RAS 4626

# Official Transcript of Proceedings

# NUCLEAR REGULATORY COMMISSION

Title: Private Fuel Storage, LLC

Docket Number: 72-22-ISFSI; ASLBP No. 97-732-02-ISFSI

Location: Rockville, Maryland

Date: Thursday, June 20, 2002



Work Order No.: NRC-428

Pages 11646-11928

**NEAL R. GROSS AND CO., INC.**
**Court Reporters and Transcribers**
**1323 Rhode Island Avenue, N.W.**
**Washington, D.C. 20005**
**(202) 234-4433**

Template= SECY-032

SECY-02

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

| | |
|---|---|
| In the Matter of: | ) |
| PRIVATE FUEL STORAGE, LLC, | ) Docket No. 72-22 |
| (Independent Spent Fuel | ) ASLBP No. |
| Storage Installation) | ) 97-732-02-ISFSI |

ASLBP Hearing Room
Third Floor
Two White Flint North Building
11545 Rockville Pike
Rockville, Maryland

June 20, 2002

The above-entitled matter came on for hearing, pursuant to notice, at 9:00 a.m. before:

MICHAEL C. FARRAR, CHAIRMAN
Administrative Judge
U. S. Nuclear Regulatory Commission

DR. JERRY R. KLINE
Administrative Judge
U. S. Nuclear Regulatory Commission

DR. PETER S. LAM
Administrative Judge
U. S. Nuclear Regulatory Commission

APPEARANCES

FOR THE STATE OF UTAH:
Denise Chancellor, Esq.
Connie Nakahara, Esq.
Assistant Attorneys General
Office of the Attorney General
160 East 300 South, 5th Floor
P. O. Box 140873
Salt Lake City, Utah 84114

FOR PRIVATE FUEL STORAGE, LLC:
Paul Gaukler, Esq.
Blake Nelson, Esq.
SHAW PITTMAN
Attorneys at Law
2300 N Street, N.W.
Washington, D.C. 20037

FOR THE U.S. NUCLEAR REGULATORY COMMISSION:
Martin O'Neill, Esq.
Sherwin E. Turk, Esq.
Office of the General Counsel
Mail Stop - 0-15 B18
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

I-N-D-E-X

# E-X-H-I-B-I-T-S

## EXHIBITS

| NUMBER | DESCRIPTION | MARK | RECD |
|---|---|---|---|
| PFS | | | |
| 233 | Figure 2.6-5 | 11779 | |
| 234 | REG Guide 1.132 | 11779 | |
| 235 | SAR Figure 2.6-19 | 11780 | |
| 236 | Bartlett Depo | 11780 | |
| 237 | Unified Geotechnical Contention | 11829 | |
| 233A | Color Figure 2.6-5 | 11841 | |
| State | | | |
| 93 | SRP Excerpts | 11824 | 11826 |
| 94 | PFS SAR Rev. 21 | 11824 | 11826 |
| 95 | Stability Analysis of Pads | 11824 | 11826 |
| 96 | Stability Analysis of Transfer Building | 11824 | 11826 |
| 97 | Site Investigations for Foundations of Nuclear Power Plants | 11824 | 11826 |
| 98 | Trudeau and Chang Depo | 11824 | 11826 |
| 99 | Bartlett and Ostadan Depo | 11824 | 11826 |
| 100 | EPRI Manual on Soil | 11824 | 11826 |
| 101 | Geotechnical Parameters | 11824 | 11826 |
| 102 | Earthquake and Defamations | 11824 | 11826 |
| 103 | Tests for anisotrophy of soils | 11824 | 11826 |
| 104 | I-15 Reconstruction | 11824 | 11826 |

P-R-O-C-E-E-D-I-N-G-S

(9:00 a.m.)

CHAIRMAN FARRAR: Good morning, everyone. I understand there was a little delay getting in this morning. Glad that was resolved, and we'll pick up where we left off last evening, which is going to be the Staff redirect of Dr. Luk.

Mr. Turk, you had given an indication last night of how long you thought you might take. Do you have any --

MR. TURK: I approximated 10 minutes, Your Honor.

CHAIRMAN FARRAR: Marvelous.

MR. TURK: And Dr. Luk and I spoke last night, and again this morning. We've gone through the questions I'm going to ask, and I hope we can get through it fairly quickly.

CHAIRMAN FARRAR: Excellent. I appreciate your doing that. Thank you. Go ahead. Mr. Gaukler, you'll -- well, you won't know until he's finished.

MR. GAUKLER: Right. I would guess five, ten minutes, something in that range, at most.

CHAIRMAN FARRAR: Marvelous. Then let's have it. Go ahead, Mr. Turk.

MR. TURK: Thank you very much, Your

Honor. Good morning, Dr. Luk.

DR. LUK: Good morning.

MR. TURK: In questioning yesterday, you were asked how would you model the bonding at the interface, and I believe you replied that, "You would do what you did." When you made that statement did you mean that you would use a Mu2 of 1.0 at the interface in order to model the bonding between the two layers?

DR. LUK: Yes.

MR. TURK: You also stated that Exhibit YY shows the dissipation of energy, and you stated that the amount of energy consumed is neglectably small, as I recall. In stating that, did you mean that the amount of energy dissipated by the relative displacements between the pad and the cement-treated soil is neglectably small?

DR. LUK: Yes.

MR. TURK: At another point you stated, as I recall, something along the lines of, "For this case, we do have to consider the relative displacement of the cement-treated soil and the soil." That's my paraphrase. I don't have the transcript in front of me, but when you made that -- do you recall making a statement along that line?

DR. LUK: Yes. I think I may also use the wrong word. Instead of consider, that means we did not go into the details in the analysis results.

MR. TURK: Okay. When you made that statement, that had to do with the relative displacements between the cement-treated soil and the soil at the PFS facility? That's correct, yes?

DR. LUK: Yes.

MR. TURK: Okay. Did you, in fact, consider the relative displacement between the cement-treated soil and the underlying soil?

DR. LUK: Yes. There's interface between the bottom of cement-treated soil and the top of the soil foundations, so we did investigate a relative displacement at the interface.

MR. TURK: And would any such displacement be reflected in the results shown, for instance, in Table 8 of your report with respect to how much cask rotation or how much cask displacement occurs?

DR. LUK: The integrated effect of all those interfaces relative displacements were reflected in the summary results in Tables 8 through 10.

MR. TURK: Okay. At another point, you indicated that the team had concluded, or your team had concluded in conjunction with the Staff, that it was adequate to use a Mu2 at the top of the pad, and the top of the soils. I thought that's what you had said.

First of all, was this a reference to anything having to do with the PFS case, or is this the generic study that you are discussing?

DR. LUK: This in only limited to the future generic studies.

MR. TURK: Okay. That was not a PFS discussion, or a discussion about the PFS modeling.

DR. LUK: Correct.

MR. TURK: Okay. And when you said it was appropriate -- that the decision had been made that it's appropriate to use a Mu2, in fact, did you mean it would be appropriate to use Mu1 at the top of the pad, and Mu2 at the top of the soils?

DR. LUK: Yes.

MR. TURK: Okay. At another point, I believe you stated that for the dry cask, the behavior of the cask is not sensitive to the Young's modulus. In referring -- do you recall making a statement along that line?

DR. LUK: Yes.

MR. TURK: In using the term "dry cask", were you referring to a cask that has become moistened, for instance, by snow or rain?

DR. LUK: No, when I use --

MR. TURK: I'm sorry. A cask that had not been moistened by snow or rain.

DR. LUK: When I mentioned dry cask, I mean this is the storage mode of the cask system, is the dry storage cask system instead of make reference to the moisture content at the interface.

MR. TURK: So you're not -- what you were stating is that regardless of whether the cask has become wet due to environmental conditions or not, that's not what you were referring to.

DR. LUK: Correct.

MR. TURK: In your testimony with respect to shake tables, you indicated that you were familiar with a shake table in Japan that had an 8 meter by 8 meter dimension. Do you recall that?

DR. LUK: Yes.

MR. TURK: Could you identify the name of that facility?

DR. LUK: To the best of my recollection is Tedatsu test facility, which is one of the facilities belong to NUPAC. NUPAC is a government agency for the Japanese government.

MR. TURK: And are you familiar with the

quality of the feedback or results of the shake table testing that is conducted at that facility?

DR. LUK: That is a very large facility, but unfortunately if large inertia force is put on the shake table during the test, the feedback system is not very good. But in the past two or three years, I was told that substantial remodeling took place, but I don't know the current status, whether it's ready to conduct new tests.

MR. TURK: Okay. You also were describing a decision made by the NRC Staff not to spend the money that would be required in order to some 1-dimensional shake test results. Do you recall that line of questions and answers?

DR. LUK: Yes.

MR. TURK: Did that testing involve either the high storm cask or the PFS facility?

DR. LUK: The cask they used in that Japanese test, to the best of my knowledge, is actually a Japanese designed cask.

MR. TURK: So that's not relevant to the PFS facility, or at least it's not the PFS cask.

DR. LUK: Correct.

MR. TURK: At one point, you indicated in response to Ms. Nakahara that there is a link between

Young's modulus and shear modulus, which is provided by the Poisson's ratio. Could you explain what you meant by that?

DR. LUK: Yes, I think within the elastic domain, that means when the material behaved elastically, the relationship is linear. Means Young's modulus equals to product of the Poisson's ratio times Young's modulus.

MR. TURK: The shear modulus.

DR. LUK: The shear modulus equals to the product of Poisson's ratio and Young's modulus.

MR. TURK: And that's when you're within the elastic limits of the material.

DR. LUK: Yes.

MR. TURK: Did Mr. Po Lam include a shear modulus in modeling the soil and the cement-treated soil at the PFS facility?

DR. LUK: Yes.

MR. TURK: In using a Young's modulus of 270,000 PSI for the cement-treated soil, what effect does that have on shear modulus in your model for the cement-treated soil?

DR. LUK: I think because of the linear relationship that I just described between the Young's modulus and shear modulus, we did use a high Young's modulus, so in that perspective, a high shear modulus would also be used in our model.

MR. TURK: And does that result in more energy being transferred to the cask and pads, than would have occurred if you had used a lower Young's modulus?

DR. LUK: Yes. I think in the static sense that's correct. But I think in the highly dynamic nonlinear envelopment that we input seismic event, that consideration is still appropriate, but may not be conclusive.

MR. TURK: Do you consider this to be a significant issue with respect to the modeling that you conducted for the PFS facility; that is, the use of this larger Young's modulus for the cement-treated soil?

DR. LUK: Since yesterday, we spent a lot of time trying to struggle with this issue, so I spent quite a bit of time last night, thought through the process. Let me give you an engineering perspective of the consequence of using a higher Young's modulus, instead of using the design spec Young's modulus.

There's three perspectives I want to bring out. The first is that the horizontal layer for which the cement-treated soil that we are considering is two foot thick in our model, I want to prepare in the perspective, a two foot thick of a horizontal layer in the overall thickness of the soil foundations that we use in the model is 140 feet. So in that perspective, yes, when we change the Young's modulus, that they would have changed the results in respect to the cask response, but the effect would not be large, simply because of two foot versus 140 feet.

And the second is that throughout our investigation for the cask behavior at the Private Fuel Storage site, we did do systematic sensitivity analysis related to the site-specific soil profile data. What I mean is that we did the analysis by using best estimate lower bound and upper bound. And those material properties were tabulated in Tables 2 to 7 in the report.

If you look at the analysis results that's summarized in Tables 8 to 10, you find out yes, when we use different soil profile data, the results of cask response will change, but the amount of change has actually been demonstrated in those three tables. What I simply mean is that the change is not excessive, so in that regard, if we said, if we have a change to using the design spec Young's modulus instead of higher Young's modulus for the cement-treated soil, there would be changes, but we can, in an engineering perspective, bound the changes that would take.

MR. TURK: Let me ask you to be a little more specific on that one point. Would you turn to page 10 of your report? Do you have that handy?

DR. LUK: Yes.

MR. TURK: On page 10, you present Tables 2 and 3.

DR. LUK: Yes.

MR. TURK: The third vertical column is entitled "Young's modulus". If you look at the lowest layer in each of those tables, you see the number 6?

DR. LUK: Yes.

MR. TURK: Is that the layer number 6 of the soil in your model?

DR. LUK: Yes.

MR. TURK: And the thickness is indicated to be 50 feet thick for that soil there?

DR. LUK: Yes.

MR. TURK: If you would look at the Young's modulus in Tables 2 and 3, you see that the value used differs significantly. Doesn't it?

DR. LUK: Yes.

MR. TURK: But in Table Number 2, which is best estimate, the Young's modulus that you used for that 50 foot thick layer was 612,000 PSI?

DR. LUK: Yes.

MR. TURK: And in comparison, for the lower bound soil profile, that same 50 foot layer of soil, you used only a 306,000 PSI Young's modulus. Correct?

DR. LUK: Yes.

MR. TURK: And the net effect of that variance, as well as all the other variances between the lower bound and best estimate soil profiles, that would show up in the results in Table 8 of your report?

DR. LUK: Yes.

MR. TURK: In that regard, is it your belief that the variance of the Young's modulus had no significant affect on the results for cask displacement and cask rotation?

DR. LUK: Yes. Our observation is that yes, there will be changed in terms of the cask response, but the changes are not excessively large, so it's well within the margin. But what I want to continue my observation based on the engineering perspective is that yes, when we use a high Young's modulus for the cement-treated soil, we are going to change the results for the cask response. But when I look at the bottom line conclusions, we're going to compare the cask response of sliding to the criteria that we used to make sure there's no collisions of neighboring cask and the physical dimension is 23.75, which is half of the separation distance between neighboring casks of 47.5 inches.

MR. TURK: I see.

DR. LUK: We have quite a bit of margin. That means changes can happen in the sliding displacement of the cask, but probably will not change our conclusions. And second, related to cask rotations, the criteria is to make sure that as long as the cask rotation is less than 29 degrees, the cask will probably not likely to tip over, so in that sense, there is a huge margin of safety. So if I have to draw a bottom line conclusion, have I -- do I have to change our bottom line recommendation related to whether the cask performance were within the public safety issues, and the answer is definitely yes.

MR. TURK: I'm sorry. I'm not sure I understood the last statement. Is it your conclusion then that any difference in the result that might have been caused by using a lower Young's modulus in the cement-treated soil of 75,000, is it your conclusion that that does not affect, or that will not result in either cask tip-over, or casks sliding into each other?

DR. LUK: Yes.

MR. TURK: All right. And just one last point, when we were comparing Tables 2 and 3 for the best estimate and lower bound soil profiles, could you look at Table Number 8 on page 30 of your report?

DR. LUK: Yes.

MR. TURK: Would you point to which lines in this table would reflect the cask displacement and cask rotation that results if we're using lower bound versus best estimate for the 2000 year earthquake, as shown in Tables 2 and 3?

DR. LUK: Okay. The direct comparisons that I have to refer to is - okay - we can look at the first group of results, which are identified as "Best Estimate Model Type I", and we have to choose the case for Mu1 equals to 0.20. Mu2 equals to 0.31, versus the case for the lower bound, which is the second one from the bottom. For the Lower Bound Model Type I, and for also identical choice of the coefficient of friction at those interfaces. And those are the two sets of results we should look at.

MR. TURK: Okay. I have one more

question, Your Honor. You were discussing with Ms. Nakahara the omission of some time increments in presenting the, or in plotting the results of your study. Could you explain what you were referring to?

DR. LUK: Yes. I think Mr. Turk is correct. Something I took for granted is probably needs more explanations. When we finished the analysis, we scan the analysis results electronically for a single purpose. We want to identify when and how large is amplitude of, for example, the cask sliding displacements. And once we identified those time intervals, as well as its amplitude, then the next step is to plot the analysis results. And in order to improve the cosmetics or the optics of the plot, that we choose not to include every results in every time step, and that's when I said we skipped, mainly because the area that we skipped usually does not demonstrate large changes in the analysis results. So in that way, you will see a more smooth curve.

MR. TURK: And when you did that, did you include all of the peak values in the plots that are shown?

DR. LUK: Yes.

MR. TURK: So that extent, could you say that you did pick and choose, but you did that in a manner in order to show the maximum displacements, or rotations, or accelerations, or whatever else you were plotting?

DR. LUK: Yes. The skipping only happens in an area we identify, and we also decided that are not essential.

MR. TURK: That's all we have, Your Honor.

CHAIRMAN FARRAR: So that means in terms of our discussion yesterday, that you take every hundredth one, for example, in non-critical areas, but in areas that you view more significant, you don't take every hundredth. You make sure that you get everything that's special --

DR. LUK: Yes, sir.

CHAIRMAN FARRAR: -- or of special significance.

DR. LUK: Yes.

JUDGE LAM: Dr. Luk, as a leading expert in the field of finite element analysis, I would assume you have a vested interest in continuously improving your model. Is that correct?

DR. LUK: Yes, sir.

JUDGE LAM: Then if I may ask you to take a step back and just forget you are in an adversarial proceeding. And I'm going to ask you to take Dr.

Bartlett's criticism seriously, just with the intent of improving your model. Just forget about this adversarial proceeding. Any one of Dr. Bartlett's criticism of your modeling and analysis worthy of your consideration?

DR. LUK: Yes. As a matter of fact, when we first started the model development, we have tried with serious effort, tried to model the soil foundation not as an elastic body, but more or less tried to demonstrate the soil can behave in the plastic domain. But the state-of-the-art, what I mean is that we are not involved in the conducting the finite elements analysis using Abaqus Code, but we also go through a deconvolution process.

The deconvolution process, by its nature, is the using Abaqus Code to transform theories. Now in layman's term, is that it's in principle only deal with for each specific layer, elastic and linear systems. That's why there is -- a basic overhaul is needed in going through this mathematical model, tried to shift the surface defined seismic acceleration input to the base of the soil foundation model that we have, so if we have the permission from NRC Staff, if there is enough funding, resources and schedule, we do plan to attack the problem in a very fundamental way, but that probably takes a lot more time.

So the simple answer to your question, yes. I think, you know, Dr. Bartlett's concern is genuine, and like I say, you know, three years ago when we started this project, we want to get into it because we know some portions of the soil foundations probably will be in the plastic domain. But the question is that even if it does happen, would it change the overall cask response? And our current knowledge indicates it's probably not the case, but it does not say that there's no way that we should improve our model.

JUDGE LAM: Dr. Luk, you anticipated my next question. Thank you.

MR. TURK: I have a follow-up to that, Your Honor, if I may. The fact that you did not include plastic, potential plastic behavior of your soils, I don't understand how that's a concern here because I thought you had indicated that the strain levels here were all found to be within the elastic region.

DR. LUK: Yes, but I think we have discussions, yes, in the continuum of the soil foundation. That means, for the portions of the soil foundation which is some distance away from any boundary, for example, in a close vicinity of the soil foundation to the cement-treated soil, mainly because of the presence of this, what we call discontinuity, because they are not part of the soil foundations. High stress or strain concentrations may occur, but the question is that will they change the overall cask response? And our current knowledge indicated is no, but if people are interested in actually performing detailed stability analysis for the soil foundation, for example, that question probably cannot be well-addressed within our current state-of-the-art. Now that is our assessment.

MR. TURK: Your Honor, I realize I have one more question that I should have asked before that I didn't, if I may.

CHAIRMAN FARRAR: Go ahead.

MR. TURK: When we were looking at the results on page 30, which is Table 8 of your report, and you were discussing the lower bounds versus best estimate soil profile types, I see that there is a difference in maximum horizontal sliding displacement. This is the U1 and the U2 columns, of approximately, let's see -- it's a variation between 3.93 inches displacement for U1 for the best estimate, versus 2.34 inches of sliding in the U1 direction for the lower bound soil profile. That's approximately a 1.6 inch difference, and you can look across the chart for the U2 direction. The difference is approximately slightly over 2 inches. It goes from 3.98 down to 1.85 inches.

DR. LUK: Yes.

MR. TURK: And then again, looking in the far column for maximum rotation, I see that in the U1 direction you got the same rotation, .02 degrees.

DR. LUK: Yes.

MR. TURK: And, in fact, for the north/south U2 direction, you also obtained the same value of .01 degrees of rotation.

DR. LUK: Yes.

MR. TURK: Do you believe that the -- that if you had used a different Young's modulus for the cement-treated soil of 75,000, would the net effect be essentially bounded by the difference shown in this table between using best estimate and lower bound soils, or would it approximate those differences, at best?

DR. LUK: I think the best assessment is that in the static sense, yes, we actually did the bounding calculation. But in the dynamic world, maybe there's a little bit difference, but the changes will not be significantly different.

