Title:

TUFF PILE 1 - A JUSTIFICATION OF THE PROJECTION OF MATERIAL PROPERTIES WITHIN A PORTION OF LOS ALAMOS TEST AREAS 1, 3, 4 AND 7 - NEVADA TEST SITE

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Preamble

This report was originally issued as Los Alamos Containment Program internal document EES-CPO-83-22 in November of 1983. The work was in support of the Department of Energy Underground Nuclear Test Program. The "Tuff Pile" concept was first presented to the DOE Containment Evaluation Panel (CEP) at the Dec. 1983 containment presentation of the Los Alamos TORTUGAS underground test. The document was included as an unclassified attachment to the TORTUGAS containment prospectus. The "Tuff Pile" approach for determining geologic material properties for certain proposed underground test sites was accepted by the CEP at that meeting, and it continues as an acceptable approach for properties determination to the present time. As part of the Los Alamos weapons archiving effort, the document is being published as an LA-UR report, the main body of which is essentially unchanged from the original.

TUFF PILE 1

APPENDIX C

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TUFF PILE 1 - A Justification for the Projection of Material Properties Within a Portion of Los Alamos Test Area 1, 3, 4 and 7.

INTRODUCTION

The Los Alamos underground nuclear test area which is located west of the Yucca fault and north of Nevada state coordinate N256000 m has been used for testing since 1964. The area encompasses parts of Areas 1, 3, 4 and 7. All of the 25 events conducted in the area have been successfully contained. As knowledge of the geology has improved with additional holes and geophysical surveys, it has become increasingly apparent that this is one of the least complex areas we have for testing outside of Area 3 alluvium. Particularly in the southern three quarters of the area, we found that as each new hole was drilled, the stratigraphy and physical properties encountered were as expected. We have never been surprised. This prompted us to formally evaluate a large portion of the area as a "Tuff Pile", a term borrowed from the Area 3 "Sandpile", and one that implies that physical properties in the area are sufficiently predictable that most measurements no longer need be routinely made for containment evaluation. This report is the result of that evaluation.

GENERAL DESCRIPTION OF AREA

The region outlined in Figure 1 is that which we have designated Tuff Pile 1. It is bounded on the east by the Yucca Fault and on the west by the Topgallant Fault system. Pictured are the boundaries at the surface. Because the faults dip to the east, the Tuff Pile boundaries similarly dip east. The location of the north boundary is somewhat arbitrary; however it is coincident with the southern extremity of an east-west trending Paleozoic (Pz) ridge. We made no attempt to incorporate the area to the north into Tuff Pile 1. We may extend the Tuff Pile into this area in the future. The location of the southern boundary is controlled by the southernmost drilling in this area. For cultural reasons, the area to the south has not been used for deep testing. Geologically, the area probably is acceptable for deep or shallow testing and it is a candidate for Tuff Pile 1 extension.

Tuff Pile 1 encompasses an area of about 8 square kilometers. The stratigraphic units are generally west dipping. Three seismic lines that cross the area from west

to east (see Figure 2) provide primary stratigraphic control to the west where holes are sparse. Also, the location of the Topgallant Fault system (west boundary of Tuff Pile 1) is fixed by the seismic surveys.

TUFF PILE CONCEPT

The purpose of declaring a Tuff Pile is to minimize the logging and sampling associated with a particular test. We intend to obtain only enough measurements to assure us and others in the containment community that there are no major anomalies in the immediate vicinity of a shot that could adversely affect containment. Thus, we intend to project physical properties, by stratigraphic unit, into the intervals of interest for all future emplacements in the area. Following are the guidelines we intend to follow with regard to Tuff Pile 1.

In order to qualify as a Tuff Pile hole, the hole and experiment must meet the following minimum criteria:

1. The hole must be located within the boundaries indicated in Figure 1. This does not mean that all real-estate within Tuff Pile 1 is usable for underground testing. It means only that we feel comfortable with properties projections within the Tuff Pile boundaries. Containment issues such as proximity to faults, Pz, etc. are beyond the scope of the Tuff Pile concept.
2. The WP must be located far enough below the tuff/alluvium interface so that there is no significant CO_2 gas generated from the alluvium. The current criteria of 3300 metric tons of rock per kiloton of explosive shall be used for calculating this distance. An analysis of CO_2 occurrence within the alluvium of Tuff Pile 1 has not been performed.
3. The WP must be within a stratigraphic sequence of beds that is well known by virtue of measurements made at other sites in the area.
4. The experiment must be of relatively "standard" design. An experiment such as one with a long, unblocked LOS pipe that requires in its containment design detailed knowledge of some specific physical or mechanical

property of the rock, may not qualify for Tuff Pile treatment. Because of the great number of possibilities, each "non-standard" event will be examined individually for Tuff Pile treatment.

We may amend any of the above requirements pending further investigation and subsequent approval by the containment community.

Guidelines concerning material properties projections and measurements are as follows:

1. As a minimum, caliper and electric (resistivity) logs will be run in each hole.
2. Bulk density, grain density, and water content will be projected from a data base of measurements from 16 holes in the area. Projections will be by stratigraphic unit.
3. Cuttings samples will be obtained and analyzed in a manner consistent with current Los Alamos practice in non-Tuff Pile holes.
4. Samples will be taken and analyzed if there are low resistivity zones within 2 max-cred cavity radii of the WP that cannot be stratigraphically correlated with similar zones in other holes. The same holds true if there are missing or unexplainable sections in the resistivity log.
5. Working point and overburden velocities will be computed from a geophone travel-time curve that represents the mean of all geophone surveys in the area.
6. If, upon drilling a new emplacement hole, we encounter a stratigraphic sequence that is not consistent with the current structural interpretation in the area, we will obtain and analyze a full suite of measurements for the site.

We will continue to prepare and present the usual structural and stratigraphic workups. The above procedures should in no way compromise our ability to recognize the stratigraphic sequence present in each hole.

TUFF PILE DATA BASE

Figure 2 is a map showing the locations of holes used in the Tuff Pile 1 analysis. It is drawn to the same scale as Figure 1. The 15 holes with stars are the holes from which physical properties are used for the data base. Eventually U7au also will be included. We encountered technical problems in getting the appropriate density log for this hole into a usable form for the Tuff Pile analysis. Its eventual inclusion should have very little impact on the overall statistics. The other holes without asterisks are exploratory holes that were not used in forming the data base because the standard physical properties of samples were not obtained from them, however they were used in the general evaluation of the area.

Tables 1a, 1b, 1c, 1d and 1e list the mean and standard deviation of the individual measurements, by stratigraphic unit, at each of the 15 data base holes. It also gives the calculated saturations, total porosities, and gas porosities along with their standard deviations. For each measured physical property, the number of samples, the mean value and the standard deviation of the measurements are listed from left to right. For calculated physical properties, only the mean values and standard deviations are listed. "Sampling point averages" refer to statistics determined from sidewall sampling points. "Log averages" are statistics from all points along the gamma-gamma bulk density log. Because there are no corresponding measured grain densities and water contents for many of the log densities, there are no calculated properties (porosity, saturation) to go along with them. Water contents are measured from sidewall samples above the water table and are calculated from grain and bulk densities below the water table, assuming 100% saturation. In this Tuff Pile 1 analysis, all bulk densities are taken from gamma-gamma density logs. All averages are straight linear averages of the data points, regardless of sample distribution within the stratigraphic units. This means that there can be some biasing of data, particularly toward the "softer" lithologies for the "sample point averages". This biasing has always been present to some degree; it is not unique to the current study. We doubt that such biasing occurs regularly in the Tunnel Beds Tuff (Tt), the Paintbrush tuff (Tp), or the alluvium (Qal). On occasion it may happen in the Ammonia Tanks Tuff (Tma) and is more likely in the Rainier Mesa tuff (Tmr). The Tmr has within it a strongly welded section that rarely can be sidewall sampled. Therefore, samples are obtained primarily from the "softer"

rocks in that unit. Normally, bulk density averaged from the log is the most representative value we have for a particular stratigraphic unit, and a discrepancy between it and the average obtained from discrete sampling points along the logged interval would suggest that there is a "bias". We emphasize that the limitations of sample data as described above have always been with us. They should be kept in mind when evaluating a site, and have no more impact on Tuff Pile sites than any other sites.

