each test specimen (in columns). Sheet 3 gives the corresponding strain values.
	tuff_TS1.xls	Tuff data obtained from TS testing (1st cycle). Data format is identical to tuff_RC.xls.
	tuff_TS10.xls	Tuff data obtained from TS testing (10th cycle). Data format is identical to tuff_RC.xls.
	alluv_RC.xls	Alluvial data obtained from RC testing. Data format is identical to tuff_RC.xls.
	alluv_TS1.xls	Alluvial data obtained from TS testing (1st cycle). Data format is identical to tuff_RC.xls.
	alluv_TS10.xls	Alluvial data obtained from TS testing (10th cycle). Data format is identical to tuff_RC.xls.
	standard_rock.xls	Excel spreadsheet containing standard sand rock shear modulus and damping curve data (from ProShake curve library)
	standard_sand.xls	Excel spreadsheet containing standard sand shear modulus and damping curve data (from Seed et al., 1986). Sheets 1, 2 and 3 give the sand lower bound, average and upper bound curves respectively.
	tuff.m	Matlab m-file to plot tuff data
	alluv.m	Matlab m-file to plot alluvial data.
	tuff_curves.m	Matlab m-file to plot normalized shear modulus and damping curves for tuff data.
	curves.xls	Excel spreadsheet containing data for normalized shear modulus and damping curves for the tuff units.
	plot_output.m	Matlab m-file to plot ProShake output files (response spectra, shear stress versus depth and transfer function).
	plot_input.m	Matlab m-file to plot ProShake input time histories and response spectra (OUTPUT1.xls to OUTPUT4.xls and OUTPUT 5.xls)
	01.DAT	ProShake input file
	01.LYR	
	01.OUT	ProShake output files
	ProShake.GSP	
	DuarteH2.EQ	Input time history to ProShake program (referred to as input time history 1)
	KozaniH2.EQ	Input time history 2
	NoceraH2.EQ	Input time history 3
	SylmarH2.EQ	Input time history 4
	OUTPUT1.RAW and OUTPUT1.xls	Input time histories to ProShake program e.g. OUPUT1.RAW is identical to the input time history flies * .RAW were saved as excel
	OUTPUT2.RAW and OUTPUT2.xls	DuarteH2.EQ (input time history 1). Note: All ProShake output files * .RAW were saved as excel files with the same name.
	OUTPUT3.RAW and OUTPUT3.xls	
	OUTPUT4.RAW and OUTPUT4.xls	
Model 1	OUTPUT5.RAW and OUTPUT5.xls	Response spectra of input time histories (given as rock outcropping motions). Columns 1 and 2 give frequency (Hz) and spectral acceleration (g) respectively for input time history 1. Columns 3 and 4 give frequency (Hz) and spectral acceleration (g) respectively for input time history 2. Columns 5 and 6 give frequency (Hz) and spectral acceleration (g) respectively for input time history 3. Columns 7 and 8 give frequency (Hz) and spectral acceleration (g) respectively for input time history 4. These files are identical to the * .EQ files listed above.
	OUTPUT6.RAW and OUTPUT6.xls	Response spectra of output time histories. Columns 1 and 2 give frequency (Hz) and spectral acceleration (g) respectively for input time history 1 as a soil surface motion. Columns 3 and 4 give frequency (Hz) and spectral acceleration (g) respectively for input time history 1 as a bedrock outcropping motion. Columns 5 and 6 give frequency (Hz) and spectral acceleration (g) respectively for input time history 2 as a soil surface motion. Columns 7 and 8 give frequency (Hz) and spectral acceleration (g) respectively for input time history 2 as a bedrock outcropping motion. Columns 9 and 10 give frequency (Hz) and spectral acceleration (g) respectively for input time history 3 as a soil surface motion. Columns 11 and 12 give frequency (Hz) and spectral acceleration (g) respectively for input time history 3 as a bedrock outcropping motion. Columns 13 and 14 give frequency (Hz) and spectral acceleration (g) respectively for input time history 4 as a soil surface motion. Columns 15 and 16 give frequency (Hz) and spectral acceleration (g) respectively for input time history 4 as a bedrock outcropping motion.
	OUTPUT7.RAW and OUTPUT7.xls	Maximum shear strain versus depth. Columns 1 and 2 give % strain and depth (ft) respectively for input time history 1. Columns 3 and 4 give % strain and depth (ft) respectively for input time history 2. Columns 5 and 6 % strain and depth (ft) respectively for input time history 3. Columns 7 and 8 give % strain and depth (ft) respectively for input time history 4.
	OUTPUT8.RAW and OUTPUT8.xls	Effective shear strain versus depth. The file format is identical to OUTPUT7.RAW
	OUTPUT9.RAW and OUTPUT9.xls	Transfer functions. Columns 1 and 2 give frequency (Hz) and amplitude respectively for input time history 1. Columns 3 and 4 give frequency (Hz) and amplitude respectively for input time history 2. Columns 5 and 6 frequency (Hz) and amplitude respectively for input time history 3. Columns 7 and 8 give frequency (Hz) and amplitude respectively for input time history 4.
	SAF.xls	Excel spreadsheet of transfer function data. This file contains the same data as OUTPUT9.RAW and OUTPUT9.xls. Rows 2 to 5 are the transfer function values for input time histories 1 to 4 respectively and row 1 contains the corresponding frequency values.
	maxSAF.xls	Excel spreadsheet containing the maximum spectral amplification factors and corresponding frequency values. Rows 1 to 4 correspond to input time histories 1 to 4.
	02.DAT	ProShake input file
	02.LYR	
	02.OUT	ProShake output files
	ProShake.GSP	
	DuarteH2.EQ	Input time history 1
	KozaniH2.EQ	Input time history 2
	NoceraH2.EQ	Input time history 3
	SylmarH2.EQ	Input time history 4
Model 2	OUTPUT6.RAW and OUTPUT6.xls	Response spectra of output time histories
	OUTPUT7.RAW and OUTPUT7.xls	Maximum shear strain versus depth
	OUTPUT8.RAW and OUTPUT8.xls	Effective shear strain versus depth
	OUTPUT9.RAW and OUTPUT9.xls	Transfer functions
	SAF.xls	Excel spreadsheet of transfer function data. This file contains the same data as OUTPUT9.RAW and OUTPUT9.xls. Rows 2 to 5 are the transfer function values for input time histories 1 to 4 respectively and row 1 contains the corresponding frequency values.
	maxSAF.xls	Excel spreadsheet containing the maximum spectral amplification factors and corresponding frequency values. Rows 1 to 4 correspond to input time histories 1 to 4.
Model 3	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 4	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 5	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 6	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 7	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 8	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 9	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 10	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 11	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 12	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 13	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 14	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.
Model 15	Contains same files as Model 2 except *.DAT, *.LYR and *.OUT files are specific to directory name.	Same descriptions as files in the directory *Model 2*.

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I have reviewed scientific notebook 644 and find it in compliance with QAP-001. There is sufficient information regarding procedure used for conducting the research and acquiring and analyzing the data so that another qualified scientist could repeat the activity or activities recorded in this scientific notebook

H. Lawrence McKague 04/05/05

H. Lawrence McKague
GLGP Element Manager

ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK NO. 644

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Remarks: (computer runs, etc.)	Media contains the electronic data for Tests 1–18 files.