MR. TURK: Significantly, and they wouldn't be significantly different from the types of variations that are shown in Table 8 --

DR. LUK: Yes, sir.

MR. TURK: -- using different soil profiles. Correct?

DR. LUK: Yes.

MR. TURK: That's all I have.

CHAIRMAN FARRAR: Thank you, Mr. Turk. Mr. Gaukler.

MR. GAUKLER: I have less than five minutes, I believe.

CHAIRMAN FARRAR: Okay. Good, because we owe you five minutes from yesterday.

RECROSS EXAMINATION

MR. GAUKLER: Good morning, Dr. Luk.

DR. LUK: Good morning.

MR. GAUKLER: We're talking sensitivity in terms of various aspects today and yesterday in different parameters. Now you've done studies on three different sites, Hatch, San Onofree and the PFS site. Correct?

DR. LUK: Yes.

MR. GAUKLER: And you've evaluated the

stability of the casks at those three sites under various conditions. Correct?

DR. LUK: Yes.

MR. GAUKLER: And the various conditions include different earthquake loads, different soil properties, et cetera. Correct?

DR. LUK: Yes.

MR. GAUKLER: Would it be fair to say that as a general matter, overall the most -- the cask stability is most sensitive to earthquake amplitude or load, as opposed to other parameters?

DR. LUK: In the way that you asked the questions, yes.

MR. GAUKLER: Okay. Also, we were talking yesterday about the bonding between the soil cement in the pad, and the soil cement in the soil. And we talked briefly about the fact that in the finite element, you include the properties of the soil and the cement-treated soil, in your finite element, elements for those particular materials. And would it be fair to say that at the boundary - okay - between the soil and cement-treated soil, for example, you have your properties for the cement-treated soil and the finite element modules above the boundary, and you have your properties for the soil in the finite element modules below the boundary. And is it fair to say that in that process, you effectively modeled the cohesion across that boundary, or the cohesion effect between the two materials?

DR. LUK: The effect of soil as reflected in your terms cohesions, they re -- once we input the material properties for the specific layers of element on top and below the interface, all those effects are included in the code.

MR. GAUKLER: Okay. So the answer to my question, I take it, is yes.

DR. LUK: Yes.

MR. GAUKLER: Okay. And, therefore, basically by allowing the sliding at that interface you are, in effect, testing whether or not that cohesion exists, is what you -- as you said yesterday. Correct?

DR. LUK: The Coulomb's Law of Friction, in a nutshell, actually include all those effects that you mentioned, because that's how variation occurs for the coefficient of friction. But what I indicated yesterday is actually more than that. The coefficient of friction at the interface is very sensitive to the surface conditions. That's why that is not considered a material property.

MR. GAUKLER: I understand that. I guess my question was, I think, as you said yesterday, by allowing sliding at that interface, you are effectively testing or confirming the PFS design intent, that there was cohesion between those -- that cohesion existed. Correct?

DR. LUK: Or maybe bonding at the interface.

MR. GAUKLER: Yeah.

DR. LUK: Yes.

MR. GAUKLER: That's all I have, Your Honor.

CHAIRMAN FARRAR: Thank you very much, Mr. Gaukler. Any cross by the State?

MS. NAKAHARA: Yes, very short, Your Honor. Good morning, Dr. Luk.

DR. LUK: Good morning.

MS. NAKAHARA: In reference to the shake table data from Japan that Mr. Turk was talking about, that is for a free-standing cask, the test was. Correct?

DR. LUK: Yes.

MS. NAKAHARA: And then you mentioned -- testified this morning about the sensitivity analysis you conducted at the PFS site, using the upper bound, lower bound, and best estimate soils.

DR. LUK: Yes.

MS. NAKAHARA: But isn't it true that for each of those cases, you still used a Young's modulus for the cement-treated soil layer underneath the pad of 270,000 PSI?

DR. LUK: Yes. I think in that regard, we did not change the material properties for cement-treated soil, because we did not consider that as part of the soil foundations.

MS. NAKAHARA: And additionally, in reference to Mr. Turk's example of the lowest layer in Tables 2, 3 and 4, the Young's modulus was not the only parameter that was varied. Isn't that correct?

DR. LUK: Correct.

MR. TURK: I'm sorry. I referred to Tables 2 and 3. Table 4 refers to the 10,000 year event.

MS. NAKAHARA: Okay. Tables 2 and 3, for the lowest layer Young's modulus was not the only parameter varied. Correct? Input parameter.

DR. LUK: Correct. But you can look at it, we can go through the things systematically. The Poisson's ratio does not change. The density does not change, so the only two things that change is the

Young's modulus and the damping ratio.

MS. NAKAHARA: And in addition, between Table 2 and Table 3, layers 2, 3, 4 and 5 also varied in parameters. Isn't that true? Input parameters.

DR. LUK: Can you repeat your statement?

MS. NAKAHARA: Isn't it true that layer number 6 --

DR. LUK: Yes.

MS. NAKAHARA: -- between Table Number 2 and Table Number 3 --

DR. LUK: Yes.

MS. NAKAHARA: -- were not the only input parameters that varied -- strike that.

Isn't it true that the input parameters for layer number 6 were not the only input parameters that were varied in your analysis?

DR. LUK: Correct. All the changes are actually summarized in these two tables.

MS. NAKAHARA: And if you look at Table 8 on page 30 --

DR. LUK: Yes.

MS. NAKAHARA: -- isn't it true the displacement for the examples -- strike that.

Isn't it true the displacement for the coefficient of friction for Mu 1 equals to .2 and Mu

2 equal to .31, that the best estimate displacement in the U2 direction is double that of the lower bound?

A Un-huh.

Q In addition, the best estimate displacement in the U2 direction for the same case is double that -- strike that.

And the upper bound displacement for U2 for the same coefficient of friction parameters is double that of the lower bound?

MR. TURK: I'm sorry. I don't see what you're referring to. Could you point to which column and which --

MS. NAKAHARA: It's in the upper bound, model Type 1 for a coefficient of friction Mu 1 equals to .2, Mu 2 equals to .31 in the U2 direction.

BY MS. NAKAHARA:

Q Isn't it true that is double the lower bound model for the same coefficient of friction scenario?

MR. TURK: I'm sorry. Just so we're clear, what numbers are you -- what values are you asking are double of each other? That would just make it very clear.

MS. NAKAHARA: In the U2 direction.

CHAIRMAN FARRAR: No, tell us what numbers you're looking at.

MS. NAKAHARA: Three, point, nine, two is double 1.85 approximately.

THE WITNESS: Yes, in that way, yes.

MR. TURK: Do you mean to say 3.96?

CHAIRMAN FARRAR: No, he's talking about the upper bound and lower bound.

MS. NAKAHARA: And --

CHAIRMAN FARRAR: Or she's talking about the upper bound and lower bound.

BY MS. NAKAHARA:

Q And Mr. Gaukler asked you a question, and I can't read my writing. So I'm finished. Thank you.

(Laughter.)

THE WITNESS: Can I? I'm anticipating the question from the State. Because I don't want to leave something hanging. Yes, there's changes, but in the highly nonlinear calculations like this, we cannot just say one set of results is double the other. When you change something, you also have a factor.

What we have to look at is that, yes, there's changes, but what is the range of change? Yes, it changed it by maybe two inches. Okay? So when you change the input, there will be changes, but it's also of the same numerical value instead of a factor.

CHAIRMAN FARRAR: Let me see if I understand that. So rather than say four inches is double two inches, you would compare it to the 23 inches of leeway that you have before you get cask.

THE WITNESS: Yes, yes, yes.

CHAIRMAN FARRAR: Okay.

THE WITNESS: Yes. We have to look at the numerical value instead of a factor.

CHAIRMAN FARRAR: I see what you're saying.

THE WITNESS: Thank you.

CHAIRMAN FARRAR: I have one follow-on.

MS. NAKAHARA: May I follow up to that response?

CHAIRMAN FARRAR: Yeah, go ahead, Ms. Nakahara.

BY MS. NAKAHARA:

Q But in saying you have to look at a numerical value when you can't look at the numbers doubled, you cannot just evaluate random input parameters and determine how much of an increase or decrease in displacement of the cask; isn't that true?

A You're correct, but what I'm simply saying is that, you know, we as engineers used to do calculations in the static sense. Then we used a factor, a multiplier. But in the dynamic calculations, it's more appropriate to use the numerical results as itself and then find out the differences from case to case.

JUDGE LAM: And, Dr. Luk, you really do not care what the outcome is, do you? If they collide, they collide. I mean, if they tip over, they tip over, right?

I mean, I assume your interest here is only reporting the truth.

THE WITNESS: That is the absolute truth.

JUDGE LAM: Right. Because, you know, I assume you're not defending any position. You know, double is double, right? I mean, so --

THE WITNESS: Correct. But I -- but I -- the only reason why I tried to emphasize when we do the post analysis evaluations is that in which way when we look at the sensitivity results, I basically ask himself the bottom line questions: have we included all the cases that we need to study?

And if the answer is yes, it's good. But then there's also the next question is that for all the cases that we do not consider, would that change our baseline conclusions?

And those two are very critical issues for us, and that's why the process that we choose to evaluate the analysis results are very essential.

JUDGE LAM: And that's, I mean, the same context. That's the reason I would think that you are a strong believer in shake table test because one way or another it will validate or disprove your motto.

THE WITNESS: Yes, sir.

MS. NAKAHARA: Your Honor, may I ask my one question?

CHAIRMAN FARRAR: Yes.

MS. NAKAHARA: That I now remember.

MR. TURK: Could I just ask one quick follow-on to Judge Lam?

CHAIRMAN FARRAR: On this subject?

MR. TURK: Yes.

CHAIRMAN FARRAR: Go ahead.

FURTHER REDIRECT EXAMINATION

BY MR. TURK:

Q It would validate or invalidate the results, assuming the results of the shake table test were -- what's the word? -- properly produced; some of the output of the shake table test was a good output?

That's inherent in your answer, correct?

A If you don't mind me to substantiate a little bit, if we do have a set of test results, that would help us either to confirm our analysis model, and if we do observe any discrepancies, it would help us to -- it would guide us to improve our model.

CHAIRMAN FARRAR: Except Mr. Turk's point is you have a model that gives a certain result. The shake table gives a different result. That could mean your model is wrong or it could mean the shake table is wrong.

THE WITNESS: I like yours, but I think if you have two groups of people in the room, I think you will have different arguments from each one of them.

MR. TURK: Maybe the best way to ask you is this.

BY MR. TURK:

Q You referred to the Japanese eight meter by eight meter shake table, and you indicated they had problems with their feedback, with their output that required them now to try to put in substantial modifications. If you had used that shake table with its questionable output, would that have confirmed, either validated or invalidated your model, or would that reflect perhaps a problem in the shake table test output?

A My response to your statement is that I always stated that a bad test result is worse than no test result.

MR. TURK: Thank you.

CHAIRMAN FARRAR: Go ahead, Ms. Nakahara.

FURTHER RECROSS EXAMINATION

BY MS. NAKAHARA:

Q Dr. Luk, in response to a question to Mr. Gaukler, you've essentially agreed that the amount of displacement of a freestanding cask is most sensitive to the level of ground motion, correct?

A Yes.

MR. TURK: I think he said amplitude.

THE WITNESS: The amplitude.

BY MS. NAKAHARA:

Q But you cannot quantify the relationship between the level of ground motion and the amount of displacement of a freestanding cask without actually running it through your model with specific input parameters; isn't that correct?

A That is the test that we currently have, is precisely to answer your question. That means going through generic flow spectrum analysis, will try to answer your question.

MS. NAKAHARA: Thank you.

Thank you, Your Honor. I have no further questions.

MR. TURK: I have one, Your Honor.

CHAIRMAN FARRAR: Go ahead.

MR. TURK: And first let me apologize to Ms. Nakahara. She referred to Table 4 in one of her questions, and I misread that. I thought it was a 10,000 year return period. In fact, it is a 2,000 year return period. My pages have become stuck together, and I was looking at the next page.

FURTHER REDIRECT EXAMINATION

BY MR. TURK:

Q But now that she's raised the issue of Table 4 and she's asked you to compare upper bound and lower bound soil profiles, could we first look at Tables 2 and 4 and confirm that those, in fact, show the best estimate -- I'm sorry. Look at Tables 3 and 4 in your report.

Table 3 is lower bound soil properties for the 2000 year return period at Pacoima Dam, whereas Table 4 is the upper bound soil properties for those two earthquakes, correct?

A Yes.

Q If you would take a look at the values for Young's modulus shown for the different soil levels.

A Yes.

Q Do you see Level 2 where the lower bound Young's modulus was on the order of 6,800, whereas the upper bound in Table 4 was 17,700?

A Yes.

Q And, again, for Level 3, the comparison would be between 19,500 Young's modulus versus 51,700, correct?

A Yes.

Q And again, that goes on for Levels 4, 5, and 6. For each level there's a substantial increase in the Young's modulus between the upper bound and lower bound soil profiles, correct?

A Yes.

Q Culminating, for instance. for the 50 foot layer of Level 6 in a difference between 306,000 psi and 1,224,000 psi?

A Yes.

Q Again, Table 8, which Ms. Nakahara referred to, reflects the net difference in cask displacement and cask rotation for the upper bound and lower bound if we look at the last two lines or last two cases shown on Table 8, that is, a lower bound model Type 1 versus upper bound model Type 1, correct?

A Yes.

Q And that's where those values were input, and the values that we're just discussing, the Young's modulus variations between upper bound and lower bound soil profiles; the net effect of those, what's the damping ratio differences that you mentioned to Ms. Nakahara?

A Yes.

Q That is what is shown as this net difference in displacement and rotation, something on the order of -- for the U2 direction of approximately a two inch difference in displacement and minuscule difference in rotation, correct?

A Yes.

Q And in fact, I --

CHAIRMAN FARRAR: What was the answer?

THE WITNESS: Yes.

BY MR. TURK:

Q And does this, in fact, show a trend that would support your view that by using a lower Young's modulus, you would, in fact, be lowering the amount of cask rotation and cask displacement?

A Yes, yes. But there's a change on mindset. I mean, you know, in the static sense, it's absolutely true, but in a dynamic sense it's -- it's -- we say we think of bounds, but whether it will have small variations is -- that is the reason for the model calculations.

Q Well, in conclusion then you're satisfied that whatever the differences are, they would be very minor and would not affect your bottom line conclusion that there will not be excessive sliding of the cask; there will not be cask tip-over for the 2000 year design earthquake year?

A Yes. But also if you don't mind me saying one more thing is that when we deal with natural geological material, like soil, whatever clays, we have to understand they are not homogeneous body. Okay? There's huge variation from location to location and within, say, you know, a couple feet of areas. There's changes over there.

So I feel it's our task to try to capture the order of the problem instead of the absolute value that generated from the problem, and in our way of doing sensitivity analysis, we conclude that we have actually captured the order of the response.

MR. TURK: Thank you, sir.

CHAIRMAN FARRAR: Mr. Gaukler? State?

MS. NAKAHARA: Thank you, Your Honor, no.

CHAIRMAN FARRAR: Thank you, Dr. Luk. Can we excuse Dr. Luk? No, he's got to stay?

MR. TURK: Yes. I'm not sure what the

State intends now with respect to additional rebuttal by Dr. Bartlett. I would ask Dr. Luk to remain with me if the State does conduct any such additional rebuttal.

MS. CHANCELLOR: Yes, we intend to put Dr. Bartlett back on, Your Honor.

CHAIRMAN FARRAR: Okay. Then, Dr. Luk, we thank you for your testimony, and eventually you'll be excused from the proceeding.

THE WITNESS: Thank you.

(The witness was excused.)

CHAIRMAN FARRAR: Does the staff have -- I think that was a surrebuttal. Does the staff have anymore witnesses?

MR. TURK: I'm sorry, Your Honor?

CHAIRMAN FARRAR: Do you have anymore witnesses in this phase? I think this was surrebuttal to Dr. Bartlett.

MR. TURK: Is the State putting on Dr. Bartlett for additional surrebuttal?

CHAIRMAN FARRAR: No, no. Right now --

MS. CHANCELLOR: Rebutting what Dr. Luk put on.

MR. TURK: Right. Without hearing Dr. Bartlett, I don't know if we'll be asking Dr. Luk to appear again.

CHAIRMAN FARRAR: No, no, I mean do you have any other --

MR. TURK: No.

CHAIRMAN FARRAR: -- any other witness.

MR. TURK: For Part D of the contention?

CHAIRMAN FARRAR: Right.

MR. TURK: No.

CHAIRMAN FARRAR: At this point. All right. Then the State. Do you want to put Dr. Bartlett on?

MS. CHANCELLOR: Yes, please, Your Honor.

CHAIRMAN FARRAR: Okay.

Whereupon,

DR. STEVEN BARTLETT

was recalled as a witness by counsel for the State and, having been previously duly sworn, was examined and testified further as follows:

DIRECT EXAMINATION

BY MS. CHANCELLOR:

Q Good morning, Dr. Bartlett.

A Good morning.

Q Is cohesion a material property?

A Yes, cohesion can describe the sheer strength or resistance to sliding within a material.

So maybe the shear resistance within a failure plane that develops within a clay, yes.

Q Is it also an interface property?

A Yes, tic an be also. If you have two dissimilar materials, for example, in this case maybe a cement treated soil placed on top of a clay, the cohesion is used at least in our terminology to explain the strength of the bond at the interface between these two materials.

Q So it can be used to describe interface conditions?

A Yes, it can. It describes the resistance to shear at an interface, and that interface can be of two different, dissimilar materials, but it is the strength of the bond that develops between the two materials. In this case that we're talking about that bond is developed by cement.

Q And has it also been used to describe the interface conditions between two dissimilar bodies, such as soil and concrete?

A I think I just answered that, but, yes. It would --

Q I'm going down my --

A -- also be used as a description of the resistance to shear between concrete and a soil, particularly if there's cement involved.

Q Is it proper to use Coulumb's law of friction to model the interface between the clay and the cement treated soil layers?

A My understanding of that is that the use of Coulumb's law of friction to model the resistance to shear between two interfaces is appropriate when the interface derives its primary strength of resistance to shear from friction. We've discussed this quite at length. I understand that in the modeling that Dr. Luk has done, that he's selected to use Coulumb's law of friction to describe the resistance to shear at that interface.

My opinion on that is that's probably a modeling expediency that's done in modeling the interface conditions. It's a model expedience put on by the finite element code, and it may from a modeling viewpoint have some advantage, but the reality of the situation is that at these interfaces at least for these materials where we're using cement, the cement treated soil and concrete that derive their primary resistance to shear from bonding, that these interfaces are described best by the strength of that bond which I am referring to as cohesion.

Q And the strength of that bond at the

interfaces between the soil, Bonneville clays, and the cement treated soil, the cement treated soil and under the pad; do those bonds rely upon the frictional properties of the soil?

A Not initially. The strength of the bond is a function of the strength of the cement, and if the horizontal force is sufficient to break that bond, then the resistance to shear along those interfaces then could be somewhat a function of friction.

Q We heard testimony about best estimate, lower bound and upper bound soil properties. These were developed at the PFS site by Geomatrix; is that correct?

A That is correct. Those were derived from shear wave velocity measurements, P wave velocity measurements.

Q And Dr. Luk used those Geomatrix upper, lower, and best estimate soil bounds in his model, and they are described in Table 8 and also Tables 2, 3, and 4 of his report; is that correct?

A That is my understanding, that the dynamic properties for modeling the dynamic response to the system, those properties were provided to Dr. Luk. The source of that data would be the Geomatrix report.

Q Cohesion effects included in the soil

properties that were developed by Geomatrix and used by Dr. Luk in his model?

A No. When one does dynamic modeling, cohesion is not inherently included in the dynamic properties. The properties required for doing dynamic soil modeling are generally the shear modulus. If you want to relate shear modulus and -- well, let me back up.

Generally, just shear modulus. The shear modulus is estimated generally from the shear wave velocity and the density of the soil. Sometimes Poisson's ratio is needed. Then also the damping characteristics of the soil, some function to explain what is the damping of the soil. Those are generally what are used.

But cohesion was not developed by Geomatrix. The cohesive strengths of these properties, of these materials, has been explored by Stone & Webster and are found in the pad sliding analyses, but they would not have been transmitted as part of those dynamic properties that were given to Dr. Luk.

Q Have you conducted -- in your practice, have you conducted any dynamic response analyses for soils?

A Yes.

Q And could you comment on Dr. Luk's modeling of the Bonneville clays as an elastic body?

A I'm not sure. I think Dr. Luk's position, as I heard him explain, and I'm willing to accept that position, that treating it as an elastic body may have been a modeling expediency. The clays do have to have an chance and in my opinion can reach the plastic state, and it's something that they want to explore further on and refine their models.