Listed in Table 2 are means and standard deviations for stratigraphic unit averages from all holes in the data base. Stratigraphic averages for each hole are treated as individual sample points and the standard deviations listed relate to hole to hole deviations. Values for each stratigraphic unit are used for projections into specified depth intervals of a "target" hole with known lithologic contact depths. Final interval averages are controlled by the relative thicknesses of the units within the interval.

Of particular interest in Table 2 are hole-to-hole deviations of properties by stratigraphic unit. They are small. The maximum standard deviation for grain density is found for the Tbg (0.04 Mg/m^3). The larger than normal deviation for Tbg probably is due to the small total number of samples obtained from that thin, discontinuous unit. The deviation listed for the Tma realistically reflects the variations observed for this unit from site to site. The degree of welding in the Tma varies in a systematic and predictable manner. A more representative number for the grain density standard deviation for all other units is 0.02 Mg/m^3 . For "log average" bulk density, the maximum standard deviation is 0.10 Mg/m^3 , in dry Qal and Tma. In deeper units, the deviation is closer to 0.05 Mg/m^3 . The maximum standard deviation in water content is 4 wt.%, in the Tbg below the water table and in the Tmr above the water table. A more representative standard deviation for rocks normally present within 1 to 2 cavity radii is 3 wt.% water. These are all very "tight" numbers which support our contention that there is very little variation in material properties from one site to another in Tuff Pile 1.

Interval velocities are handled differently from other physical properties. Figure 3 is a travel-time versus depth curve that represents the mean of all travel time curves in the area; we intend to calculate interval velocities from this curve. The two curves to either side of the "mean" curve are + and - 1 standard deviation. We

know that there are systematic variations in velocity within this area (velocities are higher toward the east), and we could have taken these variations into account in arriving at interval velocities at a given site, however all variations are well within containment experience and there was no compelling reason to fine tune the projected velocities.

Figures 4a and 4b are comparisons of density logs from data base holes. Note that U7au, the hole temporarily excluded from the statistical analyses, is included here because portions of the log are useful in the hole-to-hole comparisons. The logs are arranged along two separate, southerly trending lines (line C-C' and line D-D' in Figure 2) which roughly are along strike of the beds. There is excellent hole-to-hole correlation of the character of the logs. This in itself is strong justification for Tuff Pile 1. Just by knowing the stratigraphy at a particular site, we know how density varies with depth. Figure 5a and 5b are similarly arranged comparisons of resistivity logs. Once again, we see strikingly good hole-to-hole correlations. Importantly, the zones of low resistivity are thin and/or correlatable. Any clay contents $\geq 20\%$ measured in low resistivity zones are listed along side the log. In this area, many samples were analysed for clay. The highest clay content measured in this area is 35% at 380 m depth in hole U7au. The caliper logs are shown in Figures 6a and 6b. There is relatively little hole erosion in this area, the most being observed in hole U4j near the northern boundary of Tuff Pile 1. Use of water as drilling fluid is believed responsible for the slightly enhanced sloughing in that hole.

Figures 7 and 8 display logs (density, resistivity) for the deeper exploratory holes in the area (line E-E' in Figure 2). Ue3lj, the farthest south "deep" hole, looks very similar to other holes in the area. Hole Ue1q is very close to the Topgallant fault system. The basic character of the logs are similar to that of holes to the east. We intend to project properties as far west as Ue1q. Ue4c is west of the Topgallant fault system and therefore is outside of Tuff Pile 1. Some aspects of the logs are still correlatable, but the correlations are not as straightforward as they are within the Tuff Pile. We will not project properties this far. Keep in mind that the west boundary of the Tuff Pile (the Topgallant fault) dips east. We will not cross the fault with properties projections.

As a check on how close we can come to the measured property values with projections, we performed a projection into the max-cred cavity regions of each of the 15 holes that form the data base. We did not use the measured values from each "target" hole in the data averages so as not to bias the data averages with that hole's own measurements. Figure 9a is a bar chart comparison of "sampling point" bulk densities for the measured versus projected values. In general, the projected values track well with the measurements. Figure 9b is a statistical representation of the same data. It is an X-Y plot of measured versus projected values. Because there is a one-to-one functional relationship between the two sets of values, the plotted values should scatter about the 45 degree line, the one labeled functional model in Figure 9b. The premise behind the projection scheme is that the variability in physical properties from site to site for each stratigraphic unit is less than the variability from one stratigraphic unit to another. There is the suggestion from Table 2 that this is true, however, the "measured versus projected" plots provide some additional evidence for this. The light solid line in Figure 9b is the least squares fit to the data. Note that the two solid lines (the least squares fit and the functional model) are not exactly coincident, but they are close. The implication is that our basic premise is valid. The scatter about the 45 degree line probably is primarily due to measurement errors. One standard deviation of the points about this line is about 0.07 Mg/m^3 (3.6%), a value close to what is often thought to be the analytical error associated with bulk density measurements. The correlation coefficient is the proportion of the total variation explained by the least squares fit. The 0.89 value obtained for bulk density suggests that our projection scheme is effective for predicting bulk densities.

There are 3 outliers in Figure 9b that deserve special comment. These are U3gg, U3lj, and U3gv. At U3gg, the entire density log produces densities that are higher than the Tuff Pile 1 averages, from the Qal on down. The higher density is not confined to the cavity region. We have no geologically plausible reason for this and therefore suspect that there is a "bias" to the log. We believe that the projected properties for U3gg are closer to reality than the measured values. At U3lj the cavity region is primarily within the Tma. The Tma at U3lj is less dense than the Tuff Pile 1 average, so in this instance the measured properties provide the best representation of the cavity region. Note however, that we are discussing a difference of just 0.08 Mg/m^3 . At U3gv, a substantial portion of the cavity is within the Tmr. This means that there is a "bias" in the sample data toward the

softer rocks at the site. The projected values are more representative of actual conditions at this site than are the measurements, however, neither value is as representative as is the "log averaged" bulk density shown in Figures 10a and 10b. In Figures 10a and 10b, U3gv no longer is an outlier and the values are more representative of the cavity region because the data is not biased toward the softer parts of the Tmr. In Figure 10b, the least squares fit lies very close to the 45 degree line. U3gg and U3lj remain outliers for the aforementioned reasons. Figure 11a and 11b show projected versus measured grain densities. Within Tuff Pile 1, the total variation in grain density is very small. The X-Y plot of measured versus projected values (Figure 11b) is a scatter plot. There is no good linear relationship between measured and projected values, meaning that the variability in grain density between stratigraphic units is no greater than the variability from hole to hole. The stratigraphic projection scheme breaks down in this instance, however, because the overall variability of grain density throughout Tuff Pile 1 is so small, the method of projection is relatively unimportant. The use of a single mean value of grain density for all stratigraphic units at all holes would be acceptable. The scatter about the mean is probably due to a combination of measurement error and slight variations in grain density from site to site. Figures 12a and 12b are projected versus measured plots for water content and Figures 13a and 13b are similar plots for total porosity. For convenience, in these plots we refer to calculated values such as porosity and water content below the water table as measured, in the sense that they are calculated from measurements made in the "target" hole. Because most of the water contents, and all of the porosities, are calculated from grain and bulk density, the deviations and trends noted for these properties are related to the deviations and trends observed in Figure 9a, 9b, 11a and 11b. It appears that the functional model (stratigraphic projection algorithm) accounts for over half of the total variation observed in water content throughout the area and about one-half of the observed variations in porosity.