But my position is that, yes, there's a distinct possibility that the Bonneville clay layer can reach a plastic state.

Q So treating them as entirely elastic in the model may not reflect reality at the PFS site?

A It may not reflect what could happen under severe earthquake loadings, and in the upper part of the Bonneville clay as these clays try to resist those severe earthquake loadings.

Q Getting back to our favorite topic, interfaces --

A Yes.

Q -- is it proper to treat the interfaces that we've been talking about as purely frictional as done in Dr. Luk's model?

A The bond that develops between the cementitious materials, if PFS meets its design intent is considerable. In fact, the PFS design intent, as I understand it, is to make this bond significantly strong that it precludes failure along the interfaces and will force the shear failure into the material.

Q So super Super Glue?

A Well, I wouldn't say super Super Glue, but --

Q Okay.

A -- adequately strong enough that the shear failure plane or this interface that develops between shearing cannot be at a contact between two materials, but will force the shear failure into the clay.

Q Do the relevant displacement parts in NRC Exhibit YY show sliding?

A They may. It's hard to tell because in YY we do see a change in the response. The displacements are fairly small, but we do see a change in the displacement response.

We must also keep in mind that the cases that were run there also have the soil cement abutting the pad. So the system is constrained. So sliding may be initiating, but it's constrained also on both sides by the soil cement buttress. So the displacements may not be very large.

Q So could the relevant displacements be geared to that buttressing effect of cement treated soil cement?

A No, that's not what I envision. The relative displacements, as we heard yesterday some discussion whether they're elastic, whether they're actually the initiation of sliding, it's just -- it's really difficult to tell.

Q So could you tell whether any energy is being dissipated by sliding?

A No, not completely, but there may be some.

Q And can you estimate how this may be impacting the response of the cask from these figures?

A No, I cannot.

Q Have you seen any relevant displacement time histories for the cement treated soils and soil interface?

A No, I don't think the interface that we looked at yesterday was the interface between the pads and the top of the cement treated soil. We have not seen any relative displacement plots, I believe, for the interface between the cement treated soil and the Bonneville clay.

Q Could sliding be occurring at this

interface?

A It could. It's possible. There were interface nodes that were placed there that would allow it.

Q In Exhibit YY, NRC Exhibit YY, did Dr. Luk show the relative displacements corresponding to the worst case?

MR. TURK: Objection. What is the worst case?

MS. CHANCELLOR: Doctor --

THE WITNESS: In my understanding, the case --

MR. TURK: My objection is just to make the question clear.

CHAIRMAN FARRAR: Right.

BY MS. CHANCELLOR:

Q In Dr. Luk's report, Exhibit YY, he used Mu 1 equal to 0.8 and Mu 2 equal to 1.0, correct?

A That's my recollection, that the -- at least the Mu 2 interface coefficient of friction value for that was 1.0, and I think it was also, as I recall, for lower bound dynamic soil properties.

Q Would you consider this to be the worst case?

A No, I cannot tell. As we've discussed

previously, the response of the system is a function of the stiffness of the soil column. The lower bound dynamic soil column was used in that case. Whether that represents the most severe loadings, I cannot tell. The most severe loadings may come from the upper bound case. I don't know.

Q If Dr. Luk used the Mu 2 value of 0.31, would that be maybe not worse but --

A Well, it would introduce more potential for sliding, sure, because it's a lower coefficient of friction.

Q So you believe the relative displacements may increase if Dr. Luk used a Mu 2 value of 0.31 in plotting Exhibit YY?

A Sure, in a hypothetical case, that would happen.

Q Moving to Young's modulus, Mr. Turk asked Dr. Luk a number of questions about change in stiffness and how it affects cask response. Do you have any comment on change in stiffness and cask response?

A The change in stiffness of how you change the stiffness in a dynamic system, in a nonlinear dynamic system is somewhat hard to guess at. Let's just think of it as a three layer system simply.

Let's think of bedrock, soil, and a cask pad system that's up above. So we've got three systems here.

The earthquake has a certain amount of energy coming in at different frequencies. So we have to consider its frequency content and where -- at what frequency content does it have most of its excitation? The soil column and its stiffness, depending on whether it matches the frequency of motion coming in from the bedrock can either amplify or deamplify the motion, depending on its stiffnesses, and then we have a pad cask system that has its own frequencies and harmonics.

So making simple judgment about whether stiffening one part of the system increases or decreases the response is extremely difficult. That's why I just don't second guess these analyses. That's why I don't proffer opinions, because I have to look at the frequency response of the bedrock motion, how the soil filters or changes that motion, and then we have a cask pad system that has its own frequencies at which it's going to be excited.

Q So you don't believe -- is it true that using a higher Young's modulus for the cement treated soil at 75,000 psi, that would not necessarily introduce conservatism into the model; is that true?

A I think, to be fair to what I just explained, I'm not going to proffer a guess.

Q Turning to the earthquake time histories that Dr. Luk used in his model, in the realistic case, the Pacoima Dam earthquake that Dr. Luk used, was that sufficient --

MR. GAUKLER: I think this goes beyond the scope of the redirect. I don't think there was any talking about that in terms of Pacoima Dam by either Mr. Turk or myself, and so I would object to this.

MS. CHANCELLOR: I'd put Dr. Bartlett on as a rebuttal witness then, Your Honor.

MR. GAUKLER: I'm sorry. I withdraw.

(Laughter.)

MR. GAUKLER: I stand corrected.

MR. TURK: But actually that's the wrong conclusion because, Judge Farrar, at the conclusion of the initial rebuttal testimony by Dr. Bartlett in Salt Lake City, it was very clear that the State was given an opportunity to present their entire rebuttal case. You explicitly stated, "That's it. That's the conclusion of the State's rebuttal."

Ms. Chancellor said yes, and it sounds like what she wants to do now is take back that commitment that that was the end of her rebuttal.

What would be proper is for Dr. Bartlett to address what we discussed in Dr. Luk's surrebuttal and nothing more. Otherwise we're voiding the entire effort of trying to define the rebuttal testimony back in Salt Lake City.

MS. CHANCELLOR: May I comment, Your Honor?

CHAIRMAN FARRAR: Yes.

MS. CHANCELLOR: I have one, two, three -- I have four very brief questions. The question of the Pacoima Dam earthquake came out in Dr. Luk's testimony. I don't know what various phase it was, but somewhere here in Rockville, and --

CHAIRMAN FARRAR: Does it relate, the question you're asking, relate to Dr. Luk's tables we've been discussing this morning, which I think are based on Pacoima Dam? Mr. Gaukler, do you --

MR. GAUKLER: I think what she's saying, it relates to Dr. Luk's testimony on Pacoima Dam yesterday, and if it's rebutting that, then it's proper. If it's directly addressed to what he said yesterday, I have no objection.

MR. TURK: The same for me, Your Honor.

CHAIRMAN FARRAR: All right. Then let's go ahead. Thank you.

BY MS. CHANCELLOR:

Q With respect to the Pacoima Dam earthquake used by Dr. Luk, was that sufficient to be used as the design basis earthquake?

MR. TURK: Objection.

BY MS. CHANCELLOR:

Q As a design basis earthquake?

MR. TURK: Objection. Dr. Luk indicated that he did not use that as a design basis earthquake. He used it as a realistic case. That was --

MS. CHANCELLOR: Could Mr. Bartlett help -- Dr. Bartlett help me ask the right question?

CHAIRMAN FARRAR: Ms. Chancellor, the form of that question is improper. We're not talking design basis earthquakes.

MS. CHANCELLOR: Okay. Got it. Thank you, Steve.

(Laughter.)

MS. CHANCELLOR: If I changed "design" to "evaluation," would that --

CHAIRMAN FARRAR: Go ahead, Dr. Bartlett.

MR. TURK: Can I ask I often would wish my witness would ask himself the question and give the answer?

(Laughter.)

BY MS. CHANCELLOR:

Q Okay. Is the Pacoima Dam earthquake used by Dr. Luk sufficient to be used as an evaluation basis earthquake?

MR. TURK: If you understand the question.

(Laughter.)

THE WITNESS: No, I'm seeing if I can answer it the way I want to without an objection.

MS. CHANCELLOR: I've got the next question.

THE WITNESS: I understand the reasons why Dr. Luk used the Pacoima Dam record, and I think from a modeling perspective I have no issues with that. One would like to run a real time history through and see the effective of that. The issue I would have of using the Pacoima Dam record to draw inferences about the PFS site is because it hasn't been matched to a target spectrum, and so it may not meet the intent of the design, and I know that it's not been used for a design intent.

BY MS. CHANCELLOR:

Q When you say "target spectrum," has it been matched to the design spectra for the PFS facility?

A Not, that was not spectrally matched.

Q Can it be, in your opinion, can it be used to fulfill the requirements of using multiple time histories, such as an ASCE 498?

A No.

MR. TURK: Objection and move to strike. That's way beyond anything we've covered. And I would ask that it be stricken especially in light of the conversation we just had about the proper scope of the rebuttal testimony. I think that's an improper attempt to exceed the permissible scope.

CHAIRMAN FARRAR: Ms. Chancellor, restate the question please or just repeat it.

MS. CHANCELLOR: Can the Pacoima Dam be used to fulfill the requirements of using multiple time histories as provided in ASCE 498?

CHAIRMAN FARRAR: Mr. Turk, elaborate on the objection, please.

MR. TURK: Dr. Luk has not testified about ASCE 498, either here or in Salt -- or previously. This is an entirely new issue, never raised before. It certainly exceeds the scope of what Dr. Luk addressed in his surrebuttal testimony, which bounds whatever the State may be permitted to ask here. It's a new issue raised by the state that's improper, and we've just had a discussion, Your Honor, about the proper bounds of the rebuttal.

This is clearly outside the scope and should be stricken.

CHAIRMAN FARRAR: Ms. Chancellor, it sounds quite new.

MS. CHANCELLOR: I believe that the staff in the report -- Dr. Luk in his report claims that he's used three sets -- three sets of time histories, and I'm just trying to -- this is my last question, and I'm just trying to understand. I'm just asking Dr. Bartlett following up on the design spec -- match of the design specter whether this time history would fulfill the requirements of ASCE 498.

MR. TURK: I don't think that --

MS. CHANCELLOR: This is my last question.

MR. TURK: That doesn't address my objection.

(Pause in proceedings.)

CHAIRMAN FARRAR: We're going to sustain the staff's objection on the grounds of being outside the scope, and I think that we're at diminishing returns, and I'm concerned that if we allow the question, then we'll start another round here. And I think we need to terminate this.

That was your last question, Ms.

Chancellor?

MS. CHANCELLOR: Yes, Your Honor, it was.

CHAIRMAN FARRAR: Okay. Cross by the staff?

MR. TURK: May we take a few minutes or perhaps take the morning break?

CHAIRMAN FARRAR: Oh.

MR. TURK: I only need about three of four minutes to talk to Dr. Luk, but maybe a break is a good thing at this point.

CHAIRMAN FARRAR: All right. That makes sense.

It's 18 after. Let's come back at half past.

(Whereupon, the foregoing matter went off the record at 10:18 a.m. and went back on the record at 10:32 a.m.)

CHAIRMAN FARRAR: Mr. Turk, what have you concluded?

MR. TURK: I think we are at the point, we were going to take my cross examination.

CHAIRMAN FARRAR: Right.

MR. TURK: I have roughly five minutes.

CHAIRMAN FARRAR: All right. Go ahead.

MR. TURK: I would ask the witness to take the witness stand.

(Laughter)

MR. GAUKLER: He started asking the questions. I think he liked --

CHAIRMAN FARRAR: Well, during the break, the Board debated whether we want to go to the Jeopardy format, and give the answers and someone come up with the questions.

MR. TURK: Dr. Bartlett, I only have a few questions for you.

DR. BARTLETT: Yes, Mr. Turk.

CROSS EXAMINATION

MR. TURK: First of all, I want to make sure I understand part of your testimony. You were talking about the data given to PFS, I guess to the rest of us, by Geomatrix.

DR. BARTLETT: Yes. That would be the dynamic properties for the soils.

MR. TURK: When you say they gave -- and you believe they gave the dynamic properties?

DR. BARTLETT: They developed the dynamic properties, so I assume wherever they came from, they had to come from Geomatrix.

MR. TURK: Okay. And when you say they gave the dynamic properties, I guess you'd be referring to the fact that the properties would include the dynamic shear modulus?

DR. BARTLETT: The shear modulus, the dynamic shear modulus. The way this modeling is done is the low strain dynamic shear modulus is estimated from the shear wave velocity and the density of the soil. Then you also have to have a relation that degrades the dynamic shear modulus as a function of strain, and those are also provided, I would assume, as part of the modeling package.

MR. TURK: And then whether or not there was cohesion within the clay material in the foundation, you wouldn't get that from those data?

DR. BARTLETT: No, you would not.

MR. TURK: You would actually need to see the earthquake excitations --

DR. BARTLETT: The cohesion --

MR. TURK: -- and then you would be able to measure the cohesion?

DR. BARTLETT: I think we're confusing things a little bit. The cohesion is not a normal dynamic property that one provides for these analyses. The cohesion is shear strength property, and it's measured by a static test. Well, it can be measured by a cyclic test, but those shear strength properties were developed in a program through Stone and Webster.

MR. TURK: You were describing Dr. Luk's use of the Coulomb Law of Friction in his model. I believe you stated you thought this was a modeling expediency, which was required or use because of the code.

DR. BARTLETT: Well, I'm just saying that it was -- I'm not sure if it's -- I'm not going to say it's a limitation of the code. I don't know the code. It just seems to have been used as a way to describe these interfaces for some modeling purpose. I'm just putting out the point that the real interface conditions is the bond.

MR. TURK: When you use the word "expediency", could another way to describe that be to say it's a modeling technique, rather than a modeling expediency? You're not saying that there are some expediency sought by the use of the Coulomb Law of Friction in the model, are you?

DR. BARTLETT: That's probably a question better put to Dr. Luk, but there might be some reason why the selection of a high coefficient of friction, say for one, felt that that captured a bonding condition, I don't know, but my position is it's a bond, and it doesn't derive its interface strength from friction. It's bond.

MR. TURK: So whether it's an expediency or not, you really don't know because you're not familiar with the code, or why that --

DR. BARTLETT: That's true. I'm not familiar with the Abaqus Code, and how it models all of these interfaces. I'm just putting my position, what's actually to be created in reality through the construction process.

MR. TURK: Is it fair to say that you have not done any quantitative calculations or modeling on your own to verify the correctness of Dr. Luk's model?

DR. BARTLETT: Oh, no. I would not do anything like that.

MR. TURK: I have nothing further. Thank you.

CHAIRMAN FARRAR: Thank you, Mr. Turk. Mr. Gaukler

MR. GAUKLER: About five minutes, Your Honor.

CHAIRMAN FARRAR: Okay.

MR. GAUKLER: Dr. Bartlett, you mentioned that you don't second-guess the results of dynamic analyses. Correct?

DR. BARTLETT: I don't second-guess the

results of --

MR. GAUKLER: You said something, you don't second-guess the results of these analyses.

DR. BARTLETT: Well, I think in the context we're talking about, is how stiffness affects the amplitude or energy of the system.

MR. GAUKLER: And it's true that you haven't done any type of modeling with respect to the dynamic analysis of cask stability conditions. Correct?

DR. BARTLETT: I don't model casks and pads. I just model soils, yes.

MR. GAUKLER: And you haven't done any finite element modeling. Correct?

DR. BARTLETT: That's not correct. I have done finite element modeling.

MR. GAUKLER: No dynamic finite element modeling.

DR. BARTLETT: That is correct.

MR. GAUKLER: You also claim that cohesion was not a property that could -- was included in the model. Is that what you're saying?

DR. BARTLETT: No. My understanding was, is that there was an implication that the properties, the dynamic properties given to Dr. Luk and his team to do the dynamic modeling somehow inherently included cohesion. That is not true.

MR. GAUKLER: But you can evaluate or approximate cohesion from the soil properties that they were given. Correct?

DR. BARTLETT: No. They were dynamic soil properties.

MR. GAUKLER: So you can't --

DR. BARTLETT: You cannot.

MR. GAUKLER: So you cannot.

DR. BARTLETT: You cannot evaluate --

MR. GAUKLER: Okay.

DR. BARTLETT: -- cohesion from dynamic soil properties. And let me define what those dynamic soil properties are, so we don't go too far into this. They are the maximum shear modulus, the density of the soil, Poisson's ratio, and some way of estimating shear modulus degradation and damping degradation with a function of a strain. Those are the dynamic properties.

MR. GAUKLER: Now you don't know how the Abaqus Code takes those dynamic properties and incorporates them into the model. Correct?

DR. BARTLETT: It would be very surprising to me, and I know --

MR. GAUKLER: I asked you a specific question.

DR. BARTLETT: I know of no theory of getting from a dynamic soil property to cohesion.

MR. GAUKLER: I just asked you a simple question.

DR. BARTLETT: Okay.

MR. GAUKLER: You don't know what Abaqus, how Abaqus takes those soil properties to incorporate them into the model, do you?

DR. BARTLETT: I would be very surprised if Abaqus could account for the cohesion properties, which are shear strength properties of these soils, from dynamic properties.

MR. GAUKLER: I just asked you a simple question. The answer, I take it, is no?

DR. BARTLETT: I would believe that Abaqus does not do that.

MR. GAUKLER: But you don't know.

DR. BARTLETT: I do not know definitely.

MR. GAUKLER: You were also talking about the range of stiffness from soil properties, different soil properties would give different stiffnesses. Correct?

DR. BARTLETT: Different soil properties

will give different stiffness? Different soils have different stiffnesses.

MR. GAUKLER: Right. And isn't one purpose for having a lower bound, upper bound, and best estimate soil properties is to get a range of the soil properties that may exist at site, taking into account uncertainties?

DR. BARTLETT: The way that it was used by Geomatrix was to get a lower bound, upper bound, and best estimate of the dynamic soil properties at the site. That is correct.

MR. GAUKLER: And that's one way you can get a range in terms of the effect of those soil properties on your dynamic analysis.

DR. BARTLETT: A range of how the stiffnesses of the soil properties affect the dynamic response. That is correct.

MR. GAUKLER: Okay. That's one purpose of the lower bound, upper bound, best estimate soil conditions provided by Geomatrix.

DR. BARTLETT: Is to provide a variability in the dynamic properties of the soils, and how that may affect the response.

MR. GAUKLER: And that variability would include stiffness, therefore.

DR. BARTLETT: It has stiffness.

MR. GAUKLER: And you've also seen the results that Dr. Soler has run at different stiffnesses. For example, he tuned the stiffness of the spring to get a result at 5 Hertz, a natural frequency of the earthquake. Correct?

DR. BARTLETT: I'm not quite sure exactly what Dr. Soler was trying to attempt to do, but he was tuning the spring to match some frequency vibration.

MR. GAUKLER: And that was, again, changing the stiffness to what he believes was --

DR. BARTLETT: He was changing the stiffness of the spring. That's correct.

MR. GAUKLER: To what he believed was the State's position --

DR. BARTLETT: No, that has not been our position --

MS. CHANCELLOR: Your Honor --

MR. GAUKLER: I said to what he believed. Okay?

MS. CHANCELLOR: No, no. I'd object to this line of questions. There's nothing that's come up about the Holtec report, and we're talking about Dr. Luk's report, not the Holtec report, so I would object to this line of questioning.

CHAIRMAN FARRAR: Mr. Gaukler.

MR. GAUKLER: It's relevant to his concern about stiffness being taken into account in general, and that's based on my last question, as well.

CHAIRMAN FARRAR: Mr. Gaukler, just like with the State's question earlier, it sounds like this is a new subject. And even though it's your last one, I don't want to -- last question, I don't want to open up something new, so objection sustained. That was your last question?

MR. GAUKLER: Yes, it was.

CHAIRMAN FARRAR: The Board has no questions. Ms. Nakahara, any redirect?

MS. CHANCELLOR: And I have none either, Your Honor.

CHAIRMAN FARRAR: I'm sorry. Then we're done with Dr. Bartlett. Thank you again, sir.

I hesitate to say this, but is that the end of Section D?

MR. TRAVIESO-DIAZ: I believe so, Your Honor.

CHAIRMAN FARRAR: Mr. Turk and Mr. O'Neill.

MR. TURK: Your Honor, I'm talking with Dr. Luk about possibly additional surrebuttal for one or two limited points. He's resisting, but I need to ask --

CHAIRMAN FARRAR: Good. He's resisting, and he's more than likely correct, so --

MR. TURK: Can I ask him to put me on the stand?

CHAIRMAN FARRAR: No, but you should listen to him like I listen to my colleagues up here.

MR. TURK: May I consult with him just for one minute, Your Honor?

CHAIRMAN FARRAR: Go ahead.

MR. TURK: Your Honor, we have just one question and answer.

CHAIRMAN FARRAR: Do it from right over there.

MR. TURK: Okay.

CHAIRMAN FARRAR: You're still under oath, sir.

DR. LUK: Yes, sir.

DIRECT EXAMINATION

MR. TURK: Dr. Luk, in Dr. Bartlett's most recent testimony, he indicated that he didn't believe that the Abaqus Model would account for the affects of cohesion at the interface between two different -- as I understood his testimony --

MS. CHANCELLOR: Objection. It mischaracterizes Dr. Bartlett's testimony.

MR. TURK: Then I won't characterize, Your Honor. I'll simply ask the question.

CHAIRMAN FARRAR: That would be good.

MR. TURK: In your opinion, Dr. Luk, would any potential affect of cohesion at an interface between, for instance, the pad and the cement-treated soil be accounted for by use of the Mu2 factor?

DR. LUK: Let me try to answer the questions in the mechanics perspective. Probably that's the difference between different disciplines. The two disciplines that we're talking about, one is mechanics, the other one is geotech engineering. For people who are working in the structural mechanics of the interface conditions is basically described by the Coulomb's Law of Friction.

Now that actually includes some of the cohesive effect with the soil, but the subject matter on hand is that if proper numerical value of coefficient of friction has been described at the boundary, it will take care of the physical phenomena related to relative sliding at the interface. That is probably we try to model at the interface, and we did that not because of convenience. We did that because we tried to simulate physical condition.

MR. TURK: And that's with the use of 1.0 from Mu2.

DR. LUK: Yes.

CHAIRMAN FARRAR: Any cross necessary?

MS. CHANCELLOR: No, Your Honor.

MR. GAUKLER: No, Your Honor.

CHAIRMAN FARRAR: Okay. Thank you. Then that concludes Section D. Nothing more at all. Is that correct, Mr. Turk?

MR. TURK: Nothing comes to mind, Your Honor.

CHAIRMAN FARRAR: I mean, there are no more witnesses, no more rebuttal. We've heard Section D. Mr. Gaukler?

MR. GAUKLER: Yes.

CHAIRMAN FARRAR: Ms. Chancellor?

MS. CHANCELLOR: No more, Your Honor.

CHAIRMAN FARRAR: All right. Done. It's now 10 minutes to 11. We've got til 2:00 tomorrow. We're now going to do the soils part of Section C. Is there anything else we need to accomplish by 2:00 tomorrow besides that?

MR. TRAVIESO-DIAZ: Not as far as we're concerned.

MS. CHANCELLOR: Not as far as we're concerned either, Your Honor.

CHAIRMAN FARRAR: Staff.

MR. TURK: Just that I would ask that Dr. Luk be excused if we're ready to go into --

CHAIRMAN FARRAR: Right. Thank you, Dr. Luk. We appreciate your testimony and your coming back.

Okay. Let's figure out how we're going to get through this. As I understand it, each party has one witness. The soils portion of the Trudeau/Wissa testimony.

MR. TRAVIESO-DIAZ: That is correct.

CHAIRMAN FARRAR: The soils portion of the Ofoegu testimony, and separate testimony by Dr. Bartlett.

MS. CHANCELLOR: That's correct.

CHAIRMAN FARRAR: Then what will we have in terms of rebuttal?

MR. TRAVIESO-DIAZ: There will be rebuttal, which I hope to be able to distribute this afternoon, by Mr. Trudeau to the direct testimony of Mr. Bartlett.

CHAIRMAN FARRAR: That's not something you have now, so we could do it all as --

MR. TRAVIESO-DIAZ: I have the text of the testimony, and we could put it in. The only hesitation is the exhibits, which are still copying. But I guess if you are amenable to having his rebuttal testimony presented and admitted into the record now, and have the exhibits admitted later, my only concern would be that I believe what's going to happen is that the cross examination this morning is going to be on his direct. And, therefore, having the text of the rebuttal in one place, and the examination later on, may be impractical. I don't care which way we do it, but my recommendation would be that we distribute the rebuttal, and that we proceed with the examination from the direct which, of course, has been pre-filed.

MS. CHANCELLOR: That would be our preference too, Your Honor, because we haven't had a chance to review the rebuttal.

CHAIRMAN FARRAR: Ms. Chancellor, how long will your cross be?

MS. CHANCELLOR: Oh, not too long. Everyone knows everybody else's position on this one. This is part of the original contention, and in most part an hour.

CHAIRMAN FARRAR: How about the Staff?

MS. CHANCELLOR: If you've got -- Your

Honor, I'll say two.

(Laughter)

CHAIRMAN FARRAR: We knew we had a limited time where our techniques would work before you wised up to that. Mr. O'Neill, how long will your cross be?

MR. O'NEILL: Of Mr. Trudeau? It should be fairly quick. Hopefully, we can do it in half an hour or 45 minutes, if that.

CHAIRMAN FARRAR: Okay. Maybe now is the time, with people who are essentially on the same side of the case, that you just can't take that long. I mean, we call it cross, but between the Applicant and the Staff, it's -- we have to -- they're on the same side of the case you are.

MR. TRAVIESO-DIAZ: Mr. Chairman, may I make a comment?

CHAIRMAN FARRAR: Yes.

MR. TRAVIESO-DIAZ: As you know, I'm very hesitant to make predictions as to time, particularly based on prior experience, but while I was away, I tried to streamline my examination of Dr. Bartlett, who is going to follow Mr. Trudeau and Dr. Ofoegu. And I believe I can have my examination of Dr. Bartlett through in probably two to three hours maximum, and accounting for rebuttal and everything else. I am pretty confident that we can finish by 2 p.m. tomorrow, with a margin to spare, so I just want to convey to you my, not a commitment, but my strong belief that this is achievable. As Ms. Chancellor told you, this is a contention that has been with us for some time. There has been discovery. The positions of the parties are fairly well known, so I'm just advising you that I think that we can do this one fairly expeditiously.

CHAIRMAN FARRAR: But you said two to three hours.

MR. TRAVIESO-DIAZ: Well, you know, I --

CHAIRMAN FARRAR: Here's our problem. We've got eleven hours until 2 p.m. tomorrow.

MR. TRAVIESO-DIAZ: Well, let me put it this way.

CHAIRMAN FARRAR: And we've not had a good track record on the rebuttal. You know, we start with direct, and we think we've accomplished something, and we've got rebuttal, and surrebuttal, and at the rate you're talking, we're not going to get done in eleven hours.

MR. TRAVIESO-DIAZ: Well, again, of course, I can -- I'm prepared. I just don't know, because of the answers, how long the entire process will take, but I am pretty confident that we can do it.

CHAIRMAN FARRAR: How about the State's cross of Dr. Ofoegu?

MS. NAKAHARA: I have very few questions, Your Honor. A half hour to an hour, and that's on the high side.

JUDGE LAM: The way I look at the available time, Judge Farrar mentioned eleven hours. My arithmetic tells me about ten hours, from now until 2 p.m. tomorrow, assuming we have three witnesses, and so the amount of time I think to be devoted to each witness is no more than three hours, just to be realistic. Then I think the party may want to plan on that basis, no more than three hours of total time devoted per witness.

MS. CHANCELLOR: Can we use credit from one to the other?

JUDGE LAM: Sure. There's only about ten hours from now until 2 tomorrow.

CHAIRMAN FARRAR: All right. Then we'll give the State the hour they asked for on Mr. Trudeau, and we'll look to finish each witness in the three hours Judge Lam has suggested.

Go ahead, Mr. O'Neill.

MR. O'NEILL: Yeah, Your Honor, I was just going to note, a number of my questions were really aimed at just further elucidation of terms and concepts. I can certainly cut back on that. Initially, I thought the record would benefit, but I understand.

CHAIRMAN FARRAR: We don't need -- when my colleagues and I don't understand something, we tend to speak up, as you've noticed. And let's get into what needs to be resolved, for purposes of deciding the case.

Mr. Travieso-Diaz, which portion of the previously filed testimony are we looking at here?

MR. TRAVIESO-DIAZ: Yes. We are looking at Sections I through IV of the April 1st, 2002 testimony by Mr. Trudeau and Dr. Wissa. It goes through the top of page 21. And since the testimony is in evidence already, Mr. Trudeau is available for cross examination on it.

CHAIRMAN FARRAR: That's then questions and answers through number 28.

MR. TRAVIESO-DIAZ: I believe that's correct.

CHAIRMAN FARRAR: Okay. And as you've just indicated, Mr. Trudeau has previously adopted that testimony as his own, and it's been bound into the record.

MR. TRAVIESO-DIAZ: That is correct.

CHAIRMAN FARRAR: All right.

(Insert pre-filed testimony of Mr. Peter Trudeau and Dr. Anwar Wissa.)

June 20, 2002

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| PRIVATE FUEL STORAGE L.L.C. | ) | Docket No. 72-22 |
| | ) | |
| (Private Fuel Storage Facility) | ) | ASLBP No. 97-732-02-ISFSI |

# REBUTTAL TESTIMONY OF PAUL J. TRUDEAU TO TESTIMONY OF STATE OF UTAH WITNESS DR. STEPHEN F. BARTLETT ON SECTION C OF UNIFIED CONTENTION UTAH L/QQ (SOILS CHARACTERIZATION)

## A. Factors of Safety Sought to be Achieved in the Geotechnical Design of the PFSF Foundations

**Q1.** In his answer to question 13 in the "State of Utah Testimony of Dr. Steven F. Bartlett on Unified Contention Utah L/QQ (Soil Characterization)" ("Bartlett Direct Testimony"), Dr. Bartlett characterizes the PFSF as a large site with complex layering. Is that characterization accurate?

**A1.** No. PFS has made borings and performed cone penetration tests, and has taken soil samples and conducted laboratory tests, to characterize site soil conditions. All site investigations conducted by PFS have led to the determination that the site is remarkably uniform in the horizontal direction, that is, as one moves across the site. The site soils are layered vertically in the sense that there are a number of soil layers having distinct composition and physical characteristics, as is the case for most soil configurations. The overall layering arrangement (i.e., the types of soil, the general thickness and arrangement of soil layers, and the properties of the soil at each layer) are well-known and not "complex".

**Q2.** In his answer to question 15 of the Bartlett Direct Testimony, Dr. Bartlett states that the minimum factors of safety against sliding of the pads, bearing capacity failure of the pads, and sliding of the Canister Transfer Building ("CTB") are, respectively, 1.27, 1.17 and 1.26, and that as a result the soil's capacity to resist earthquake forces has only about 6 to 15 percent margin "above the value required to produce an acceptable factor of safety," from which Dr. Bartlett concludes that "variations or small decreases (about 6 to

15 percent) in the soil's strength below the values used in the design "could lead to potentially unsafe conditions." Is there any validity to Dr. Bartlett's argument?

**A2.** No. First, it must be understood that the minimum factors of safety calculated by PFS and quoted by Dr. Bartlett are factors of safety against the potential onset of the failure mechanism in question using very conservative assumptions. Thus, the minimum calculated factor of safety against sliding of the pads of 1.27 provides a margin against sliding of at least 27%. The minimum calculated factor of safety against bearing capacity failure of the pads of 1.17 provides a margin against failure of at least 17%. In addition, a factor of safety against sliding of the CTB of 1.26 provides a margin against sliding failure that is at least 26%. All of these margins are calculated using the peak force due to the design earthquake, which acts only for one brief instant in time; at all other times during the earthquake, the forces are much less than this peak value. Thus, the margin available at all other times during the earthquake will be much larger than these values, as evidenced by the factors of safety against sliding plotted versus time in PFS Exhibit WW. Even with these and other conservative assumptions, the reduction in minimum soil strength would have to be 27%, 17% and 26% before failure through one of these mechanisms became possible.

Dr. Bartlett states that a drop of 6 to 15 percent in soil strength (presumably, according to his analysis, reducing one of these factors of safety to 1.1) "can lead to potentially unsafe conditions." That is clearly incorrect. Even ignoring all the conservatisms that are built into the factor of safety estimates, a reduction in one of these calculated minimum factors of safety to 1.1 would still leave a 10% margin of safety against the failure mechanism in question, nowhere near the onset of a "potentially unsafe condition." Moreover, a reduction of a factor of safety to a value below 1.1 on account of a decrease in the calculated value of minimum shear strength would be the type of unanticipated occurrence against which factors of safety are provided.

**Q3.** What other conservatisms have been incorporated into the calculations of minimum factors of safety against sliding and bearing capacity failure such that there is additional margin against the possibility of failure of the pads or the CTB through one these failure mechanisms?

**A3.** The following are some of the main conservatisms that are built into the calculation of the minimum factor of safety (1.27) against sliding of the pads:

- PFS computed the FS against sliding using the strength of the weakest section of the Upper Lake Bonneville clay layer (also known as "Layer 2") even though soils directly under the cement-treated soil will in most cases be much stronger than those below them. The use of the weaker strength of the soil at the lower section of the layer is quite conservative because there is a stronger crust, approximately 2 to 3 ft thick, at the top of the Upper Lake Bonneville clay layer, upon which most of the pads and cement-treated soil will be founded. This stronger crust is evident in all of the foundation profiles, which are included in the PFSF Safety Analysis Report ("SAR") as Figure 2.6-5, Sheets 1 to 14. For example, referring to Foundation Profile 5–5' (SAR Figure 2.6-5 Sheet 7 of 14) (PFS Exh. 233), which is the profile running from west-to-east across the southern half of the PFSF pad emplacement area, the plots of the tip resistance data from the cone penetration tests ("CPTs") demonstrate that there is a stronger crust just below the eolian silt layer – at the top of the "silty clay/clayey silt" layer identified in the profile. (This silty clay/clayey silt layer is what is referred to as the Upper Lake Bonneville clay layer.) The undrained shear strength of these clayey soils is proportional to the tip resistance values measured in the CPTs. As shown in this figure (all other soil profiles are similar), the tip resistance values in the upper 2 to 3 ft of the Upper Lake Bonneville clay layer typically are more than twice as large as the tip resistance values measured for the soils at depths of approximately 5 to 10 ft below grade – the range of depths where the samples were obtained that were tested in the laboratory to measure the undrained strengths used in the sliding stability analyses. Therefore, giving due consideration to the fact that the strength of the soils (i.e., the stronger crust at the top of the Upper Lake Bonneville clay layer) directly beneath the cement-treated soil and pads will generally be at least twice that of the weaker underlying soils, it is reasonable to conclude that the factor of safety against sliding will be at least twice the minimum value shown above, or on the order of 2.5, without taking other conservatisms into account.

- The minimum FS against sliding of the pads was computed without taking into account the increase in strength of clayey soils that occurs under cyclic dynamic loadings. Taking credit for this well-known phenomenon would increase shear strength by at least 50%, thus increasing the minimum factor of safety against sliding to 1.9 (or a margin of or 90%), again without taking other conservatisms into account.

- The minimum FS was computed without taking into account the passive resistance of the soil cement around the pads. Taking credit for that passive resistance would increase the FS of the design base case from 1.27 to 3.3, without considering other conservatisms.

- All these increases in the minimum FS are independent of each other and, thus, their effects are cumulative. Combining their effect would lead to a minimum FS against sliding of the pads of at least 5.

Likewise, the minimum factor of safety against bearing capacity failure of the pads is 1.17. This minimum factor of safety was also computed using many conservative assumptions:

- PFS computed the minimum FS against bearing capacity failure using the strength of the weakest section of Layer 2, even though for bearing capacity computations the standard practice is to average the contributions of all soil layers over a depth equal to the shortest dimension of the foundation, or thirty feet in the case of the pads. However, as discussed above, the soils directly under the cement-treated soil layer will in most cases be much stronger than those below them, and the presence of a 1 to 2 ft thick layer of cement-treated soils directly beneath the pad will also increase the allowable bearing capacity of the underlying soils. In addition, the soils below the Upper Lake Bonneville clay layer (i.e., the layer labeled "clayey silt/silt & some sandy silt," as well as the underlying layer of "silty clay/clayey silt" shown in the foundation profiles) (see, e.g., PFS Exh. 233), which represent close to two-thirds of the profile and which are much stronger than the soils from the Upper Lake Bonneville clay layer, were conservatively also assumed to have the same strength as the weaker Upper Lake Bonneville clay layer. The increase in minimum FS to account for these effects would be more difficult to compute than in the case of the factor of safety against sliding, but it would nonetheless be quite significant.

- The minimum FS against bearing capacity failure of the pads was computed without taking into account the well-known 50% or greater increase in soil strength that occurs under cyclic dynamic loadings. Taking this increase into account would boost the FS against bearing capacity failure from 1.17 to 2.6.

- The minimum FS was computed using the extremely conservative assumption that 100% of the earthquake loads act in both horizontal directions at the same time. If load combinations allowed by ASCE 4-86 were used instead, this would increase the factor of safety against bearing capacity failure from 1.17 to 2.1.

- All these increases in the minimum FS are independent of each other; thus, their effects are cumulative. Combining these effects (without attempting to quantify the increase due to the strength of the soils which underlie the pad and the cement-treated soil) would lead to a minimum FS against bearing capacity failure of the pads of at least 3.6.

There are many other conservatisms built into the estimate of FS against sliding or bearing capacity which are more difficult to quantify, but which nonetheless further increase the real margin of safety. For example:

- Any measurement of the strength of soils that is obtained by performing laboratory tests on soil samples will, by necessity, disturb the samples to some degree and result in a strength measurement that is less than the actual strength that the soils will exhibit in situ. Studies performed at MIT have demonstrated that carefully conducted unconsolidated undrained triaxial tests performed on high quality undisturbed samples of saturated clays yielded undrained shear strengths that ranged from 50% to 80% of field measured strengths.

- The minimum FS is applicable only during the brief period in which the earthquake reaches its peak magnitude. At all other times, there is considerable more margin available, as discussed above.

Because of the existence of these quantifiable and non-quantifiable conservatisms, the concern expressed by Dr. Bartlett about the potential effect of a reduction in minimum soil strength on the safety of the pads is unfounded.

Similar conservatisms exist with respect to the factor of safety against sliding failure of the CTB; thus the concerns about the potential effect of a reduction in minimum soil strength on the sliding stability of the CTB are also unfounded.

**B. Spacing of Borings for Pad Emplacement Area**

**Q4.** In answers 16 through 18 of the Bartlett Direct testimony, Dr. Bartlett alleges that the number of borings made by PFS for the pad emplacement area is insufficient because the borehole and cone penetration test spacing is approximately 221 feet apart instead of the 100 feet spacing recommended in Reg. Guide 1.132. Does the boring spacing cited by Dr. Bartlett constitute a deficiency in PFS's soils characterization program?

**A4.** No. No such deficiency exists. In the first place, as its title indicates, Reg. Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants" is a guidance document issued by the NRC Staff with respect to soils investigations for the foundations of nuclear power plants. It does not apply to Part 72 facilities such as the PFSF. Indeed, the NRC guidance document of Independent Spent Fuel Storage Installations ("ISFSIs"), NUREG-1567, does not specify any recommended boring spacing for ISFSIs.

In addition to not being applicable, Reg. Guide 1.132 need not be used for soils investigations for structures such as storage pads because they are significantly different than nuclear power plant structures in the following respects:

- Nuclear power plant buildings are typically large and heavily loaded structures. By comparison, the storage pads are relatively small and lightly loaded.

- Nuclear power plant structures, systems and components contain interconnected safety-related piping, electrical cable, conduit and other components which are often buried and which are sensitive to building movements. Therefore, the soils beneath nuclear power plant structures require detailed characterization of soil conditions. Storage pads are free-standing and do not include any buried components or safety-related connections to other structures.

Even if the guidance in Reg. Guide 1.132 were to apply, the guide makes it clear from the outset that its recommendations should be only considered guidance "and should be tempered with professional judgment. Alternative and special investigative procedures that have been derived in a professional manner will be considered equally applicable for conducting foundation investigations." PFS Exh. 234 (Reg. Guide 1.132), at 1.132-1. PFS elected to follow the guidance in Reg. Guidance 1.132 with respect to the borings in the CTB because that building is somewhat analogous to a nuclear power plant structure. For the pads, however, PFS exercised professional judgment and developed a subsurface investigation program which combined the drilling of boreholes and the performance of cone penetrometer tests and geophysical testing to the extent warranted by site conditions and the size, loading, and isolation of the storage pads. The elements of the professional judgment that PFS exercised in implementing its boring program for the storage pads included:

- PFS conducted an initial set of borings in 1996 which served to establish that the soil properties were reasonably uniform across the pad emplacement area of the PFSF site.