Overall, we believe that the projection scheme used is useful for predicting properties within Tuff Pile 1 and that the deviations between measured and projected values are small enough to justify the use of such projections in lieu of measurements. In fact, we believe that in many instances, the projected values more accurately represent the true properties at a site because the influence of individual measurement errors is reduced.

STRUCTURE

From the foregoing analysis, it is evident that material properties do not vary much within this region. Part of the reason for this uniformity is that the region is structurally uncomplicated. Figures 14 through 17 are structure contour maps of the top of the Tma, Tmr, Tp, and Tt, respectively. The depths are referenced to an elevation datum of 4100 ft. (note: For convenience, feet were used instead of meters in constructing the contour maps). To eliminate clutter, the hole names are not identified on the map, but the maps are drawn to the same scale as all other maps in the report. Depth below the reference datum (in feet) is given beside each hole. In the eastern and central portions of the region, contours are based on stratigraphic tags, supplemented by the seismic data. To the west, where holes are sparse, contours are based primarily upon the seismic surveys. Seismic record quality in this area is fair to good. The data are usable throughout the area. The main conclusions we draw from the seismic data are that there are no major fault systems that cut the shallow tuff section (Tp and above) within Tuff Pile 1, and that the Topgallant fault system extends no farther east than indicated on the maps. There very well could be numerous "minor" faults (less than 25 m displacement) in the region that are not discernable on the seismic sections. There is some faulting evident in the seismics in the vicinity of holes U4j, U4f, and Ue7f that we chose not to show on the structure contour maps because we know nothing about their orientation. The fact that the maps can be contoured smoothly without resorting to faults (discontinuous contours) suggests that the faults are of relatively small displacement. Experience shows that these faults are insignificant to containment.

Because the region is structurally uncomplicated, we believe that we are justified in extending the Tuff Pile as far west as shown. We do not expect any localized anomalies in physical properties due to structure in this area. The holes in the extreme south (U3lj, U3gv, U3lo) are quite shallow, but the stratigraphic sequence that is penetrated in these holes fits very well with the rest of this west-dipping structural block.

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SUMMARY

Los Alamos believes that there is sufficient justification for using material properties projections in lieu of measurements within the defined Tuff Pile 1 region. The two measurements that we will continue taking (resistivity, caliper), along with continued analysis of cuttings for lithology, are sufficient to alert us to any anomalous situation that requires additional measurements and study. If the concept of Tuff Pile 1 is approved by the containment community, Los Alamos intends to implement a program of reduced properties measurements in the area.

Figure 1: Tuff Pile Boundaries

TUFF PILE 1

GENERAL LOCATION MAP

Table 1a

U7ap - Above Water Table

SAMPLING POINT AVERAGES															LOG AVERAGES			
	Grain Density			Bulk Density			% Water			Porosity		Gas Porosity		Saturation		Bulk Density		
Qal	6	2.54	0.05	3	1.57	0.07	6	13.2	3.	0.464	0.032	0.257	0.045	0.447	0.093	10	1.60	0.13
Tma	5	2.48	0.05	3	1.90	0.41	5	11.9	2.	0.328	0.146	0.103	0.195	0.687	0.463	18	1.83	0.34
Tmr	6	2.44	0.05	6	1.88	0.16	6	16.4	5.	0.358	0.068	0.050	0.099	0.859	0.267	45	1.82	0.21
Tp	8	2.46	0.03	8	1.79	0.09	8	18.1	4.	0.404	0.040	0.079	0.060	0.805	0.146	49	1.83	0.09
Tbg	0	0.00	0.00	0	0.00	0.00	0	0.0	0.	0.000	0.000	0.000	0.000	0.000	0.000	1	1.78	0.00
Ttu	12	2.44	0.04	12	1.92	0.10	11	20.1	4.	0.370	0.045	-0.017	0.068	1.045	0.184	25	1.89	0.08

U7ap - Below Water Table

SAMPLING POINT AVERAGES											LOG AVERAGES		
Grain Density		Bulk Density		% Water		Porosity					Bulk Density		
Ttu	34	2.51	0.06	19	2.00	0.08	17.0	4.	0.340	0.051	22	1.95	0.08

U7br - Above Water Table

SAMPLING POINT AVERAGES														LOG AVERAGES														
	Grain Density				Bulk Density				% Water				Porosity				Gas Porosity				Saturation				Bulk Density			
Qal	2	2.50	0.10		2	1.92	0.02		2	11.3	2.		0.319	0.032		0.101	0.037		0.681	0.107		53	1.79	0.12				
Tma	2	2.47	0.03		2	1.61	0.13		2	14.2	4.		0.440	0.053		0.211	0.075		0.521	0.145		71	1.56	0.11				
Tmr	7	2.46	0.05		7	1.63	0.27		7	14.4	2.		0.431	0.096		0.195	0.136		0.546	0.219		235	1.70	0.26				
Tp	12	2.48	0.06		8	1.64	0.12		12	20.4	2.		0.475	0.042		0.140	0.066		0.705	0.121		244	1.65	0.12				
Ttu	4	2.44	0.04		2	1.77	0.00		4	23.6	4.		0.445	0.029		0.027	0.041		0.940	0.096		46	1.78	0.06				

U7br - Below Water Table

SAMPLING POINT AVERAGES										LOG AVERAGES			
Grain Density		Bulk Density		% Water		Porosity		Bulk Density					
Ttu	31	2.45	0.09	31	1.93	0.06	18.7	4.	0.360	0.070	144	1.93	0.08

U7ba - Above Water Table

SAMPLING POINT AVERAGES															LOG AVERAGES			
	Grain Density			Bulk Density			% Water			Porosity		Gas Porosity		Saturation		Bulk Density		
Qal	3	2.50	0.05	1	1.61	0.00	3	14.2	1.	0.446	0.011	0.216	0.013	0.515	0.026	38	1.77	0.17
Tma	2	2.43	0.00	2	1.50	0.13	2	15.3	1.	0.478	0.046	0.249	0.066	0.480	0.089	57	1.55	0.09
Tmr	7	2.44	0.04	7	1.81	0.40	7	13.9	4.	0.360	0.144	0.108	0.201	0.699	0.452	199	1.90	0.39
Tp	19	2.47	0.03	18	1.93	0.17	19	17.6	3.	0.355	0.061	0.016	0.092	0.955	0.254	290	1.92	0.16
Ttu	13	2.45	0.03	12	1.96	0.07	13	18.9	3.	0.350	0.035	-0.022	0.052	1.064	0.149	53	1.94	0.07

U7ba - Below Water Table

SAMPLING POINT AVERAGES											LOG AVERAGES		
Grain Density			Bulk Density			% Water		Porosity			Bulk Density		
Ttu	26	2.46 0.03	24	2.00 0.10		15.6	4.	0.313	0.021		100	1.99	0.10

U7av - Above Water Table

SAMPLING POINT AVERAGES														LOG AVERAGES				
	Grain Density			Bulk Density			% Water		Porosity		Gas Porosity		Saturation		Bulk Density			
Qal	4	2.53	0.03	4	1.83	0.12	4	11.9	1.	0.363	0.045	0.145	0.060	0.601	0.125	79	1.83	0.09
Tma	4	2.50	0.07	4	1.72	0.12	4	13.3	1.	0.404	0.046	0.176	0.061	0.564	0.108	85	1.72	0.14
Tmr	7	2.46	0.04	7	1.75	0.26	7	14.3	3.	0.391	0.095	0.140	0.134	0.643	0.271	268	1.86	0.27
Tp	12	2.47	0.06	12	1.88	0.12	12	18.0	4.	0.375	0.051	0.037	0.076	0.901	0.197	241	1.84	0.12

U7av - Below Water Table

SAMPLING POINT AVERAGES											LOG AVERAGES	
Grain Density			Bulk Density			% Water		Porosity		Bulk Density		
Ttu	20	2.47 0.03	20	1.92 0.07		19.6	3.	0.376	0.028	132	1.91	0.07

U7an - Above Water Table

SAMPLING POINT AVERAGES														LOG AVERAGES				
	Grain Density			Bulk Density			% Water		Porosity		Gas Porosity		Saturation		Bulk Density			
Qal	4	2.52	0.02	3	1.59	0.05	4	13.5	2.	0.452	0.020	0.237	0.028	0.475	0.057	55	1.65	0.09
Tma	11	2.50	0.06	9	1.52	0.12	11	15.2	4.	0.486	0.047	0.256	0.067	0.474	0.119	63	1.61	0.15
Tmr	7	2.42	0.02	6	1.64	0.20	7	16.8	3.	0.437	0.072	0.163	0.107	0.628	0.197	213	1.82	0.31
Tp	11	2.46	0.04	8	1.84	0.11	11	21.1	4.	0.411	0.048	0.024	0.074	0.942	0.180	234	1.85	0.11

U7an - Below Water Table

SAMPLING POINT AVERAGES											LOG AVERAGES		
Grain Density			Bulk Density			% Water		Porosity		Bulk Density			
Tp	0	0.00	0.00	0	0.00	0.00	0.0	0.	0.000	0.000	4 1.90 0.02		
Tbg	2	2.44	0.01	2	1.75	0.02	27.0	1.	0.474	0.006	13 1.78 0.04		
Ttu	42	2.45	0.03	36	1.87	0.06	21.7	3.	0.404	0.025	425 1.95 0.11		

U7bu - Above Water Table

SAMPLING POINT AVERAGES														LDG AVERAGES									
	Grain Density				Bulk Density				% Water				Porosity		Gas Porosity		Saturation		Bulk Density				
Qal	9	2.51	0.04		9	1.84	0.11		9	12.3	1.		0.359	0.042		0.132	0.056		0.631	0.121	219	1.85	0.13
Tma	3	2.51	0.06		3	1.61	0.09		3	14.0	1.		0.448	0.033		0.222	0.044		0.505	0.066	124	1.72	0.21
Tmr	5	2.44	0.05		5	1.56	0.04		5	15.9	2.		0.462	0.022		0.215	0.030		0.535	0.067	240	1.80	0.27
Tp	22	2.45	0.05		20	1.74	0.12		22	21.7	4.		0.443	0.050		0.064	0.079		0.855	0.174	100	1.79	0.12

U7bu - Below Water Table

SAMPLING POINT AVERAGES											LOG AVERAGES			
	Grain Density			Bulk Density			% Water		Porosity			Bulk Density		
Tp	26	2.47	0.06	23	1.86	0.10	22.3	6.	0.415	0.047		98	1.89	0.13
Tbg	3	2.46	0.06	3	1.86	0.07	22.3	4.	0.413	0.048		12	1.84	0.07
Ttu	1	2.51	0.00	1	1.88	0.00	22.3	0.	0.418	0.000		2	1.85	0.04

Table 1c

U31a - Above Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation	Bulk Density
Da1	10 2.54 0.03	10 1.81 0.09	10 10.8 4.	0.365 0.043	0.169 0.060	0.537 0.166	219 1.83 0.11
Tma	4 2.51 0.07	4 1.74 0.30	4 10.8 3.	0.380 0.110	0.192 0.143	0.496 0.249	120 1.69 0.23
Tmr	7 2.44 0.05	7 1.75 0.32	7 13.6 3.	0.381 0.115	0.143 0.160	0.625 0.317	246 1.90 0.26
TP	8 2.46 0.03	8 1.89 0.06	8 18.1 2.	0.370 0.025	0.029 0.037	0.923 0.099	131 1.85 0.09

U31a - Below Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Bulk Density
TP	29 2.47 0.06	23 1.88 0.13	21.4 6.	0.402 0.046	132 1.88 0.12
Tbg	3 2.44 0.03	3 1.91 0.12	19.6 6.	0.373 0.026	15 1.91 0.09
Ttu	21 2.46 0.06	19 1.90 0.07	20.0 4.	0.381 0.050	92 1.90 0.07

U3gg - Above Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation	Bulk Density
Da1	10 2.51 0.04	10 1.93 0.08	10 11.9 2.	0.322 0.032	0.092 0.044	0.714 0.125	1036 1.96 0.11
Tma	4 2.49 0.06	4 1.77 0.16	4 12.2 2.	0.375 0.061	0.158 0.081	0.579 0.164	572 1.79 0.16
Tmr	2 2.45 0.06	2 1.62 0.02	2 16.0 1.	0.443 0.018	0.184 0.022	0.585 0.044	911 1.92 0.30
TP	4 2.50 0.05	3 1.89 0.10	4 16.8 3.	0.369 0.040	0.051 0.059	0.862 0.153	233 1.94 0.09

U3gg - Below Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Bulk Density
TP	47 2.45 0.06	40 1.98 0.10	16.3 5.	0.323 0.052	758 1.98 0.11
Ttu	4 2.49 0.02	2 2.10 0.01	12.3 1.	0.259 0.019	24 2.08 0.04

U31o - Above Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation	Bulk Density
Da1	16 2.54 0.05	15 1.66 0.39	16 12.5 2.	0.428 0.135	0.220 0.184	0.486 0.273	247 1.88 0.23
Tma	24 2.45 0.03	24 1.67 0.06	24 14.4 1.	0.419 0.022	0.179 0.030	0.573 0.057	114 1.67 0.08
Tmr	2 2.42 0.02	0 0.00 0.00	2 30.1 1.	1.000 0.000	1.000 0.000	0.000 0.000	0 0.00 0.00

U4j - Above Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation	Bulk Density
Da1	13 2.54 0.04	12 1.86 0.17	13 10.8 2.	0.346 0.062	0.145 0.082	0.582 0.176	259 1.92 0.16
Tma	3 2.42 0.01	3 1.75 0.09	3 13.1 1.	0.371 0.034	0.143 0.047	0.616 0.100	79 1.69 0.08
Tmr	5 2.48 0.09	5 1.75 0.31	5 19.5 7.	0.430 0.114	0.087 0.178	0.796 0.383	213 1.94 0.30
TP	8 2.44 0.03	8 1.88 0.11	8 20.8 4.	0.389 0.047	-0.002 0.073	1.005 0.187	118 1.88 0.14