- Based on these initial results, PFS determined that it was sufficient to drill boreholes in a uniform grid across the entire pad emplacement area, so that all sections of the area were covered. Such a grid was subject to supplementation with additional borings, should anomalous or irregular conditions be encountered, but no such conditions were identified.

- Standard penetration tests were conducted that provided estimates of soil strength and compressibility and allowed visual inspection of samples and index property testing of the samples in the laboratory. These inspections and tests confirmed that the subsoil characteristics are uniform and consistent across the pad emplacement area.

- As the borings were made, standard penetration tests were performed. The "blow count" values required to drive the standard split-spoon sampler into the soil at various depths were consistent across the pad emplacement area and identified the Layer 2 soils as the critical layer with respect to the stability and settlement of the structures.

- Cone penetration tests performed subsequently yielded essentially the same value of tip resistance for comparable depths at various locations across the pad emplacement area, indicating that the stratigraphy across the site is uniform.

- Because no significant variations in soil conditions were encountered, the initial decision to provide a broad grid was retained. At the end, the borehole and CPT spacing of approximately 221 feet testified to by Dr. Bartlett was achieved and deemed sufficient to properly characterize the pad emplacement area.

In my opinion, the above described program would meet the intent of Reg. Guide 1.132 if the guide were applicable to the soils investigations at the PFSF.

**Q5.** Assuming the guidance in Reg. Guide 1.132 were applicable and the borings program implemented by PFS failed to satisfy it, what would be the safety significance of such a failure?

**A5.** There is no significance to having lower density of borings than called for in Reg. Guide 1.132 because the subsoil in the pad emplacement area is reasonably uniform across the area and its characteristics have been fully determined through the subsurface investigations conducted by PFS.

**C. PFS's Soil Sampling Program**

**Q6.** In his answer to question 18, Dr. Bartlett opines that the pad emplacement area has been "significantly undersampled" in terms of retrieving soil samples for testing, and asserts that "[t]his undersampling is even more acute when one considers that only nine boreholes (A1, B1, C1, A2, B2, C2, A3, B3 and C3) were drilled in or near the pad emplacement area for the purpose of retrieving samples for laboratory testing and analysis." Are Dr. Bartlett's assessments correct?

**A6.** No. Dr. Bartlett's opinion that the pad emplacement area has been significantly undersampled is incorrect. Moreover, the assertion that "only nine boreholes" were drilled in or near the pad emplacement area for the purpose of retrieving samples for laboratory testing is factually incorrect. PFS drilled a total of sixteen borings (the nine listed by Dr. Bartlett plus boreholes A4, B4, C4, D1, D2, D3 and D4) in or near the pad emplacement area and took soil samples from all sixteen boreholes for testing. In addition, PFS conducted continuous sampling of soil properties in 37 CPT soundings within the pad emplacement area. See PFS Exh. 235 (SAR Fig. 2.6-19).

**Q7.** In answer to question 20 in the Bartlett Direct Testimony, Dr. Bartlett faults the PFS sampling program for the pad emplacement area for failing to comply with the guidance in Reg. Guide 1.132 that continuous sampling should be conducted in "critical layers," such as Layer 2. What is your response?

**A7.** I would again note that the guidance in Reg. Guide 1.132 does not apply to ISFSIs. In my opinion, continuous soil sampling is not required for the pad emplacement area because the pads are unlike the large, heavy nuclear power plant structures and have no safety-related connections.

Even if the guidance in Reg. Guide 1.132 were applicable, PFS's sampling program would be in compliance with that guidance for several reasons:

- PFS performed continuous sampling because it conducted 37 cone penetration tests in the pad emplacement area that sampled continuously the soil properties throughout Layer 2. See PFS Exh. 233 for examples of plots of the data collected continuously throughout the upper 25 to 30 ft. of the profile in the CPTs. Those CPT data confirm that there are no weak layers that have been missed by the soil sampling that was performed in the borings drilled in the pad emplacement area.

- PFS obtained sufficient number of disturbed and undisturbed samples of Layer 2 soils from the pad emplacement area to conduct laboratory tests that permitted a proper determination of the shear strength and other properties of the soils in this layer. In fact, five out of the nine pad emplacement area boreholes cited by Dr. Bartlett had undisturbed samples from Layer 2 soils taken for testing. See Table 1 of the Joint Direct Testimony of Paul Trudeau and Anwar E. Z. Wissa on Section C of Unified Contention Utah L/QQ ("Trudeau Direct Testimony"). These samples were taken in the borings, alternating with standard split-spoon samples as the boreholes were advanced, as recommended under Section 6, "Sampling", of Reg. Guide 1.132.

**Q8.** Dr. Bartlett claims in his answer to question 22 of the Bartlett Direct Testimony that the Layer 2 soils "have not been continuously sampled and characterized with depth," and that this incomplete characterization "adds additional uncertainty to the Applicant's estimate of the shear strength of this important layer." Do you agree with Dr. Bartlett's conclusions?

**A8.** No. <u>First</u>, for the reasons just stated, it is incorrect to assert that the Layer 2 soils have not been continuously sampled and characterized with depth. <u>Second</u>, the purpose of continuous sampling is, as indicated in Reg. Guide 1.132, to identify "[r]elatively thin zones of weak or unstable soils [that] may be contained within more competent materials and may affect the engineering characteristics or behavior of the soil or rock." PFS Exh. 234 at 1.132-5. If such zones existed within Layer 2, they would have been detected through changes in cone tip resistance measured in the CPT tests, which sampled Layer 2 continuously throughout the pad emplacement area. No such zones were identified in the extensive CPT tests, so there is no reason to believe that any exist. Therefore, continuous sampling in borings through Layer 2 of the pad emplacement area was not required. Finally, PFS performed continuous sampling of Layer 2 soils in boreholes in the CTB and did not identify any zones of weak or unstable soils, confirming that such zones do not exist in the areas of interest at the PFSF site.

**D. PFS Soil Testing Program**

**Q9.** Dr. Bartlett expresses the view, in answer to question 23 of the Bartlett Direct Testimony, that "[t]he most egregious weakness of the Applicant's sampling program is the extreme undersampling that has been performed of the upper Lake Bonneville sediments." The basis for such a harsh criticism is the assertion that PFS "has calculated the sliding resistance of the pads based on one set of direct shear tests obtained form borehole C-2 from a depth interval of 5.7 to 6 feet." How do you respond to Dr. Bartlett's criticism?

**A9.** Dr. Bartlett's criticism is way off the mark. The sample from which the shear strength of the Upper Lake Bonneville clay layer was measured in direct shear tests had the highest void ratio and lowest density of any samples taken in pad emplacement area. (High void ratios and low densities are indicative of low shear strengths.) The sample was taken from the section of pad emplacement area that was expected, based on previous tests, to have weakest soils. Further, the sample was taken from the portion of the Upper Lake Bonneville clay layer known to have lowest strength (5 to 7 feet below surface). For all these reasons, the sample used to determine the shear strength value of the soil provided a minimum strength value for use in the sliding stability analyses of the soils in the pad emplacement area.

**Q10.** Dr. Bartlett expresses the view in answer 25 that the minimum shear strength value calculated by PFS "may be subject to severe bias and could potentially lead to overestimation of shear strength capacity available," and did not account for the potential variation of shear strength properties of Layer 2 soils across the pad emplacement area. Is there merit to Dr. Bartlett's view?

**A10.** No. As stated earlier, the Layer 2 soils are "monotonous" – that is, uniform – across the pad emplacement area, as Dr. Bartlett himself recognized in his November 17, 2000 deposition ("Bartlett November 2000 Deposition"), Tr. at 495. (See PFS Exh. 236). Because of this uniformity, the horizontal variations in shear strength across the Layer 2 soils in the pad emplacement area do not exist.

**Q11.** In answer 26 of the Bartlett Direct Testimony, Dr. Bartlett seeks to support his contention that there are potential variations in shear strength across the Layer 2 soils by citing a set of figures he prepared (State Exh. 99) in which he plotted measured cone penetration resistance tests results. He cited these plots as suggesting that there is a factor of 2 variation in cone penetration tip resistance, from which he infers that there may be a factor of 2 variation in shear strength across the pad emplacement area. What is your assessment of Dr. Bartlett's analysis?

**A11.** There is no technical or factual basis for Dr. Bartlett's analysis. First, contrary to his assertion, the correlation between cone tip resistance and the undrained shear strength of the soil is not as simple as Dr. Bartlett would have us believe. The relationship between the two parameters is complex, and involves a number of parameters which may be variable, even for a given soil type. Therefore, a constant or nearly constant shear strength may be accompanied by variations in cone tip resistance on account of variations in these other parameters. This matter was discussed at length in Dr. Bartlett's deposition. See Bartlett November 2000 Deposition Tr. 471 - 496 (PFS Exh. 236.

Second, the plots prepared by Dr. Bartlett and included in State Exh. 99 are too crude and prepared in too unreliable a manner to convey any meaningful information. See PFS Exh. 236, Tr. at 474-75. The alleged factor of two variation in cone penetration tip resistance from one set of Layer 2 measurements to another can be accounted for by plotting errors, the width of the marker with which he traced the enlarged SAR plots, the enlargement process itself, and the scale of the plot, which is too compressed to provide any accurate readings. I do not believe that such plots would be considered acceptable in serious scientific circles.

Third, I interpret the CPT resistance plots presented in SAR Figure 2.6-5, Sheets 1 through 14 (from which Dr. Bartlett prepared State Exh. 99) in the totally opposite manner as he does. I view those plots as demonstrating remarkable uniformity of properties of Upper Lake Bonneville clay soils across the pad emplacement area.

Finally, even if there were any locations in the pad emplacement area with soils that exhibited lower shear strength than the minimum value calculated PFS, the existence of such locations would be of no consequence because:

- Any lower values of shear strength would be localized effects.
- The actual shear strength of the soil under the cement-treated soil beneath a storage pad depends on the average strength of the soil in the area under the pad. It is extremely unlikely that the average shear strength of the soil in the 30' x 67' area under a pad would be less than minimum value measured by PFS, for the reasons stated above.
- Because of all the conservatisms in the computation of the factor of safety against sliding to which I referred earlier, the actual FS would remain above the 1.1 guideline even if the shear strength value dropped significantly.

**E. Concerns re Non-Performance of Cyclic Triaxial Tests**

**Q12.** In his answer to question 30, Dr. Bartlett asserts that PFS should have performed strain-controlled cyclic triaxial tests to ensure that there was no significant degradation of shear strength at the soil strain (deformation) levels caused by the design earthquake. Is he right?

**A12.** PFS conducted stress-controlled cyclic triaxial tests to determine collapse potential of soil. The results of those tests are presented in Attachment 6 of Appendix 2A of the SAR, and are described in Section 2.6.4.7 of the SAR at pages 2.6-98 to 2.6-100. The results of the tests did not show any degradation of the shear strength of the samples throughout 500 cycles of loading at extremely high cyclic ratios. The resulting cyclic strains were very small, indicating essentially elastic response throughout the tests. For such low values of cyclic strain, Fig. 2 of the Makdisi and Seed treatise (State Exh. 102) shows that the ratio of shear strength after cyclic loading to the original strength is essentially 1.0, which indicates that there is no strength degradation for these soils due to the high levels of cyclic stress applied. Since the cyclic stresses applied during the tests (500 cycles) are greatly in excess of those that take place during the design basis earthquake for the PFSF (approximately 7 to 11 cycles), no significant degradation of shear strength is anticipated to take place, and strain-controlled cyclic triaxial tests are unnecessary.

F. Concern Over Non-Performance of Triaxial Extension Tests

Q13. In his response to question 32 of the Bartlett Direct Testimony, Dr. Bartlett asserts that triaxial extension tests, which measure the shear strength in extension of the soil, should have been performed by PFS but were not. What is your response?

A13. I responded to this claim in answer 29 of the Trudeau Direct Testimony, where I explained why those tests are not needed at the PFSF.

G. Strength of Soils in the CTB Area

Q14. In answer 29 of the Bartlett Direct Testimony, Dr. Bartlett alleges that PFS has used potentially unconservative estimates of the undrained shear strength in the dynamic bearing capacity analyses of the CTB because the strength was based on shear strengths measured in UU tests that were performed on samples obtained from borings drilled more than 1,000 ft away from the CTB. Is this a legitimate concern?

A14. No. As indicated on page 8 of S&W Calculation 05996.02-G(B)-13-6 (PFS Exh. VV):

> "The undrained shear strengths measured in the triaxial tests are used for the dynamic bearing capacity analyses because the partially saturated, fine-grained soils will not drain completely during the rapid cycling of loadings associated with the design basis ground motion. As indicated in Figure 6, the undrained strength of the soils within ~10 ft of grade is assumed to be 2.2 ksf. This value is the lowest strength measured in the UU tests, which were performed at confining stresses of 1.3 ksf. This confining stress corresponds to the in situ vertical stress existing near the middle of the upper layer, prior to construction of these structures. It is much less than the final stresses that will exist under the cask storage pads and the Canister Transfer Building following completion of construction. Figure 6 illustrates that the undrained strength of these soils increase as the loadings of the structures are applied; therefore, 2.2 ksf is a very conservative value for use in the bearing capacity analyses of these structures."

Figure 6 of PFS Exh. VV presents the results of all the triaxial tests that were performed on soil samples obtained at the PFSF site, including all those obtained from the CTB area. The curve shown in that figure provides a reasonable estimate of the strength to use in bearing capacity analyses based on the triaxial test results. Therefore, the undrained strength used in the bearing capacity analyses of the CTB, although it equals the value measured for the UU test that was performed on Sample U-3D from Boring B-4, was developed based on the summary plot of all of the triaxial tests that were performed on samples of soils obtained from the PFS site – those in the pad emplacement area as well as those from the CTB area. As shown by the curve in Figure 6 on p. 57 of the G(B)-13-6 calculation, the value of 2.2 ksf used for the bearing capacity analyses is a reasonable lower-bound value based on the results of all of the triaxial tests that were performed by PFS. Moreover, the effective vertical stresses, $\sigma_v$, increase as one goes deeper in the profile, and the undrained shear strength increases as well. For example, as shown in Figure 6, at 7 ft below the CTB mat, $\sigma_v$ equals 2.1 ksf and the undrained shear strength is ~3.3 ksf; therefore, it is very reasonable to have adjusted the undrained shear strength used in the bearing capacity analysis of the CTB to 3.18 ksf based on the strength increase noted at depth in the CPTs that were performed in the CTB area.

In any event, the minimum factor of safety against bearing capacity failure for the CTB calculated by PFS is 5.5. Even eliminating the adjustment factor that Dr. Bartlett finds inappropriate would result in a factor of safety against bearing capacity failure of approximately 3, which is still well above the 1.1 FS considered acceptable under NRC guidance for nuclear power plants. Therefore, the concern raised by Dr. Bartlett is both erroneous and inconsequential.

**Q15.** Does this conclude your testimony?

**A15.** Yes.

MR. O'NEILL: Is the witness available?

MR. TRAVIESO-DIAZ: Yes, he is.

CHAIRMAN FARRAR: He is. Just a minute. Go ahead, Mr. O'Neill.

MR. O'NEILL: Good morning again, Mr. Trudeau.

MR. TRUDEAU: Good morning.

MR. O'NEILL: Well have to get you and Dr. Bartlett some permanent name placards up here. Just a few quick questions.

CROSS EXAMINATION

MR. O'NEILL: I know for purposes of your site investigations, you used standard penetration test, cone penetrometer test, and meter test. Correct?

MR. TRUDEAU: That is correct.

MR. O'NEILL: Now these tests are all types that are frequently used for purposes of geotechnical earthquake engineering problems or applications?

MR. TRUDEAU: Yes, for subsurface investigations.

MR. O'NEILL: One thing that struck me from your testimony is that you perform a number of different correlations among different field tests, between field tests and lab tests. Could you identify some of these correlations that you performed? I mean, the more significant ones and why they're important to your investigation?

For instance - okay - I notice in answer 11 on page 5, you said that you used Donnell geophysical measurements in two borings to corroborate the geophysical measurements that were made in the seismic cone penetration test.

MR. TRUDEAU: That is correct. We had done some geophysical testing in 1996, and when we went out and did the cone work in 1999, I believe it was, we had some additional seismic cone penetration tests performed to get corroborating evidence that the shear wave velocities were such and so across the site. And as Dr. Bob Youngs had testified earlier in these proceedings, those shear wave velocities had extremely low variability across the site, which is further evidence that this is a fairly uniform in the horizontal direction, that the soil properties are fairly uniform in the horizontal direction at the site.

MR. O'NEILL: And again, this is a fairly common practice, you know, to complement one field test with a different type of field test?

MR. TRUDEAU: Yes, it is.

MR. O'NEILL: Or lab test? It's my understanding that the site stratigraphy, as it was reflected largely in the foundation profiles that are contained in Figure 2.6-5 of the SAR, which contains 14 different sheets. And I believe there's several other figures associated with the CTB. Now these foundation profiles are based on a combination of different data types. Is that correct?

MR. TRUDEAU: Yes. Those include the information from the borings, as well as the information from the cone penetration test.

MR. O'NEILL: You mentioned your assessment of uniformity in site soils. Specifically, what tests were aimed directly at trying to ascertain whether there are lateral variations in soil properties?

MR. TRUDEAU: Well, the standard penetration test performed during the borings permit us to retrieve a sample of the soil, that upon extraction from the ground, we would perform a visual classification of that sample. We describe what it is. It is a sand, is it a silt, is it a clay, that kind of thing.

During the process of taking that standard split spoon sample using this standard penetration test, we also record the number of blows of a 140 pound hammer dropping 30 inches to drive that spoon into the ground. And that gives us what's referred to as the "Standard Penetration Test Blow Count Value", which is a measure of the apparent density or strength of the soil.

There are correlations between Standard Penetration Test Blow Counts and consistency of clay soils at the shear strength, as well as correlations between blow count and relative density of granular soils.

The cone penetration testing provides a, more or less, continuous record through the depth of penetration. The cone itself is called the cone because it is cone-shaped, conical shaped at the tip. And it's instrumented to measure the stress required to advance that cone through the soils. And when they perform this cone penetration test, they record that tip resistance value, as well as making measurements of pore pressure for sites where ground water is a lot higher than it is here, although pore pressures were still measured in these tests.

There is also a sleeve that's advanced as part of this operation, and they measure how much force it takes to advance this sleeve into the ground as a measurement of the -- essentially like the friction that it takes to overcome to drive that -- move that sleeve down into the ground.

MR. O'NEILL: Okay.

MR. TRUDEAU: So those subsurface foundation profiles that you referred to, the Figure 2.6-5 of the SAR, plots up those data as they were found at various sections through the site. There are six of them north/south, and six of them east/west through the pad emplacement area, and I believe there are three of them to east/west and one north/south through the canister transfer building. And where those sections intercepted the boring location, the boring information showing where the sample taken. The unified soil classification symbol that Dr. Bartlett was kind enough to describe well for us yesterday, is also shown. The blow count values are shown for those split spoon samples. And where a cone penetration test was performed, the actual data that are measured continuously through the profile, the tip resistance, the sleeve friction information, and the pore pressure information are plotted for each of the cones. So all of that data is plotted up on those sections, and based largely on the descriptions of the soil samples from the split spoon testing, and from the undisturbed samples -- I forgot to mention we also took some three inch thin wall Shelby samples, which is a standard sampler for obtaining undisturbed soil samples for the more sophisticated laboratory tests, like consolidation tests, and the tri-axial tests.

MR. O'NEILL: Okay. Mr. Trudeau, in, I believe it's -- I'm not sure if it was answer 12 or answer 11, that you had indicated that the geological plates prepared by Geomatrix can be correlated with the data on subsurface conditions presented in the foundation profiles that you had developed? And that there was a strong correlation between the two sets of data, or documents? Could you just quickly explain how Geomatrix had constructed its plates, and how the data used by Geomatrix as opposed to the data used by you, and what the significance of this particular correlation is.

MR. TRUDEAU: Geomatrix did an extensive faulting study back in early 1999, I believe. And as part of that study, they were interested in trying to find evidence of any faults within the soils underlying the site, so they drilled quite a number of shallow borings that more or less continuously sampled the upper 20 to 30 feet, as I recall. Some of them went down to the Quaternary, which is around 85 or 90 feet.

As part of that program, they also excavated a trench that was several hundred feet long, and nearly 30 feet deep. And they did extensive -- this was right across the middle of the pad emplacement area, and they did geologic mapping of the horizons that they saw there, and prepared an extensive geologic description of the geology that they encountered in both these borings, and in this trench that they did on-site. They also did some additional geophysical work, as well, as part of that faulting study.