U4j - Below Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Bulk Density
TP	9 2.47 0.05	8 1.82 0.14	24.2 7.	0.441 0.042	27 1.82 0.16
Tbg	1 2.37 0.00	0 0.00 0.00	0.0 0.	1.730 0.000	0 0.00 0.00
Ttu	29 2.48 0.05	19 1.98 0.11	17.2 5.	0.340 0.040	84 2.02 0.11

U4f - Above Water Table

SAMPLING POINT AVERAGES														LOG AVERAGES				
	Grain Density			Bulk Density			% Water		Porosity		Gas Porosity		Saturation		Bulk Density			
Qa1	17	2.54	0.04	17	1.83	0.08	17	11.4	1.	0.361	0.032	0.151	0.042	0.581	0.090	377	1.25	0.08
Tma	3	2.43	0.01	3	1.55	0.05	3	11.6	1.	0.437	0.020	0.257	0.027	0.411	0.042	77	1.56	0.06
Tmr	5	2.47	0.06	5	1.78	0.23	5	14.8	6.	0.385	0.093	0.121	0.133	0.686	0.315	204	1.89	0.23
Tp	2	2.48	0.04	1	1.80	0.00	2	19.7	6.	0.417	0.046	0.064	0.067	0.847	0.177	37	1.79	0.09

U4f - Below Water Table

SAMPLING POINT AVERAGES											LOG AVERAGES
	Grain Density		Bulk Density		% Water		Porosity				Bulk Density
Tp	31 2.47 0.06	30	1.82 0.14		24.2 8.	0.441 0.050					198 1.82 0.13
Tbg	3 2.49 0.01	3	1.80 0.03		25.9 2.	0.465 0.004					25 1.81 0.06
Ttu	14 2.53 0.04	11	1.96 0.09		18.7 4.	0.368 0.033					59 1.95 0.08

U4r - Above Water Table

SAMPLING POINT AVERAGES												LOG AVERAGES						
	Grain Density			Bulk Density			% Water			Porosity		Gas Porosity		Saturation		Bulk Density		
Qa1	17	2.55	0.04	17	1.96	0.10	17	11.2	2.	0.317	0.041	0.098	0.054	0.691	0.144	400	1.96	0.13
Tma	2	2.42	0.00	2	1.72	0.03	2	13.8	0.	0.386	0.010	0.149	0.014	0.615	0.027	98	1.67	0.09
Tmr	7	2.46	0.05	7	1.75	0.09	7	21.2	5.	0.438	0.048	0.066	0.072	0.850	0.167	186	1.95	0.22

U4r - Below Water Table

SAMPLING POINT AVERAGES											LOG AVERAGES
	Grain Density		Bulk Density		% Water		Porosity				Bulk Density
Tmr	5 2.41 0.01	5	1.74 0.04		27.3 2.	0.476 0.011					30 1.73 0.05
Tp	41 2.47 0.06	24	1.86 0.13		22.3 7.	0.414 0.044					97 1.87 0.12

U7aq - Above Water Table

SAMPLING POINT AVERAGES													LOG AVERAGES					
	Grain Density			Bulk Density			% Water		Porosity		Gas Porosity		Saturation		Bulk Density			
Qa1	17	2.52	0.02	17	1.90	0.10	17	11.4	2.	0.333	0.040	0.116	0.054	0.651	0.143	393	1.91	0.12
Tma	6	2.49	0.05	6	1.85	0.21	6	11.4	2.	0.343	0.080	0.132	0.105	0.614	0.231	130	1.83	0.21
Tmr	3	2.42	0.05	2	1.67	0.05	3	21.1	4.	0.456	0.036	0.104	0.052	0.772	0.123	177	1.97	0.27

U7aq - Below Water Table

SAMPLING POINT AVERAGES											LOG AVERAGES
	Grain Density		Bulk Density		% Water		Porosity				Bulk Density
Tmr	1 2.38 0.00	1	1.78 0.00		24.5 0.	0.436 0.000					24 1.77 0.05
Tp	40 2.47 0.07	19	1.84 0.10		23.3 5.	0.428 0.057					119 1.89 0.10
Tbg	3 2.44 0.06	3	1.89 0.03		20.1 3.	0.380 0.045					9 1.87 0.05
Ttu	12 2.51 0.08	12	1.93 0.22		20.1 10.	0.387 0.062					259 1.97 0.13

U3lj - Above Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density			Bulk Density			% Water			Porosity		Gas Porosity		Saturation		Bulk Density		
Oal	28	2.53	0.04	27	1.80	0.09	28	12.6	2.	0.377	0.037	0.150	0.051	0.603	0.120	349	1.81	0.12
Tma	12	2.44	0.03	12	1.55	0.06	12	12.4	1.	0.444	0.024	0.252	0.032	0.434	0.049	66	1.56	0.07

U3gv - Above Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density			Bulk Density			% Water			Porosity		Gas Porosity		Saturation		Bulk Density		
Qa1	17	2.54	0.05	13	1.77	0.09	17	12.0	2.	0.385	0.037	0.172	0.050	0.554	0.109	261	1.80	0.13
Tma	23	2.48	0.03	20	1.55	0.11	23	12.9	3.	0.454	0.044	0.255	0.061	0.440	0.116	86	1.52	0.08
Tmr	11	2.49	0.05	10	1.62	0.20	11	15.8	3.	0.452	0.073	0.197	0.107	0.564	0.184	101	1.88	0.31

Summary Table

Above Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation	Bulk Density
Qal	15 2.53 0.02	15 1.79 0.13	15 12.1 1.	0.376 0.045	0.160 0.061	0.576 0.115	15 1.83 0.10
Tma	15 2.47 0.03	15 1.67 0.12	15 13.1 1.	0.413 0.045	0.195 0.062	0.528 0.105	15 1.67 0.10
Tmr	14 2.45 0.02	13 1.71 0.09	14 17.4 4.	0.423 0.044	0.126 0.065	0.703 0.156	13 1.87 0.07
Tp	10 2.47 0.02	10 1.83 0.09	10 19.2 2.	0.401 0.032	0.050 0.050	0.876 0.117	10 1.83 0.08
Tbg	0 0.00 0.00	0 0.00 0.00	0 0.0 0.	0.000 0.000	0.000 0.000	0.000 0.000	2 1.78 0.00
Ttu	3 2.44 0.01	3 1.89 0.10	3 20.9 2.	0.389 0.038	-0.005 0.060	1.013 0.155	4 1.86 0.07

Below Water Table

SAMPLING POINT AVERAGES

LOG AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Bulk Density
Tmr	2 2.40 0.02	2 1.76 0.03	25.9 2.	0.456 0.017	2 1.75 0.03
Tp	7 2.47 0.01	7 1.87 0.06	21.9 3.	0.409 0.005	8 1.88 0.05
Tbg	6 2.44 0.04	5 1.84 0.06	22.6 4.	0.416 0.031	5 1.84 0.05
Ttu	11 2.48 0.03	11 1.95 0.07	18.4 3.	0.359 0.022	11 1.96 0.06

-22-
ESS-CPO-83-22

TUFF PILE 1

SUMMARY TRAVEL-TIME PLOT

Figure 3

TUFF PILE 1 — DENSITY LOGS

(densities in Mg/m^3)

Figure 4a

TUFF PILE 1 — DENSITY LOGS

(densities in Mg/m³)

TUFF PILE 1 — ELECTRIC LOGS

(resistivity in ohm-meters)

Figure 58

TUFF PILE 1 — ELECTRIC LOGS

(resistivity in ohm-meters)

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TUFF PILE 1 — CALIPER LOGS

(hole diameter in meters)

Figure 6a

TUFF PILE 1 — CALIPER LOGS

(hole diameter in meters)

Figure 6u

EXPLORATORY HOLES IN TUFF PILE 1—DENSITY LOGS

Figure 7

EXPLORATORY HOLES IN TUFF PILE 1—ELECTRIC LOGS

Figure 8

CAVITY REGION BULK DENSITY COMPARISON MEASURED—VS—PROJECTED

Figure 9a

Figure 9a

CAVITY REGION "LOG AVERAGE" BULK DENSITY COMPARISON MEASURED—VS—PROJECTED

Figure 10a

LOG AVERAGES BULK DENSITY (Mg/m^3)

Figure 10b

CAVITY REGION GRAIN DENSITY COMPARISON MEASURED—VS—PROJECTED

-36-
ESS-CP0-83-22

Figure 11a

GRAIN DENSITY (Mg/m^3)

Figure 11b

CAVITY REGION WATER COMPARISON MEASURED—VS—PROJECTED

-38-
ESS-CP0-83-22

Figure 12a

Figure 12b

CAVITY REGION TOTAL POROSITY COMPARISON MEASURED—VS—PROJECTED

-40-
ESS-CP0-83-22

Figure 13a

Figure 13b

TUFF PILE 1

DEPTH CONTOURS TO BASE Tma

DATUM ELEVATION = 4100 ft
CONTOUR INTERVAL = 100 ft

Figure 15

Figure 16

Figure 17

Addendum

Subsequent to the original EES-CPO-83-22 report, Rainier Mesa Tuff (Tmr) was subdivided into an upper unit comprised of low density, non-welded tuff (designated Tmru), a middle unit comprised of high density, welded tuff (Tmrm), and a lower unit comprised of low density non-welded tuff (Tmr1). This addendum provides hole-by-hole properties averages for units of the subdivided Tmr plus an updated summary table to be used for projections that include the subdivided Tmr.

Neither this report or the addendum reflect more recent subdivisions of the unit referred to in this document as the Paintbrush Tuff (Tp). It is now recognized that what was originally called the Paintbrush Tuff actually consists of up to five formations or groups between the Rainier Mesa Tuff (Tmr) and the Grouse Canyon Tuff (Tbg). These are accurately referred to as the Timber Mountain Group (Tm), Paintbrush Group (Tp), Calico Hills Formation (Th), Wahmonie Formation (Tw), and Crater Flat Group (Tc), rather than Tp (Sawyer et. al. 1994). Physical properties are very similar among these units, with the exception of the Wahmonie Formation, which has somewhat higher grain and bulk densities than the other four. Also, of these formations, only the Wahmonie is readily recognizable. In the opinion of the authors, however, the differences between these formations or groups are not great enough to warrant breaking them out for purposes of properties projections.

REFERENCE

Sawyer, D. A., R. J. Fleck, M. A. Lanphere, R. G. Warren, D. E. Broxton, and M. R. Hudson, "Episodic caldera volcanism in the Miocene southwestern Nevada volcanic field: Revised stratigraphic framework, $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology, and implications for magmatism and extension", *Geol. Soc. Amer. Bull.*, Vol. 106, p. 1304-1318, October 1994.

Summary Table

Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	15 2.52 0.03	15 1.83 0.10	15 12.1 1.	0.362 0.036	0.142 0.049	0.609 0.101
Tma	15 2.47 0.03	15 1.65 0.09	15 13.1 1.	0.420 0.035	0.204 0.048	0.515 0.083
Tmrw	14 2.45 0.03	13 1.59 0.07	14 17.0 5.	0.461 0.041	0.191 0.060	0.586 0.145
Tmrn	12 2.50 0.03	13 2.12 0.08	10 12.6 2.	0.259 0.035	-0.009 0.049	1.034 0.190
Tmrl	11 2.42 0.02	12 1.62 0.09	11 19.2 4.	0.460 0.040	0.149 0.060	0.677 0.131
Tp	10 2.47 0.02	10 1.83 0.08	10 19.2 2.	0.400 0.030	0.047 0.047	0.881 0.112
Tbg	0 0.00 0.00	1 1.81 0.00	0 0.0 0.	0.000 0.000	0.000 0.000	0.000 0.000
Ttu	3 2.44 0.01	4 1.86 0.07	3 20.9 2.	0.399 0.028	0.011 0.044	0.973 0.110

Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Tmrl	2 2.40 0.02	2 1.76 0.03	26.1 2.	0.458 0.017
Tp	7 2.47 0.01	8 1.89 0.06	20.8 3.	0.393 0.005
Tbg	6 2.44 0.04	5 1.85 0.05	22.3 3.	0.411 0.031
Ttu	11 2.48 0.03	11 1.96 0.06	18.1 3.	0.354 0.022
Tf	0 0.00 0.00	2 2.13 0.13	100.0 0.	0.000 0.000
Pzt	0 0.00 0.00	2 2.41 0.08	100.0 0.	0.000 0.000
Pzc	0 0.00 0.00	1 2.66 0.00	100.0 0.	0.000 0.000
Tpf	0 0.00 0.00	1 2.01 0.00	100.0 0.	0.000 0.000

U7br - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	2 2.50 0.10	53 1.79 0.13	2 11.3 2.	0.365 0.053	0.162 0.067	0.555 0.136
Tma	2 2.47 0.03	71 1.56 0.11	2 14.2 4.	0.457 0.045	0.236 0.064	0.485 0.125
Tmru	2 2.47 0.07	46 1.52 0.09	2 13.6 3.	0.468 0.038	0.262 0.051	0.440 0.090
Tmrm	4 2.51 0.02	105 1.96 0.14	2 13.3 1.	0.322 0.050	0.061 0.069	0.810 0.185
Tmrl	3 2.42 0.04	84 1.48 0.08	3 15.7 2.	0.485 0.032	0.253 0.045	0.479 0.069
Tp	12 2.48 0.06	244 1.64 0.12	12 20.4 2.	0.473 0.045	0.137 0.070	0.711 0.129
Ttu	4 2.44 0.04	46 1.79 0.06	4 23.6 4.	0.441 0.034	0.020 0.052	0.955 0.119

U7br - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Ttu	31 2.45 0.09	144 1.93 0.08	16.9 5.	0.358 0.070

U31a - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	10 2.44 0.32	219 1.83 0.11	10 10.8 4.	0.332 0.100	0.134 0.109	0.596 0.246
Tma	4 2.51 0.07	120 1.69 0.23	4 10.8 3.	0.398 0.086	0.216 0.113	0.459 0.188
Tmru	2 2.42 0.01	28 1.53 0.08	2 11.8 0.	0.440 0.029	0.260 0.038	0.409 0.047
Tmrm	6 2.52 0.05	161 2.08 0.14	2 10.8 1.	0.265 0.052	0.041 0.067	0.844 0.226
Tmrl	3 2.44 0.01	57 1.60 0.08	3 16.7 1.	0.453 0.029	0.185 0.043	0.592 0.072
Tp	8 2.46 0.03	131 1.85 0.09	8 18.1 2.	0.385 0.035	0.051 0.053	0.867 0.129