MR. O'NEILL: But generally, their work conforms with your's? I mean, you believe it supports your --

MR. TRUDEAU: Yes, the main or most significant difference would be that for the geotechnical borings that we performed, the visual classifications were based on the Unified Soil Classification System. Their geologists work on description of soil types that is more like the Soil Conservation Service description, so there may a little bit of disparity between what we would have called a silt, and what they would have called a clay, or vice versa, I guess, is probably the better way to say it.

MR. O'NEILL: But ultimately, from a geotechnical engineering standpoint, you're really concerned with the -- concerned most with the specific engineering properties, as opposed to the nuances of the classification system. Correct?

MR. TRUDEAU: That's correct. I think it's fair to say that this trench, for instance, permitted a very quick and easy determination across this several hundred feet long trench. I think it was 300 feet long. It may have been 200, but I believe it was 300 feet long, and you could see that -- there were pictures in the report that shows that its fairly uniform conditions in the horizontal direction.

MR. O'NEILL: Now at some point, you also indicated that the primary soil layer of interest was layer 2. Correct?

MR. TRUDEAU: Yes, sometimes referred to as layer 1B.

MR. O'NEILL: You anticipated my question. And in the SAR and in Dr. Ofoegu's testimony, it's referred to as layer 1B.

MR. TRUDEAU: That's correct. It's what we've been calling the upper Lake Bonneville Clay layer.

MR. O'NEILL: You referred to a great uniformity, you know, across the site locations, particularly with respect to this layer. Are you referring to a uniformity in soil strength and compressibility?

MR. TRUDEAU: Yes. And primarily, the strength, I would say, as evidenced by the tip resistance values measured in the cone penetration tests across the site.

MR. O'NEILL: I'm going to touch on something that we had discussed a little bit in Part D because of the overlap. In question -- response to question 20 you indicated, "A weighted average strength based on the increase in strength noted in the cone penetration tests that were performed within the CTB area was used because of the large size of the foundation mat relative to the thickness of the upper 30 feet of the soil." Could you again clarify why it's acceptable to use such a weighted average?

MR. TRUDEAU: Well, for a bearing capacity analysis for a mat that large, a bearing failure would engage the soils down to at least the width of the foundation. I mean, we're talking 200 feet, 240 feet down below the site, and this is not the -- I don't think there is in anybody's mind a concern about the bearing capacity of this canister transfer building. The soils below a depth of 30 feet are much stronger than the upper 25 to 30 feet in resisting a bearing failure. They're granular at a depth of 30 to 60 feet, which have high -- in a dense granular soil, so they have much higher resistances to bearing capacity failure. But in our bearing capacity analyses, we didn't even include those effects. We just assumed that the strengths from the upper 30 feet were very conservative for this analysis.

We recognized that the layer 1B, or the layer 2, the upper Lake Bonneville Clay deposits were the weaker layers that site the critical layer, so those are the ones that we had the strength data for. Rather than just use that strength for the top, I mean, that layer is about 5 to 10 feet thick, we felt it was appropriate to boost those up a little bit to account for the increased strength in the bottom half to two-thirds of that up to 25 to 30 foot layer based on the strength increases that we measured in the cone penetration test there.

MR. O'NEILL: So this practice is based on accepted bearing capacity theory.

MR. TRUDEAU: Yes. And it's -- I mean, if we wanted to try to factor in the strong soils below a depth of 30 feet, there are methods to do that, but when you're talking factors of safety on the order of 5, it just doesn't make sense to go to the extra numerical effort to try to justify a higher number, when you're looking to get numbers like 1.1.

MR. O'NEILL: I know an issue that comes up sometimes when this dynamic context or the dynamic properties of soil is high strain versus low strain. Could you just quickly distinguish between those two terms, and generally, what we're looking at at this site?

MR. TRUDEAU: The dynamic moduli are measured in geophysical testing techniques that involve shear strengths that are on the order of --

MR. O'NEILL: Excuse me. You may have misheard me. I was talking about strain, high strain versus low strain. I was getting at something else. I apologize. I'll just cut to the chase. I wanted to get at the difference between resonant column test and strain controlled cyclic tri-axial test. This is an issue. I mean, what's the difference between the two, and specifically why you view the resonant column test to be adequate in this case?

MR. TRUDEAU: I -- can you help me with

where it is in this testimony?

MR. O'NEILL: Okay. I apologize. It's answer 26, page 18.

MR. TRUDEAU: Okay. As I indicated in this response, we did perform resonant column tests on two different specimens of the soils at the site, and resonant column tests are capable of performing, or measuring shear moduli and damping characteristics of the soils over a wide range of strains. And as I indicate in my answer here, the range of strains over which these moduli were measured in these samples was comparable to the range of strains that Dr. Youngs found were applicable for the effect of strains from his development of the strain compatible soil properties that we've been talking about earlier.

So based on that, in my estimation, the resonant column tests that we performed were sufficient to cover the range of strains applicable for the design earthquake at the site, so that we didn't need to perform the strain controlled cyclic tri-axial test to measure the degradation of the shear modulus at a higher strain level, because it was beyond the strain level that Dr. Youngs needed in his analysis anyway.

MR. O'NEILL: And specifically, what is

shown by the plots of G/Gmax and damping versus shear strain? I presume this relates to this issue.

MR. TRUDEAU: Those are the so-called shear modulus degradation curves that we've heard mentioned, that Dr. Youngs needs to use as input to his analysis that generated the strain compatible properties.

He sets up a one-dimensional model of the site, and assigns various properties to the soils in that model. And one of those is the dynamic modulus, the low strain modulus. Another is this shear modulus degradation, or shear modulus versus shear strain curve, and the damping versus shear strain curve. The analysis iterates, measures, calculates what the strain is in each of these layers of soils, and a comparison is made between the strain at the start of the iteration, and the strain calculated in the iteration.

The shear modulus that used to come up with that number was -- is then adjusted, either up or down, to -- and another iteration is performed measuring -- calculating what the strains are, again. And when the strains have converged to a point where there's little need for change, the analysis is considered to be complete. And hence, the strain compatible description of the soil properties.

MR. O'NEILL: And in answer 26 on the bottom of page 18, to the top of page 19, you refer to the extrapolation, the results from the testing of Sample U-3C along those curves as measured in this resonant column testing to the sample U-7C. Again, I presume this extrapolation is what precludes the need to do any strain controlled cyclic tri-axial tests. Correct?

MR. TRUDEAU: Yes. This is a fairly obvious thing. Let me just pull out the figures that are applicable from the SAR. It'll just take two minutes.

CHAIRMAN FARRAR: Ask a question. That was a simple question that didn't ask for an explanation. Maybe we've got to start ask a question, give the answer. If they want an explanation, we'll get it.

MR. O'NEILL: Sorry, Your Honor.

CHAIRMAN FARRAR: And I'll say this to all the witnesses, I know you're proud of all the work you've done for a long time on this case. I mean, this project has been something the company has been working on for a long time, but we're not here -- this is not the place to hear about everything you've done, unless it's crucial to the case, because Judge Lam's three hours have to cover both direct testimony and rebuttal. And so, listen -- I caution all the witnesses, listen to the question, give the direct answer. And if counsel wants an explanation that would be useful to us, they'll ask for it.

Go ahead, Mr. O'Neill.

MR. O'NEILL: So it's that extrapolation process though that --

MR. TRUDEAU: Yes, but as I indicated in my response, the strains appropriate for the lower sample encompassed the effective strains from Dr. Youngs' analysis, so no extrapolation was needed for that. But the shallower sample was not strained as high as the effective strains in the shake analyses indicated, but superimposing those two sets of data, you can see that the trends are exactly the same, so that the extrapolation is a reasonable thing to do for the upper sample.

MR. O'NEILL: And just one last thing. If you could explain specifically what you mean by "effective strain."

MR. TRUDEAU: The effective strain is typically for these analyses considered to be .65, or two-thirds times the peak strain calculated in the analysis.

MR. O'NEILL: I think that's all I have for now. Thank you.

CHAIRMAN FARRAR: Thank you, Mr. O'Neill. Ms. Chancellor, do you need a minute or two, given the Staff's cross to get ready?

MS. CHANCELLOR: No, I don't believe so, Your Honor.

CHAIRMAN FARRAR: All right. And you had previously indicated you thought you needed an hour or so?

MS. CHANCELLOR: That's what I'll try and do it in, Your Honor. Good morning, Mr. Trudeau.

MR. TRUDEAU: Good morning, Ms. Chancellor.

MS. CHANCELLOR: I believe you stated in the soil cement testimony, that you are not familiar with the basin and range problems, other than the work that you've done at the PFS site. Is that correct?

MR. TRUDEAU: This is correct.

MS. CHANCELLOR: And so you haven't previously worked with the Lake Bonneville deposits.

MR. TRUDEAU: Correct.

MS. CHANCELLOR: Have you personally performed dynamic soil tests, such as cyclic tri-axial tests and resonant column tests?

MR. TRUDEAU: Yes. My thesis at MIT was based on the performance of resonant column tests.

MS. CHANCELLOR: Did you perform any of those tests for the PFS project, resonant column or cyclic tri-axial?

MR. TRUDEAU: I did not personally, but we did at Stone and Webster perform resonant column tests for the Private Fuel Storage project.

MS. CHANCELLOR: Did you personally perform any dynamic tests for the PFS project?

MR. TRUDEAU: Yes.

MS. CHANCELLOR: Which ones?

MR. TRUDEAU: The cyclic tri-axial tests that are in attachment 6, I believe it is, of Appendix 2-A of the SAR, and the resonant column tests that are in that same attachment.

MS. CHANCELLOR: Dr. Chang didn't perform those tests?

MR. TRUDEAU: No. Stone and Webster's geotechnical laboratory performed those tests. I did not personally perform them.

MS. CHANCELLOR: Personally. Okay.

MR. TRUDEAU: Dr. Chang did not personally perform them.

MS. CHANCELLOR: Okay. Were you involved in the planning and design of the geotechnical investigation from the inception of the PFS project?

MR. TRUDEAU: I was not involved in the 1996 boring program.

MS. CHANCELLOR: Who was in charge of that program?

MR. TRUDEAU: I believe it was -- that Mr. Nuri Georges was the lead geotechnical engineer at the time. That's N-U-R-I.

MS. CHANCELLOR: And what are his qualifications?

MR. TRUDEAU: I believe he is a Master of Science graduate in geotechnical engineering. I know he's got a Bachelor's of Civil Engineering, and I believe his Master's was in geotechnical type engineering.

MS. CHANCELLOR: There were additional investigations, site investigations performed in 1999. Is that correct?

MR. TRUDEAU: That's correct.

MS. CHANCELLOR: And why were these additional investigations performed?

MR. TRUDEAU: They were performed to obtain additional information to confirm that we had, indeed, sampled and tested the weakest and most compressible soils at the site. They were also performed to develop the subsurface information necessary to design the canister transfer building foundations, and perform those stability analyses.

Borings had not been performed in the vicinity of the canister transfer building in 1996 because we hadn't progressed far enough, as I understand it, with the design to know exactly where the canister transfer building would be at that time.

MS. CHANCELLOR: Were additional shear wave velocity measurements made in 1999, using seismic penetrometer tests?

MR. TRUDEAU: Yes.

MS. CHANCELLOR: How were these measurements incorporated into the estimates of the design basis ground motions calculated by Geomatrix?

MR. TRUDEAU: Yes.

MS. CHANCELLOR:. How? Not were they, how?

MR. TRUDEAU: Yes, but they were incorporated by Dr. Youngs in his analyses, which were reported in calculations GPO 18-1, -2, and -3, I believe.

MS. CHANCELLOR: Did the incorporation of the CTB data, did that result in a change in ground motions at the PFS site?

MR. TRAVIESO-DIAZ: I am going to start objecting to these questions. These are outside the scope of the testimony the witness has given. That has to do with the Geomatrix soil characterization, soil property characterization. It is irrelevant to the soils testimony that Mr. Trudeau has given.

MS. CHANCELLOR: He talks about the 1999 investigation.

MR. TRAVIESO-DIAZ: Yes, but you're asking what was done with it about redefining earthquake, and that's certainly no part of the testimony that Mr. Trudeau has given.

MR. O'NEILL: That was to provide kind of a brief overview of the chronology of --

CHAIRMAN FARRAR: I didn't hear the beginning of that, Mr. O'Neill.

MR. O'NEILL: OH, I said -- I mean, my impression was in that particular response, he was intending to provide kind of an overview of the chronology of the different work done at the site.

CHAIRMAN FARRAR: And, therefore, you'd support the objection?

MR. O'NEILL: Yes.

CHAIRMAN FARRAR: Mr. Travieso-Diaz, if

the test -- if the questioning is not apropos at this time, are you suggesting that the question dealt with Section D?

MR. TRAVIESO-DIAZ: I'm suggesting that it's totally outside the scope of the contention QQ as framed. What the new earthquake values were arrived and how they were obtained, has not been brought into contention by anybody. And secondly, Mr. Trudeau is not the person to testify about that. That could have been Dr. Youngs, when he was here, if they wanted to know that.

If we are going to be expeditious and we're going to be effective, we need to limit ourselves to the testimony as provided, and don't stray into other areas. I normally don't like to object, but I want to move along.

MS. CHANCELLOR: So do I, Your Honor.

CHAIRMAN FARRAR: The objection is sustained, Ms. Chancellor. Looking at Mr. Trudeau's testimony, it is fairly limited to what they found about the soils, not with how that information was later processed.

MS. CHANCELLOR: I could lay a -- I was trying to be expeditious. I can lay a foundation.

CHAIRMAN FARRAR: All right. Go ahead.

MS. CHANCELLOR: Mr. Trudeau, were you responsible for the 1999 investigation of the PFS site?

MR. TRUDEAU: Yes.

MS. CHANCELLOR: Did you oversee the seismic cone penetrometer tests?

MR. TRUDEAU: Those were performed by Cone Tech, in accordance with our engineering services scope of work, and our engineer's field inspector oversaw that work. I was not personally there, but people working for me were there.

MS. CHANCELLOR: Had PFS conducted any other cone penetrometer tests prior to the 1999 tests?

MR. TRUDEAU: Not at the PFS site.

MS. CHANCELLOR: So Geomatrix, in its initial analysis, would not have had any cone penetrometer tests in them.

MR. TRUDEAU: That's correct. Referring to seismic cone penetrometer tests, correct?

MS. CHANCELLOR: Correct. And who decided that there was a need to gather seismic cone penetrometer data?

MR. TRUDEAU: I was the one that recommended that we collect the data, so that we -- I mean, it's not an expensive test to perform once you are out on site performing cone penetration testing.

MS. CHANCELLOR: You say it wasn't very expensive, but was it requested by Geomatrix?

MR. TRUDEAU: No, not that I recall. This is a standard subsurface investigation technique. If you're going to go collect standard cone information, you most typically would also collect the seismic cone data. We're doing the same thing right now at the Marks project, and I mean, it's just a standard operating procedure for collecting subsurface information when you're doing a cone penetration testing program.

MS. CHANCELLOR: So you collected data that wasn't requested by Geomatrix, but nonetheless, Geomatrix used that data?

MR. TRUDEAU: I understand they used it in their calculations for the strain compatible soil properties, yes.

MS. CHANCELLOR: That's the soil properties in the free field. Correct?

MR. TRUDEAU: That's what the one-dimensional response analysis is. Yes.

MS. CHANCELLOR: And that's the calculation from which you obtained ground motions for the design basis earthquake. Correct?

MR. TRUDEAU: No, that was the strain compatible soil property development calculation.

MS. CHANCELLOR: Okay. Could you briefly describe the soil profile at the PFS site, starting at the top and going down to the bottom? You can stop at 30 feet.

MR. TRUDEAU: The top 30 feet, at the top surface we have a thin layer of Aeolian Silt. Below that, we have Lake Bonneville deposits. The upper five to ten foot thickness of the upper -- of the Lake Bonneville deposits are a silty clay, clay silt layer that our borings and our cone penetration test data has indicated are the weaker soils in the profile, and the more compressible soils in the profile.

Beneath -- that's the layer 1B as described in the SAR. Below that is what the SAR refers to as layer 1C, and this is, as I said, a Lake Bonneville deposit, but it's a little less clayey than the upper Lake Bonneville layer that we just talked about. It has more silt, and in some places it has some fine sand in it. It also is about ten feet thick.

Underneath that is a three to five foot silty clay, clay silt layer again, but stronger than the layer 1B material, the upper Lake Bonneville deposit, based on the cone penetration test data.

MS. CHANCELLOR: So it's fair to say you agree that the critical layer from the strength and compressibility standpoint is the upper Lake Bonneville sediments.

MR. TRUDEAU: Yes.

MS. CHANCELLOR: And the approximate depth, you said, was five to ten feet of the upper Bonneville?

MR. TRUDEAU: No, I think I said it was a thickness of five to ten feet and it, in some places, may be as shallow as three feet at the site, so it's -- in my estimation it runs between three and maybe twelve feet below grade out there at the site. The surface topography varies a little bit, plus or minus a foot perhaps, so that would make up for any differences in these numbers that I'm giving you.

MS. CHANCELLOR: In question 18 of your testimony you used the -- question 18. It's actually answer 18 on page 12, you state that, "The soil properties are reasonably uniform." What do you mean by the use of the term "reasonably uniform"? What do you mean by "uniform?"

MR. TRUDEAU: Uniform?

MS. CHANCELLOR: Uniform.

MR. TRUDEAU: Means that there's little variation, for instance, in the strength as evidenced in the cone penetration tip resistances, the blow count values from the standard penetration tests.

MS. CHANCELLOR: You don't mean to say that there's no variability at the site. Is that correct?

MR. TRUDEAU: That's correct.

MS. CHANCELLOR: What properties or soil attributes are you referring to when you talk about the uniformity of the soils?

MR. TRUDEAU: The soil types, the standard penetration test blow counts, the cone penetration test readings.

MS. CHANCELLOR: Compressibility?

MR. TRUDEAU: Compressibility is another property that I would say is --

MS. CHANCELLOR: Uniform?

MR. TRUDEAU: Sure, yes.

MS. CHANCELLOR: Shear strength?

MR. TRUDEAU: Shear strength is.

MS. CHANCELLOR: Have you reviewed whether or not any of those properties we just talked about vary from location to location at the site?

MR. TRUDEAU: Only by visually comparing

the cone penetrometer tip resistance plots across the foundation profiles that are in the SAR's Figure 2.6-5.

MS. CHANCELLOR: So you haven't done any calculations to determine the range or standard deviation that these properties may vary -- I'll delete that last question.

What is the range or standard deviation of the tip resistance across the site for the upper Bonneville Clays with respect to the CTB?

MR. TRUDEAU: I don't know.

MS. CHANCELLOR: Have you determined that the percentage of upper Bonneville Clay -- have you determined what percentage of the upper Bonneville Clays is a plastic soil, a CH or MH material that we talked about in soil cement?

MR. TRUDEAU: I don't recall ever trying to break it down by the Hs versus the Ls.

MS. CHANCELLOR: In Table 1 of your testimony on page 10, you show locations of undisturbed samples taken at the PFS site. Correct?

MR. TRUDEAU: Yes.

MS. CHANCELLOR: Of these, how many are taken from the upper ten feet of the upper Lake Bonneville deposits?

MR. TRUDEAU: How many of these are taken from the upper ten feet? Is that the question?

MS. CHANCELLOR: That's correct. In the pad emplacement area - sorry - not the CTB.

MR. TRAVIESO-DIAZ: I'm sorry. I heard you to ask two different questions. Are you asking him just to count how many are taken on the upper ten feet for the pad emplacement area?

MS. CHANCELLOR: That's correct, Mr. Travieso-Diaz.

MR. TRAVIESO-DIAZ: All right. Thank you.

MR. TRUDEAU: There are six samples that were taken in the borings, the A, B, C and E Series borings within the top ten feet. The CTB borings were taken in the canister transfer building area.

MS. CHANCELLOR: That's okay. We'll just concentrate on the pad area. When were the borings in the pad emplacement area done? Was that part of the initial investigation?

MR. TRUDEAU: Yes, it was, 1996.

MS. CHANCELLOR: Were there any -- for the pad emplacement area, were there any additional borings other than the borings done in 1996 for undisturbed sampling?

MR. TRUDEAU: E-2 I think was done in '99, but other than that, no. '98, I see, December '98.

MS. CHANCELLOR: What type of laboratory shear tests were done to determine the sliding resistance of the pads for the upper Bonneville Clays?

MR. TRUDEAU: Direct shear tests.