U31a - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Tp	29 2.47 0.06	132 1.88 0.11	19.5 6.	0.402 0.046
Tbg	3 2.44 0.03	15 1.91 0.08	17.5 4.	0.366 0.026
Ttu	21 2.46 0.06	92 1.90 0.06	18.3 4.	0.381 0.050

Tma 12 2.44 0.03 66 1.56 0.07 12 12.4 1. 0.442 0.026 0.249 0.035 0.437 0.053

U3gv - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	17 2.54 0.05	261 1.80 0.13	17 12.0 2.	0.376 0.050	0.160 0.067	0.575 0.139
Tma	23 2.48 0.03	86 1.52 0.08	23 12.9 3.	0.467 0.035	0.271 0.049	0.419 0.102
TmrU	10 2.48 0.04	46 1.57 0.07	10 16.5 2.	0.472 0.030	0.212 0.044	0.551 0.082
TmrM	1 2.45 0.00	55 2.13 0.17	1 8.0 0.	0.200 0.064	0.030 0.077	0.851 0.338

U4r - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	17 2.55 0.04	400 1.96 0.13	17 11.2 2.	0.317 0.049	0.099 0.065	0.689 0.169
Tma	2 2.42 0.00	98 1.67 0.09	2 13.8 0.	0.404 0.033	0.173 0.045	0.571 0.078
Tmru	2 2.46 0.06	45 1.73 0.10	2 17.1 8.	0.419 0.068	0.123 0.100	0.706 0.263
Tmrm	5 2.57 0.03	102 2.17 0.13	0 0.0 0.	0.154 0.051	0.154 0.051	0.000 0.000
Tmrl	5 2.45 0.06	39 1.75 0.09	5 22.9 3.	0.451 0.037	0.051 0.059	0.886 0.127

U4r - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Tmrl	5 2.41 0.01	30 1.74 0.05	24.8 3.	0.477 0.011
TP	41 2.47 0.06	97 1.87 0.11	19.7 6.	0.405 0.045

U7aq - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	17 2.52 0.02	393 1.91 0.12	17 11.4 2.	0.329 0.046	0.110 0.062	0.664 0.162
Tma	6 2.49 0.05	130 1.83 0.21	6 11.4 2.	0.349 0.077	0.141 0.101	0.597 0.216
Tmru	1 2.41 0.00	51 1.66 0.09	1 24.8 0.	0.483 0.027	0.072 0.049	0.851 0.093
Tmrm	5 2.52 0.04	102 2.18 0.15	1 16.1 0.	0.274 0.051	-0.077 0.075	1.282 0.326
Tmrl	1 2.38 0.00	24 1.74 0.06	1 22.3 0.	0.433 0.019	0.046 0.032	0.893 0.068

U7aq - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Tmrl	1 2.38 0.00	24 1.78 0.05	22.4 2.	0.438 0.000
TP	40 2.47 0.07	119 1.89 0.09	19.0 5.	0.393 0.058
Tbg	3 2.44 0.06	9 1.87 0.05	19.3 3.	0.397 0.045
Ttu	12 2.51 0.08	259 1.98 0.13	16.3 6.	0.351 0.063
Tf	0 0.00 0.00	64 2.22 0.15	0.0 0.	0.000 0.000
Pzt	0 0.00 0.00	69 2.46 0.26	0.0 0.	0.000 0.000
Pzc	0 0.00 0.00	22 2.66 0.07	0.0 0.	0.000 0.000
TPf	0 0.00 0.00	12 2.01 0.10	0.0 0.	0.000 0.000

U31j - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	28 2.53 0.04	349 1.81 0.12	28 12.6 2.	0.374 0.046	0.145 0.064	0.611 0.141

U3lo - Above Water Table

AVERAGES

	Grain Density			Bulk Density			% Water			Porosity		Gas Porosity		Saturation	
Qal	16	2.54	0.05	247	1.88	0.23	16	12.5	2.	0.354	0.083	0.119	0.113	0.665	0.248
Tma	24	2.45	0.03	114	1.67	0.08	24	14.4	1.	0.418	0.029	0.177	0.041	0.576	0.073
Tmru	2	2.42	0.02	0	0.00	0.00	2	30.1	1.	1.000	0.000	1.000	0.000	0.000	0.000

U4j - Above Water Table

AVERAGES

	Grain Density			Bulk Density			% Water			Porosity		Gas Porosity		Saturation	
Qal	13	2.54	0.04	259	1.92	0.16	13	10.8	2.	0.328	0.058	0.120	0.077	0.633	0.184
Tma	3	2.42	0.01	79	1.69	0.08	3	13.1	1.	0.393	0.029	0.172	0.040	0.562	0.080
Tmru	2	2.50	0.01	48	1.61	0.09	2	14.9	0.	0.453	0.031	0.213	0.045	0.529	0.066
Tmrm	5	2.51	0.05	118	2.19	0.15	1	13.6	0.	0.246	0.054	-0.052	0.074	1.212	0.348
Tmrl	2	2.39	0.03	47	1.68	0.10	2	27.1	3.	0.486	0.037	0.031	0.065	0.937	0.131
Tp	8	2.44	0.03	118	1.88	0.13	8	20.8	4.	0.390	0.054	0.000	0.084	1.000	0.215

U4j - Below Water Table

AVERAGES

	Grain Density			Bulk Density			% Water		Porosity	
Tp	9	2.47	0.05	27	1.82	0.15	22.0	8.	0.440	0.042
Tbg	1	2.37	0.00	0	0.00	0.00	0.0	0.	1.730	0.000
Ttu	29	2.48	0.05	84	2.02	0.10	14.2	4.	0.312	0.041

U4f - Above Water Table

AVERAGES

	Grain Density			Bulk Density			% Water			Porosity		Gas Porosity		Saturation	
Qal	17	2.54	0.04	377	1.85	0.08	17	11.4	1.	0.354	0.032	0.142	0.042	0.598	0.094
Tma	3	2.43	0.01	77	1.56	0.07	3	11.6	1.	0.433	0.025	0.252	0.033	0.418	0.049
Tmru	2	2.46	0.05	37	1.60	0.09	2	12.0	1.	0.428	0.034	0.237	0.044	0.447	0.063
Tmrm	5	2.52	0.05	121	2.07	0.10	2	12.9	7.	0.284	0.069	0.018	0.102	0.937	0.365
Tmrl	1	2.43	0.00	46	1.66	0.08	1	24.2	0.	0.484	0.025	0.083	0.044	0.828	0.082
Tp	2	2.48	0.04	37	1.79	0.08	2	19.7	6.	0.419	0.053	0.066	0.080	0.843	0.200

U4f - Below Water Table

AVERAGES

	Grain Density			Bulk Density			% Water		Porosity	
Tp	31	2.47	0.06	198	1.83	0.12	21.7	6.	0.435	0.050
Tbg	3	2.49	0.01	25	1.82	0.06	22.4	3.	0.448	0.004
Ttu	14	2.53	0.04	59	1.96	0.07	17.4	3.	0.372	0.033

Tma	4	2.49	0.06	572	1.79	0.15	4	12.2	2.	0.369	0.059	0.150	0.079	0.594	0.166
Tmru	2	2.45	0.06	218	1.65	0.07	2	16.0	1.	0.432	0.030	0.187	0.042	0.612	0.075
Tmrm	0	0.00	0.00	471	2.22	0.15	0	0.0	0.	0.000	0.000	0.000	0.000	0.000	0.000
Tmrl	0	0.00	0.00	224	1.64	0.07	0	0.0	0.	0.000	0.000	0.000	0.000	0.000	0.000
TP	4	2.50	0.05	233	1.94	0.09	4	16.8	3.	0.354	0.039	0.027	0.056	0.923	0.156