MR. TRAVIESO-DIAZ: I think I have to object to the form of the question. It's assuming an answer or a correlation between two different facts that has not been established. And if I clarify, my problem is that the first part of the question is how many direct shear tests were done. The second part says for purpose of establishing sliding resistance, and I don't know that there has been a foundation to establish that the two things are related. They may be, but --

CHAIRMAN FARRAR: Can you simplify that question, Ms. Chancellor?

MS. CHANCELLOR: Which type of test did you perform to determine the sliding resistance of the pads?

MR. TRUDEAU: Direct shear tests.

MS. CHANCELLOR: How many bore holes were used to obtain samples for direct shear testing in the pad emplacement area?

MR. TRUDEAU: One.

MS. CHANCELLOR: What is the size of the pad emplacement area?

MR. TRUDEAU: I think I've heard that it's 51 acres.

MS. CHANCELLOR: Which boring in Table 1 was selected for the direct shear test?

MR. TRUDEAU: C-2.

MS. CHANCELLOR: And that was taken from a depth of what, five to seven feet?

MR. TRUDEAU: Yes.

MS. CHANCELLOR: And at sample -- what's the sample number?

MR. TRUDEAU: U-1.

MS. CHANCELLOR: So you performed direct shear tests on sample U-1. Correct?

MR. TRUDEAU: That's correct. That test consisted of three specimens that were sheared in the direct shear test at three different confining pressures. Those results are in Attachment 7, I believe, of Appendix 2-A in the SAR.

MS. CHANCELLOR: Do you recall what the results were in terms of cohesion intercept and friction angle?

MR. TRUDEAU: No, but I could look it up if it's important.

MS. CHANCELLOR: Well, let me ask you the next question and I'll see if it's important. Were the values that you obtained for these three samples that were taken from one bore hole from the pad emplacement area, were the values, the cohesive intercept, and three, the friction angle, were they used in the sliding calculations that you performed for the pads?

MR. TRUDEAU: Indirectly, I would say yes. The strength that was used in the sliding stability was based on the equation of the line shown in the plot of those results from that direct shear test on those three specimens. That line where it intercepts the zero axis is the cohesion, and the angle is related to the friction angle. The undrained strength was determined from that line by entering it at the effective stress that applies for the base of the pad.

MS. CHANCELLOR: Did the sliding analysis of the pads include any other test data in determining the Mohr-Coulomb Failure Envelope in your sliding calculations for the pads?

MR. TRAVIESO-DIAZ: I'm sorry. Where in the testimony are you asking him from? I don't recall seeing Mohr-Coulomb being mentioned anywhere.

MS. CHANCELLOR: It relates to the number of samples that were taken, Mr. Travieso-Diaz, and what use was made of those samples. There's testimony that states that this data -- the purpose of the -- of gathering soil properties was used as imports into the design of site structures on answer 15. And I'm finding out where -- what -- whether this one -- three samples taken from one bore hole in the pad emplacement area was used in the design -- in the -- as an import into the calculations.

MR. TRAVIESO-DIAZ: That's not at all the question that I heard. You're asking him about Mohr-Coulomb, which I -- that conversation related to the previous set of panel of witnesses on Part D. I don't know that Mr. Trudeau has referred to Mohr-Coulomb, or even where that is one of the things that he did in his calculation. I'm saying there is no foundation.

MS. CHANCELLOR: That's fine, Your Honor. I was trying to be efficient. I will lay a foundation.

CHAIRMAN FARRAR: Go ahead.

MS. CHANCELLOR: Did you use the Mohr-Coulomb Failure Envelope in your sliding calculation GB04 Rev9, PFS Exhibit, it's either UU or VV?

MR. TRUDEAU: I just answered that question two minutes ago, and I believe I said yes, indirectly, inasmuch as I used the line, which is defined that relationship by entering at the confining pressure applicable for the loading at the base of the pad, to come up with the undrained strength used in the sliding stability analysis.

MS. CHANCELLOR: Did you use any other test data to determine that failure envelope?

MR. TRUDEAU: The failure envelope used was --

MS. CHANCELLOR: We're talking about --

MR. TRUDEAU: -- the one from the direct shear test performed on sample C-2, boring C-2, U-1, which has similar results to the other direct shear tests that were performed in the canister transfer building area, but I did not use the results for the canister transfer building area in the pad stability analysis.

MS. CHANCELLOR: And a single date in point was used to demonstrate in your sliding calculations a factor of safety of 1.27 in the base case?

MR. TRUDEAU: For a very conservative analysis, yes, that ignored all the passive resistance, for instance.

MS. CHANCELLOR: In answer 20, continuing over onto page 14, you state that, "PFS' boring program conforms to the general requirements of Reg Guide 1.132." It doesn't comply completely. Is that what you're saying there?

MR. TRUDEAU: Where is it that we're reading?

MS. CHANCELLOR: On page 14, at the beginning of the first full paragraph, you see the indented language just prior to that. "At any rate, the PFSF boring program conforms to the general guidance in Reg Guide 1.132"?

MR. TRUDEAU: Yes, I see that.

MS. CHANCELLOR: So it doesn't comply completely with Reg Guide 1.132. Isn't that true?

MR. TRUDEAU: I'm not sure I can agree with that, no.

MS. CHANCELLOR: You state that in the beginning of answer 20, you state that, "Reg Guide 1.132 only applies to nuclear power plants." Correct?

MR. TRUDEAU: That's correct.

MS. CHANCELLOR: And you don't believe PFS has to comply with this guidance because it relates to nuclear power plants. Is that correct?

MR. TRUDEAU: I didn't say that either.

MS. CHANCELLOR: Well, do you agree with

that statement?

MR. TRUDEAU: I guess yes, I do agree with it. This is not a nuclear power plant.

MS. CHANCELLOR: I'd like to turn to resonant column testing. This is on answers 24 through 26 of your testimony. Is the resonant column test considered to be a high strain or a low strain dynamic test?

MR. TRUDEAU: It's kind of in-between.

MS. CHANCELLOR: Well, at what shear strain level is it considered to be appropriate?

MR. TRUDEAU: From low strains out to about .2 to .5 percent, would be my guess.

MS. CHANCELLOR: Is a cyclic tri-axial test considered to be a high strain or a low strain dynamic test?

MR. TRUDEAU: The cyclic tri-axial test can be run at higher strain levels, so I guess in that regard I would call it a high strain.

MS. CHANCELLOR: At what shear strain levels would be -- is it considered appropriate to run cyclic tri-axial tests?

MR. TRUDEAU: I don't know the range, complete range for which it's applicable, but I believe that it's -- it overlaps the range from the resonant column test, and it may go as high as one or two percent. I don't know, maybe higher.

MS. CHANCELLOR: Have you calculated the peak shear strain that develops in the upper Bonneville Clays directly underneath a fully loaded pad?

MR. TRUDEAU: I'm not sure. I think I may have as part of the development of the resonant - excuse me - the cyclic tri-axial testing that we did, but that was a long time ago. It's in the SAR. If you want, I can check through and see what I can find.

MS. CHANCELLOR: Would you recall at what strain level?

MR. TRUDEAU: No. Well, it's been several years, so I don't recall those details. No.

MS. CHANCELLOR: Do you have any idea of what strain levels would be developed under the upper Bonneville -- under a fully loaded pad on the upper Bonneville?

MR. TRUDEAU: I guess I would say no. I under -- you know, I know what they are for the free field case, but I don't know what they are under the pad.

MS. CHANCELLOR: In your testimony you state that, "The results of resonant column tests can be extrapolated to higher strains", and you discuss effective strains in the soils for the design earthquake. Correct?

MR. TRUDEAU: Yes.

MS. CHANCELLOR: What are the applicable -- I've asked that.

In your opinion, could you extrapolate resonant column tests for shear strains as high as one percent?

MR. TRUDEAU: I would say yes, based on the measure data that we have, applying it atop similar data that's been published in the literature, and seeing the trends in the data are similar, I would feel comfortable extrapolating that data, yes.

MS. CHANCELLOR: So that extrapolation that you mentioned in your testimony is based on published literature, not from any tests run on the PFS site. Is that correct?

MR. TRUDEAU: No. The extrapolation that's discussed here was extrapolating the data from the shallow sample to the strains applicable for the free field strain compatible soil property shake runs to encompass the full set of effective strains. The deeper sample measured moduli and damping values for strains wider than the effective strains applicable for the worst case, which I believe was the lower bound case, but I'm not positive, from the shake analyses that Dr. Youngs had performed.

MS. CHANCELLOR: Your Honor, I'm almost done, but I'd like to take a break and consult with Dr. Bartlett, if that's acceptable.

CHAIRMAN FARRAR: How long do you need?

MS. CHANCELLOR: Five minutes.

CHAIRMAN FARRAR: All right.

(Whereupon, the proceedings went off the record at 11:58 a.m. and resumed at 12:06 p.m.)

CHAIRMAN FARRAR: Ms. Chancellor?

MS. CHANCELLOR: I'm done, Your Honor.

CHAIRMAN FARRAR: Okay, thank you, very well done. Excellent. So the record will reflect, that is about 35 minutes.

JUDGE LAM: Way ahead of schedule, Ms. Chancellor.

CHAIRMAN FARRAR: Thank you.

MR. TRAVIESO-DIAZ: I will try to take advantage of that.

MS. CHANCELLOR: No, I get the credit time, Your Honor.

CHAIRMAN FARRAR: Mr. Travieso-Diaz, what are you thinking about?

MR. TRAVIESO-DIAZ: Excuse me? I can give you many answers to that.

CHAIRMAN FARRAR: How long do you think you will need?

MR. TRAVIESO-DIAZ: Redirect? I probably have no more than ten minutes, more or less.

CHAIRMAN FARRAR: Okay. Before you do that the Board has a couple of questions.

MR. TRAVIESO-DIAZ: Thank you.

JUDGE LAM: Mr. Trudeau, in your prefiled testimony you indicated that there are more than 200 pages of description of how the soils were tested in the safety analysis report.

The question is, I mean, your testimony seems to indicate this is a comprehensive program. The question is, on what basis did you stop? I mean, it seems to me there can always be more tests.

MR. TRUDEAU: That is correct. It is difficult to understand what is below the ground surface, because you can't see it. And it is expensive to get the information from below the ground surface.

So you can't just do everything. So you try to lay out a program to learn what information you can with a reasonable expenditure of funds. So this program was originally laid out as a grid of borings.

And those borings indicated that the subsurface profile at the site was monotonous, in the horizontal direction. And subsequent investigations have, excuse me, as part of that initial program we had done some laboratory testing on what was identified as the weaker and more compressible layer, layer 1B material.

And subsequent investigations were designed to demonstrate in a denser pattern of cone penetration testing, that that was, indeed, the case across the entire site; that the layer 1B soils exhibited the lower strength and consequently higher compressibilities than the materials down deeper in the profile.

JUDGE LAM: So you basically had a program to explore, to begin with, and then you modified it as you went along?

MR. TRUDEAU: We supplemented it in 1999, correct.

JUDGE LAM: Now, Ms. Chancellor's questions seem to imply that there may be two areas of error. One is the errors of commission, the other one is errors of omission.

The first area seems to imply that perhaps you did not know where to look. The second one is when you are doing a test perhaps you had some errors in the test.

Would you comment on these two types of errors?

MR. TRUDEAU: With respect to the errors in the test, I think it is safe to say that when you are extracting samples from the subsurface, those soils, no matter how good a job you do, are going to be somewhat disturbed.

When you take that undisturbed, but in reality somewhat disturbed sample, into the lab now, and you cut it open, and trim it, and put it into the testing device, you can readily appreciate that you are causing some more disturbance to the sample.

Then you run your tests, there are techniques that you use to try to compensate for some of those effects of disturbance due to sampling, and trimming, and sample set up, which is to apply higher confining pressures in the laboratory for some sample types.

But in reality it is easy to see, or recognize, that even the best undisturbed sample is going to exhibit some disturbance. And this disturbance, for these types of soils, is going to manifest itself as a decrease in the strength.

So the strengths that we are measuring will be lower than what they actually are in the field. It is just a given, because of the operations that you have to go through, to try and get that sample of soil set up in the laboratory, to run your tests.

JUDGE LAM: So these errors are well recognized by the people in the field?

MR. TRUDEAU: That is correct. And therein lies an additional conservatism, in that we are really measuring a lower bound strength for these soils when we test them in the laboratory.

If we had not disturbed them, at all, the strength would be higher. But we can't get them into the lab apparatus without disturbing them somewhat. We do everything we can to minimize the amount of disturbance.

JUDGE LAM: Thank you, Mr. Trudeau.

CHAIRMAN FARRAR: Go ahead, Mr. Travieso-Diaz.

REDIRECT EXAMINATION

BY MR. TRAVIESO-DIAZ:

Q Mr. Trudeau, let me start with one of the questions that Judge Lam asked you as to, the issue as to whether you didn't know where to look.

Is it correct to say that in the program that you described, in answer to Ms. Chancellor's questions, you testified that you actually looked everywhere in the pad emplacement area?

A Yes, the borings and the cone penetration test covered the whole area.

Q Is there any portion of the pad emplacement area that you didn't cover by one or both type of tests?

A No, the grid of borings and CPTs covered the entire pad emplacement area.

Q So there is no question that you looked everywhere that you should have looked, is there?

A No.

Q Now, Ms. Chancellor asked you a few questions. And would you turn to page 10 of your testimony, table 1?

She asked you a number of questions. Are you there?

A Yes, I am.

Q She asked you a number of questions about the one sample that you used for determining the shear strength of the soil. Do you remember those questions?

A Yes, the direct shear tests.

Q Right. And you testified that the sample that you used was sample U-1 from boring C2?

A That is correct.

Q That is the eighth line down on the table?

A Yes.

Q Tell us about that sample. First of all, where was it taken from?

A That was taken from within the layer 1B soils, within the weaker portion of the profile. It, as I said earlier, the specimens, this is the silty clay/clayey silt material, the sample, we were able to set up three direct shear test specimens from that sample.

This particular sample, for those that don't know, are three inch diameter thin walled steel tube samples that are typically pushed 24 inches into the ground. So we oftentimes have a full 24 inch long sample.

The direct shear specimens are on the order of one to two inches thick, from that three inch diameter sample. So we set up these three direct shear specimens from this one tube sample, and ran the tests, and got the strength results from it.

And the void ratios for these particular specimens are the highest void ratios of all of the samples that we tested in the pad emplacement area. And the void ratio is related to the density. The density is lower when the void ratio is higher.

The strength of the soil is a function of void ratio and density, as well. The higher the void ratio the lower the strength. So based on the fact that these specimens were the highest void ratio specimens of all of the triaxal testing, and consolidation testing, undisturbed sampling testing that we did in the pad emplacement area, we feel that this represents the lowest bound strength for that layer 1B material.

Q Let me ask you a couple more questions about this sample. Where is C-2 in the pad emplacement area?

A It is in the northeast quadrant.

Q Do you have any information as to the general characteristics of the soils in that quadrant?

A In general we found that that quadrant the soils are, indeed, a little bit weaker than elsewhere on site. So that particular one was one that we looked to, to test for this direct shear, to make sure that we were getting the weakest soils to test.

So it is perhaps not too surprising that we find that the void ratios were, indeed, highest for those specimens.

Q Now, tell me a little bit more about what has been described as the upper Lake Bonneville deposit clays, or layer 2, or layer 1B, is this a uniform layer in terms of strengths of the soils throughout the layer?

A Actually, no. If we look at the foundation profiles you will see that near the surface of this clay layer the tip resistance data indicates that there is like a crust on top of the silty clay/clayey silt, that exhibits tip resistances that are at least twice as high as the deeper line, like layer 1B material.

And this sample came from the deeper lying soils that would represent the weaker soils in that layer 1-B material.

Q So that 5 to 7 foot range, in terms of location, would represent the weakest portion of the layer 2 material?

A Yes.

Q All right. And if I understand your testimony, you took a sample that had the highest void ratio, meaning lower density, which correlates to lower strength, and you took it from the area that had the weakest soils, as far as you could tell, and you took it from the portion of the weakest layer in the subsoil, that you knew of, and you took it from the lowest portion of that layer, is that correct?

A Yes.

Q Is there anything else that you could have done to try to come up with a weaker sample you could find?

A No.

Q Okay. One last question. I remember that Ms. Chancellor asked you whether you had tried to do some type of statistical analysis of the standard deviation of the variations in tip resistance for your cone penetration tests, do you remember that?

A Yes.

Q Mr. Trudeau, Ms. Chancellor asked you whether you had done any type of statistical analysis on the deviation of, or variation of cone tip resistance values across the various horizontal locations of the site?

A Yes.

Q And you said that you didn't do such an analysis?

A That is correct.

Q Do you feel there was ever a need for doing such an analysis?

A No.

Q Why not?

A The site is consistent across the horizontal direction. You can just look at the tip resistance values plotted on these foundation profiles and see that we are, indeed, working with the critical layer. And as we just discussed, with this direct shear test, for instance, we've got evidence in this high void ratio that it is the weakest specimen tested at that site.

Q Thank you, that is all I have.

CHAIRMAN FARRAR: Thank you, Counsel. Any recross by the staff?

MR. O'NEILL: Quick questions.

CHAIRMAN FARRAR: Go ahead.

RECROSS EXAMINATION

BY MR. O'NEILL:

Q Mr. Trudeau, for purposes of the pad sliding stability analysis, so you are concerned mainly with undrained shear strength, correct?

A Yes.

Q Isn't it true that the only source of information that you have is not the laboratory test results of the undisturbed sample that was taken below the pad, correct?

A That is correct.
Q You have CPT data as well, correct?
A Yes. I thought I said that. If I didn't, that should be clear.
Q And you can correlate that with the laboratory test data to obtain information about the relative shear strengths of the site, correct?
A That is correct. The higher the tip resistance, the higher the strength.
Q And your CPT data was fairly extensive, correct?
A That is correct.
Q I believe it was taken from 37 different points?
A In the emplacement area, yes.
Q At the 0.2 foot intervals?
A It was, essentially, continuous readings.
Q Yes, continuous readings. So for a 10 foot thickness of soil you are going to obtain a fairly large number of readings, correct?
A That is correct.
Q Mr. Trudeau, there was also some discussion about REG Guide 1.132?
A Yes.
Q Irrespective of whether it applies to

nuclear power plants, or other nuclear facilities, it is still regulatory guidance, correct?

A That is correct.

Q And are you aware that that particular piece of guidance acknowledges the exercise of professional judgement in the use of alternative site investigation techniques?

A Yes.

Q Thank you.

CHAIRMAN FARRAR: That is it, Mr. O'Neill?

MR. O'NEILL: Yes.

CHAIRMAN FARRAR: Thank you. Ms. Chancellor, any recross?

MS. CHANCELLOR: Just one second, Your Honor.

CHAIRMAN FARRAR: Okay.

(Pause.)

RECROSS EXAMINATION

BY MS. CHANCELLOR:

Q I really only have one or two very quick questions.

With respect to the U1 sample taken from location C2, which you state was in the northeast quadrant, you said that that had the highest void ratio?

A Of all of the specimens that we tested in the pad emplacement area.

Q And the lowest density, or low density?

A The high void ratio would result in a low density, yes.

Q And then we go from low density to lowest strength, is that right?

A Yes.

Q And from that we go to the assumption that these are the weakest soils, correct?

A Yes.

Q And then Mr. Travieso-Diaz asked is there anything else you could have done, do you recall that question?

A I guess so, yes.

Q There were five or six other bore holes in the pad emplacement area, correct?

A Yes.

Q Another thing you could have done is taken samples from those six bore holes, correct?

A We did take samples from those six bore holes.

Q For the direct shear test?

A I guess that is true, you could have done that if you were --

Q Prudent?

A -- you could have if you wanted to do it when you were drilling the borings. But you don't take undisturbed samples in every boring, necessarily.

Q For a 55 acre area?

A Correct.

Q You take one sample --

A As REG guide 1.132 recommends, you would alternate split spoons with undisturbed samples in some borings, and the split spoon technique is a normal method of doing a site investigation.

Q But the bottom line is you could have taken additional samples --

A Yes.

Q -- from the 5 or 6 other bore holes in the pad emplacement area?

A Yes.

Q Thank you very much, Mr. Trudeau.

MS. CHANCELLOR: No further questions, Your Honor.

CHAIRMAN FARRAR: Mr. Travieso-Diaz any more --

MR. TRAVIESO-DIAZ: I have one question to follow-up with Ms. Chancellor.

CHAIRMAN FARRAR: Yes.

FURTHER REDIRECT EXAMINATION

BY MR. TRAVIESO-DIAZ:

Q Ms. Chancellor asked you, a couple of times, whether you could have taken samples, undisturbed samples for determination of shear strength from five or six other locations.