U3gg - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
TP	47 2.45 0.06	758 1.98 0.10	15.0 5.	0.324 0.051
Ttu	4 2.49 0.02	24 2.09 0.04	11.9 2.	0.270 0.018

U7av - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	4 2.53 0.03	79 1.83 0.09	4 11.9 1.	0.362 0.034	0.143 0.046	0.605 0.101
Tma	4 2.50 0.07	85 1.72 0.14	4 13.3 1.	0.405 0.054	0.178 0.073	0.561 0.127
Tmru	2 2.47 0.04	61 1.62 0.10	2 12.7 1.	0.428 0.036	0.223 0.048	0.480 0.074
Tmrm	6 2.51 0.05	138 2.09 0.13	2 12.1 0.	0.269 0.048	0.018 0.063	0.935 0.223
Tmrl	3 2.44 0.01	69 1.61 0.10	3 17.0 4.	0.453 0.042	0.180 0.062	0.602 0.131
Tp	12 2.47 0.06	241 1.84 0.12	12 18.0 4.	0.388 0.051	0.056 0.076	0.855 0.189
Tbg	0 0.00 0.00	14 1.81 0.05	0 0.0 0.	0.000 0.000	0.000 0.000	0.000 0.000
Ttu	0 0.00 0.00	5 1.87 0.07	0 0.0 0.	0.000 0.000	0.000 0.000	0.000 0.000

U7av - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Ttu	20 2.47 0.03	132 1.91 0.07	18.1 3.	0.379 0.028

U7an - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	4 2.52 0.02	55 1.65 0.09	4 13.5 2.	0.432 0.032	0.210 0.045	0.515 0.081
Tma	11 2.50 0.06	63 1.61 0.15	11 15.2 4.	0.452 0.057	0.207 0.082	0.543 0.151
Tmru	2 2.42 0.01	51 1.46 0.10	2 19.4 2.	0.512 0.034	0.229 0.053	0.553 0.081
Tmrm	5 2.47 0.04	92 2.14 0.11	2 13.9 1.	0.254 0.040	-0.044 0.056	1.173 0.242
Tmrl	3 2.41 0.01	70 1.66 0.10	3 16.9 4.	0.429 0.044	0.149 0.064	0.652 0.142
Tp	11 2.46 0.04	234 1.85 0.10	11 21.1 4.	0.408 0.047	0.018 0.072	0.956 0.177

U7an - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Tp	0 0.00 0.00	4 1.96 0.02	0.0 0.	0.000 0.000
Tbg	2 2.44 0.01	13 1.79 0.04	23.0 2.	0.453 0.006
Ttu	42 2.45 0.03	425 1.94 0.10	16.8 4.	0.356 0.026
Tf	0 0.00 0.00	56 2.04 0.05	0.0 0.	0.000 0.000
Pzt	0 0.00 0.00	61 2.35 0.19	0.0 0.	0.000 0.000

U3gg - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	10 2.51 0.04	1036 1.96 0.10	10 11.9 2.	0.313 0.041	0.080 0.056	0.744 0.157

Tp 22 2.45 0.05 100 1.79 0.12 22 21.7 4. 0.430 0.050 0.042 0.079 0.902 0.181

U7bu - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Tp	26 2.47 0.06	98 1.89 0.12	18.9 6.	0.393 0.048
Tbg	3 2.46 0.06	12 1.85 0.07	20.8 4.	0.421 0.047
Ttu	1 2.51 0.00	2 1.85 0.04	21.5 2.	0.436 0.000

U7ap - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	6 2.54 0.05	11 1.60 0.06	6 13.2 3.	0.452 0.030	0.240 0.043	0.469 0.094
Tma	5 2.48 0.05	16 1.59 0.11	5 11.9 2.	0.438 0.042	0.249 0.056	0.431 0.097
Tmru	1 2.52 0.00	5 1.61 0.10	1 14.8 0.	0.454 0.035	0.216 0.051	0.526 0.075
Tmrm	5 2.48 0.04	24 2.06 0.16	2 15.6 7.	0.299 0.079	-0.023 0.116	1.077 0.388
Tmrl	3 2.41 0.01	16 1.62 0.12	3 17.4 6.	0.445 0.054	0.164 0.080	0.632 0.179
Tp	8 2.46 0.03	50 1.83 0.11	8 18.1 4.	0.393 0.045	0.062 0.068	0.843 0.167
Ttu	12 2.44 0.04	25 1.83 0.05	11 20.1 4.	0.400 0.034	0.032 0.049	0.921 0.124

U7ap - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Ttu	34 2.51 0.06	35 1.97 0.08	16.7 4.	0.358 0.051

U7ba - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	3 2.50 0.05	38 1.77 0.17	3 14.2 1.	0.392 0.060	0.140 0.084	0.642 0.161
Tma	2 2.43 0.00	57 1.55 0.09	2 15.3 1.	0.459 0.033	0.222 0.048	0.517 0.071
Tmru	2 2.43 0.04	40 1.54 0.12	2 19.0 3.	0.486 0.043	0.193 0.066	0.602 0.113
Tmrm	4 2.46 0.04	108 2.23 0.21	3 10.3 2.	0.189 0.080	-0.039 0.103	1.207 0.622
Tmrl	2 2.44 0.03	51 1.50 0.12	2 14.1 0.	0.471 0.043	0.260 0.059	0.449 0.077
Tp	19 2.47 0.03	290 1.92 0.16	19 17.6 3.	0.357 0.059	0.019 0.088	0.947 0.242
Ttu	13 2.45 0.03	53 1.94 0.07	13 18.9 3.	0.358 0.034	-0.010 0.051	1.028 0.142

U7ba - Below Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity
Ttu	26 2.46 0.03	100 2.00 0.09	14.4 4.	0.315 0.021

U7bu - Above Water Table

AVERAGES

	Grain Density	Bulk Density	% Water	Porosity	Gas Porosity	Saturation
Qal	9 2.51 0.04	219 1.85 0.13	9 12.3 1.	0.353 0.049	0.125 0.066	0.646 0.144
Tma	3 2.51 0.06	124 1.72 0.21	3 14.0 1.	0.410 0.072	0.168 0.101	0.591 0.176
Tmru	3 2.43 0.06	56 1.58 0.06	3 15.1 2.	0.447 0.030	0.207 0.041	0.537 0.084
Tmrm	5 2.52 0.04	123 2.07 0.15	0 0.0 0.	0.177 0.061	0.177 0.061	0.000 0.000
Tmrl	2 2.45 0.05	61 1.52 0.09	2 17.0 2.	0.485 0.034	0.227 0.049	0.532 0.084

DATABASE: nts
HOLES TO PROJECT FROM:

U7ap
U7ba
U7bu
U7av
U7an
U3gg
U3lo
U4j
U4f
U4r
U7aq
U3lj
U3gv
U7br
U3la

HOLE TO RECEIVE PROPERTIES PROJECTIONS: U31r
PROJECT INTO INTERVAL: 1245.000 1500.000
U31r S BD (LOG AVERAGE)
GRD BD H2O Psi Phi
2.45 1.80 17.3 0.082 0.393 0.792