In retrospect, looking at the results of the strength that you obtained from the sample that you took, do you feel there was a need for that?

A No, I don't think so.

Q Why not?

A For the reasons we discussed earlier, that this particular sample yielded the highest void ratios of all of the samples that we tested from the pad emplacement area.

So, you know, I just don't think that it would have been necessary.

Q Thank you.

CHAIRMAN FARRAR: All right, that concludes. I want to commend Counsel, it looks like we did that witness in a little less than an hour and a half, which puts us a bit ahead of schedule, and we will also, if direct only takes that long, in rebuttal, if it eventually comes, it should be shorter.

So, perhaps, we are in good shape. It is almost 12:30, let's take a lunch break until 1:30, and then we will have Dr. Ofoegbu with fairly limited questioning, I understand.

(Whereupon, at 12:28 p.m., the above-entitled matter was recessed for lunch.)

CHAIRMAN FARRAR: Back on the record for the afternoon session. Mr. Travieso-Diaz, I believe you had a procedural matter you wanted to deal with before we start?

MR. TRAVIESO-DIAZ: Yes, Mr. Chairman. I had distributed to the Board, the Court Reporter and the Parties, the written rebuttal testimony of Mr. Trudeau to the prefiled direct testimony of Dr. Bartlett.

This piece of rebuttal testimony has four exhibits, and I would like to mark them now because I may have occasion to use them with Dr. Bartlett, and rather than do it twice, I would rather do it at the beginning.

CHAIRMAN FARRAR: All right, let's do that.

MR. TRAVIESO-DIAZ: The first of the four exhibits, to Mr. Trudeau's testimony, and this is going to be PFS exhibit 233, is Figure 2.6-5 of the safety analysis report.

Actually this figure consists of 14 sheets, but I'm marking only one of them, sheet 7 of 14.

CHAIRMAN FARRAR: All right.

(Whereupon, the above-referenced to document was marked as PFS Exhibit No. 233 for identification.)

MR. TRAVIESO-DIAZ: The second document that I'm marking as an exhibit is a complete copy of REG guide 1.132.

CHAIRMAN FARRAR: That will be 234?

MR. TRAVIESO-DIAZ: It is 234.

CHAIRMAN FARRAR: All right.

(Whereupon, the above-referenced to document was marked as PFS Exhibit No. 234 for identification.)

MR. TRAVIESO-DIAZ: The third document that I want to mark as an exhibit, 235, if Figure 2.6-19 of the SAR, which is entitled: Locations of Geotechnical Investigations in Pilot Placement area.

(Whereupon, the above-referenced to document was marked as PFS Exhibit No. 235 for identification.)

MR. TRAVIESO-DIAZ: And the last exhibit that I want to mark at this time is exhibit 236, PFS exhibit 236, which consists of the cover page, and excerpts from Dr. Bartlett's deposition of November 17, 2000.

(Whereupon, the above-referenced to document was marked as PFS Exhibit No. 236 for identification.)

CHAIRMAN FARRAR: All right. Then those will be marked, and we will deal with them at the appropriate time, and thank you for providing them, in advance, to everyone.

MS. CHANCELLOR: Just a point of clarification. This is the deposition of Bartlett and Ostadan, of all the question and answers here, questions by you and answer by Dr. Bartlett?

MR. TRAVIESO-DIAZ: Yes, Ms. Chancellor, if you can remember that far back, and it is hard, Dr. Bartlett was by himself for most of the second day of the deposition.

MS. CHANCELLOR: Right.

MR. TRAVIESO-DIAZ: And this is off of

that portion, from the end.

MS. CHANCELLOR: Okay, thank you.

CHAIRMAN FARRAR: All right, then let's get back to the regular order of business, which was going to be the direct testimony of Dr. Ofoegbu on soils.

Dr. Ofoegbu, consider yourself still under oath, please.

MR. O'NEILL: The witness is available. I would note, at the outset, that I believe the testimony extends through up to question 19, and not including question 19, it is my understanding.

CHAIRMAN FARRAR: This is the same --

MR. O'NEILL: The same piece of testimony, that has been admitted.

CHAIRMAN FARRAR: Right. And it goes up through what question?

MR. O'NEILL: It appears to me to be question 19, not including question 19.

CHAIRMAN FARRAR: Right, okay.

MR. O'NEILL: Is that okay?

CHAIRMAN FARRAR: Yes, questions 1 through 18, we did the rest earlier this week. Then does the Applicant have any cross?

MR. TRAVIESO-DIAZ: Mr. Chairman, I'm

going to ask no questions at this time, and that should be carried to me for at least an hour towards the balance of the Hearing.

CHAIRMAN FARRAR: Nice try. I will consult with my colleagues and we will let you know.

MR. TURK: Just so the record is clear, and I would simply note that Dr. Ofoegbu has already adopted this testimony as his sworn statement in the Proceeding, back when we did the soil cement portion, that applied to the entire testimony, as I understood his questions and answers.

CHAIRMAN FARRAR: Right. Ms. Chancellor, I believe you indicated you would have only a few questions? Ms. Nakahara?

MS. NAKAHARA: Actually I overestimated between 30 minutes and an hour, and it should be much less.

CHAIRMAN FARRAR: All right. Let's see what we can do.

CROSS EXAMINATION

BY MS. NAKAHARA:

Q Good afternoon, Dr. Ofoegbu.

A Good afternoon.

Q How many EPRI sites have you developed a soil sampling investigation program for, other than the -- strike that.

A Reviewed, or --

Q No, developed?

A Developed? I haven't developed any.

Q How many have you reviewed, and how many soil investigation plans have you reviewed, or evaluated, other than the PFS site?

A Related to EPRI sites again?

Q Yes.

A The first ESPC site that I have reviewed is the PFS site, and I'm currently reviewing, I'm doing the review of the Diablo Canyon application.

Q And is the Diablo Canyon site characterized as a soil site?

A It is a mixture, it is mostly rock, but there are soils there.

Q And what is the approximate size of the actual SPC at the Diablo Canyon site?

A Well, what size of --

Q The area of --

A The entire Diablo Canyon?

Q No, just of the --

A The storage pad?

Q Yes.

A I don't know off-hand.

Q Is it fair to say that it is smaller than the PFS site?

A I believe it is smaller.

Q The PFS site is a layered soil site, is that correct?

A Yes, it is a layered soil site.

MR. O'NEILL: What is your understanding of layered? Do you understand the term?

THE WITNESS: Yes, I understand.

BY MS. NAKAHARA:

Q And the thickness of the various soil type layers at the PFS site vary across the site, correct?

A The thickness varies.

Q The soil properties at the PFS site vary with depth also, correct?

A That is correct.

Q And the soil properties also vary horizontally, correct?

A They vary horizontally, but they vary more with depth than horizontally.

Q The shear strength of the soil at PFS varies with depth, correct?

A That is correct.

Q And the shear strength also varies horizontally at the PFS site, correct?

A As I said before, the properties, and that includes the shear strength, vary more with depth than horizontally. I believe there is some horizontal variation.

Q And do you agree that the pad emplacement area at the PFS site is approximately 51 acres?

A Actually I've never measured, but if you have, then --

Q I have not, but I'm relying on Mr. Trudeau's testimony.

You were present for Mr. Trudeau's testimony this morning, is that right?

A Yes, I was.

Q Do you agree that Mr. Trudeau testified that the sliding resistance of the pad was determined, in part, based on a direct shear test from a single bore hole? Do you recall that testimony?

A I recall that testimony. The question and the answer given led them to give an incorrect impression of the amount of data collected to characterize the shear strength of the soil.

The purpose of the direct shear test they did was to determine undrained shear strength of the soil. The purpose of penetration resistance did at the site was also to determine the undrained shear strength as well as other properties.

In fact I did a calculation when that question was being discussed. And by my own count I would say there were 1,850 tests, undrained shear tests, across the pad area.

Q Are those laboratory tests?

A Those are in situ tests, so they are not laboratory.

Q And would you define what --

A In situ, done in place. There are two groups of tests that are done to measure the shear strength of soils. There are the laboratory tests, and the in situ tests can do this using several types of instruments.

At the PFS site they used cone penetrometer to do in situ test of undrained shear strength.

MR. TRAVIESO-DIAZ: Dr. Ofoegbu we are having trouble understanding what you are saying. Are you meaning to say in situ, S-I-T-U?

THE WITNESS: In situ, americans would say in situ.

MR. TRAVIESO-DIAZ: Thank you very much.

BY MS. NAKAHARA:

Q Isn't it true that the pads were designed based on the laboratory test, and not the in situ test?

A Well, the laboratory test is, you can't test them separately. The way site characterization on (Unintelligible due to accent) you do an in situ test, the in situ test give you relative variation, or shear strength.

And you do laboratory test that can be combined with the in situ test to determine what the shear strength is.

Q Have you, yourself, performed any site specification correlation to relate the in situ test to the one direct shear test, to undrained shear tests?

A Well, actually the correlation is done in figure 2.6-5 of the safety analysis report, there are 14 sheets, showing how the cone penetrometer varies. That is actually a correlation because it tells you how the undrained shear strength varies with depth at each sounding location.

This is discussed in the safety evaluation report, as well as in my prefiled testimony.

Q What was the basis of correlation with the CPT data, and the undrained shear strength test in the lab?

A I need a little bit of help. What is the basis for correlation, what exactly --

Q Isn't it true you stated that you can use the CPT data to determine the undrained shear strength?

A The CPT data shows that the undrained shear strength of the soils, it shows clearly how they vary with depth, and how they vary from one sounding location to another sounding location.

That is the correlation in my understanding of it.

Q And you said it varies with depth. How do you determine what the actual value is in the undrained shear strength from the CPT data?

A Oh, there are, which are available in text books that can be used. But the best way, and this is what was actually done at the PFS site, is that you take a location where you have measurements, laboratory test data, and then compare them with the CPT measurement, at those nearby locations, and then you can get actual value, if you are looking for the actual value.

Q And did you do that?

A Hold on, I'm trying to finish my answer. The PFS did it in a different way. For calculation of undrained, I mean, of bearing capacity, there is collected samples from layer 1B soil, and I think this is in dispute.

And determine the shear strength, based on laboratory test, on layer 1B soil. The CPT data shows clearly that the shear strength that have determined is the minimum at every location.

That is where you look at it, profile of shear strength with depth. Now, in the work bearing capacity, the shear strength available for bearing capacity calculation is the average over the 30 feet depth, starting from the depth of three feet, at the base of the foundation, to a depth of 33 feet.

And this average, instead of calculating this average, they use the minimum value, and it is very clear at every point that the value they have used is much smaller than the value they could have used.

Q Isn't it true PFS has not developed a specific, a site specific correlation to -- strike that.

Isn't it true PFS has not developed the site specific correlation that relates the CPT data to undrained shear strength?

A Well, that is not true. They have

developed, and it showed in the figure 2.6-5, 14 sheets.

Q But that just shows the CPT data, correct?

A Well, that shows how undrained shear strength varies with depth.

Q But they have not correlated to specific shear -- they have not correlated to a specific undrained shear strength value, correct?

A Okay. It looks like we need to define what we mean by correlation.

Q Isn't it true those plots you are referring show tip resistance, and not undrained shear strength?

A Undrained shear strength is proportional to tip resistance. So it shows how the undrained shear strength varies with depth, and from point to point.

Q It is proportional but it does not specify the undrained shear strength, correct?

A It doesn't tell you the absolute value of undrained shear strength. It tells you how the undrained shear strength varies with depth, and varies laterally across the site.

Q And has PFS specifically developed the values for each of the cone penetrometer tip resistance values to correlate with the undrained shear strength?

A They didn't need to. All they needed to show was that the value used for their design calculation was less than the value they could have used based on an interpretation of the CPT data.

Q In your answer to question 18 you state: The Applicant in the SAR, regarding the stress strain characteristics of the native foundation soil, information provided by the Applicant in the SAR regarding the stress strain characteristics of the native foundation soils is sufficient to demonstrate that the soil conditions are adequate, correct?

A Yes.

Q Do you know the shear strain levels that were developed in the upper Bonneville clay?

A Shear strain level?

Q Yes.

A I didn't need to know that.

Q You didn't --

A -- this conclusion, no.

Q You didn't need to know that, for the design of the pads?

A Not at all. Geotechnical analysis of foundations is based on strength, not on strain, unless you go into numerical analysis, but that wasn't done, and that wasn't used.

Q What about for the dynamic analysis of the pads?

A Well, dynamic analysis of the pad was done on the -- the bearing capacity design on analysis shows that shear failure of the soils, that there are sufficient factors, safety factors against shear failure.

Which means that when the soils, if the soils were subjected to loading from the design basis earthquake, they would not reach the peak shear strength.

Now, based on that, then the elastic assumption can be used to analyze the stress strain behavior of the soil under that specific loading. And this is why for the dynamic pad analysis they used the elastic assumption.

And because the bearing capacity analysis proved the static calculation of stability, showed that the soils would not be loaded to their peak strength under the design basis earthquake.

Q Is it your opinion that the Bonneville clays remain in the elastic range during dynamic loading?

MR. TURK: I think I need --

BY MS. NAKAHARA:

Q For the design basis earthquake.

A That is what the analysis shows, and that is correct, yes. And while we are here, remember that this is actually based on a model that is used prevalently in soil engineering, that is if you can show that soils would not be loaded to their peak strength, then the relationship between stress and strain is reasonably linear below the peak.

Now each time you load the soil, in reality, there is a combination of recoverable deformation, and non-recoverable deformation.

Now, provided the load level, the stress level is below the peak, the assumption is met that the soil is analyzed using an elastic model. And the reason for that is that the percentage of plastic deformation is very small compared to the total deformation.

Q Did Geomatrix use an elastic model to model the stress strain behavior of the Bonneville clays?

A Geomatrix? Well, they used the non-linear elastic. And the reason for that is that the instantaneous shear modulus of soils varies with strain level.

And when you do a dynamic analysis to get the correct shear modulus applicable to a given strain level, you know, you need to determine, I mean, you need to allow the shear modulus to vary with strain.

So the codes that do this allow that kind of variation. But it is still an elastic model because it is non-linear elastic.

Q But isn't it true you are trying to model a non-linear process?

A What am I trying to model? I'm sorry to ask you a question. I'm not supposed to, but -- but you said I'm trying to model --

Q Geomatrix analysis, they tried to model a non-linear --

A Well, the Geomatrix analysis, remember, this is site response analysis you are talking about, the analysis they conducted to determine how the soil profile affected the ground motion. Is that what you are talking about?

MR. TRAVIESO-DIAZ: Mr. Chairman, I hate to object, but in the interest of time, again, we are going back to how Geomatrix prepared the strength compatible soil properties, which was largely and extensively discussed in section D.

Those are not soil properties that we are discussing here, it is not in Dr. Ofoegbu's testimony, I don't believe, or anybody else's.

CHAIRMAN FARRAR: Ms. Nakahara?

MS. NAKAHARA: Your Honor, Dr. Ofoegbu opines that the test program, and the characterization of the soils at the PFS site are adequate. And this, even though it may be strained into other areas, it is all interrelated, and it relates to his opinion that PFS has adequately conducted an investigation and testing program for soils.

MR. TRAVIESO-DIAZ: This is not part of Part C, I'm certain. And I even wonder whether it is part of Part D. But certainly it is not part of Part C.

Any questions Dr. Ofoegbu, as to how the tests were, what properties they found, and so on, I think is within limits. Getting into what Geomatrix did with them, again, and what they produced, again, that is going back to what we did in Salt Lake City.

MS. NAKAHARA: And, Your Honor, this also relates to whether there is consistent opinions whether Geomatrix took a position on one hand, and Dr. Ofoegbu is taking a different position, whether it is consistent.

MR. TRAVIESO-DIAZ: Well, we have heard no premise to that at all in this case. And I would object to having that issue introduced. That is a totally new potential issue that doesn't even exist.

CHAIRMAN FARRAR: Let me ask you this. When the company has all these soil tests done what do they hand over to Geomatrix?

In other words, do they hand over the whole test protocol, and so forth, so that -- and then Geomatrix may come back to them and say, gee, this isn't enough. Or do they just give Geomatrix some -- this isn't enough, and it wasn't done properly, or does Geomatrix just take some numbers and begin to plug them into their analyses?

And the purpose of that question is to see to what extent there is interrelationship between C and D, as it is presented here.

Anyone want to address that?

MR. TRAVIESO-DIAZ: My understanding, and I believe that Mr. Trudeau has explained this already, is that the result of the soils investigation, instead of strengths, stresses, compressibility, all those various properties, are reported and they are passed on to Geomatrix.

What Geomatrix does with them is that they do the analysis that was described by Dr. Youngs, and they come up with their own set of properties that are used for dynamic analysis.

What happens beyond the point where Geomatrix receives it, is our scope of C.

CHAIRMAN FARRAR: Well, unless Geomatrix might come back to them and say, the stuff you gave us isn't worth anything.

MR. TRAVIESO-DIAZ: Yes, but there is absolutely no allegation, evidence, proof, or even claim that that ever happened. And I invite Ms. Nakahara to show me -- if she is going to say that there is a difference of opinion between Dr. Ofoegbu and Geomatrix, I have seen no evidence that Geomatrix ever complained about not having good data.

MS. NAKAHARA: Your Honor --

CHAIRMAN FARRAR: So under that view, if we are going to attack the data, it has to be at this level on C, and not through what Geomatrix did?

MR. TRAVIESO-DIAZ: Absolutely. And if, in fact, they had any evidence, or any hope to obtain evidence, that Geomatrix wasn't happy with the data they got, they could have asked Dr. Youngs, he was here for two weeks. He was the person to ask, not Dr. Ofoegbu.

MS. NAKAHARA: Your Honor, if I may make a few points?

CHAIRMAN FARRAR: Okay.

MS. NAKAHARA: This line of questioning goes to whether PFS collected an adequate number of samples. This goes to the single bore hole sample that -- strike that.

We will just address this in redirect of Dr. Bartlett. I can move on.

CHAIRMAN FARRAR: Okay, thank you.

BY MS. NAKAHARA:

Q Dr. Ofoegbu, you were present Monday, during Dr. Wissa's testimony, correct?

A Yes, I was.

Q Do you recall that Dr. Wissa's testimony about index testing, that index testing would allow you to determine the variability of soils at the PFS site, is that correct?

A That is correct.

Q And that Dr. Wissa also testified that you may have, PFS may have 3, 4, or 5 different soils across the PFS site that would have to be considered for the soil cement mix, is that correct? Do you recall that testimony?

MR. O'NEILL: It seems to pertain to the

testimony that was proffered in connection with soil cement issues.

MS. NAKAHARA: This relates to the variability of the site, and Dr. Wissa's testimony that he believed that the soils varied across the site. And I'm just trying to ask Dr. Ofoegbu whether his opinion that there is sufficient testing supports that.

MR. TRAVIESO-DIAZ: Mr. Chairman, again, if I may comment?

First Dr. Ofoegbu testified on soil cement, and these questions could have been asked of him there. But more importantly this question totally mischaracterize what Dr. Wissa was talking about.

Dr. Wissa was talking about the eolian soil layer, the one in the surface that is going to be removed, and turned into soil cement. So I don't know how this pertains, at all, to the soil characterization issues.

The soils that we are looking at are the soils that are going to stay, not the ones that are going to be removed and turned into soil cement.

MS. NAKAHARA: And you don't believe they need to characterize the --

CHAIRMAN FARRAR: Wait, wait. Let me hear the question again, please.

MS. NAKAHARA: I was just asking whether he --

CHAIRMAN FARRAR: No, he is going to play it back.

(Whereupon, the requested portion of the proceeding was played back.)

CHAIRMAN FARRAR: We are going to sustain the objection on this theory. I think we understand, Ms. Nakahara, you may be trying to show that if the surface layer has variability, the soil has variability, that might tend to establish that the lower layer, which they've said doesn't vary, also has variability.

But our understanding of geologic conditions is that the upper layer was laid down through, at different times, and through different processes, than the lower layer. And, therefore, kind of draw an analogy isn't particularly useful.

And if we are mistaken in that Dr. Bartlett can testify to it. So we will sustain the objection.

MS. NAKAHARA: That is fine, Your Honor. And I'm smiling because your understanding is much more complex than mine. And I have no further questions.

CHAIRMAN FARRAR: Okay. I had to make this admission once, earlier in the case, during air time some times I say words that I was not smart enough to think of in the first place, but I have some, as I said before, some very good colleagues here with me.

JUDGE KLINE: And we've got a good lawyer.

(Laughter.)

CHAIRMAN FARRAR: Took him three months to admit it, but --

MS. NAKAHARA: Thank you, Dr. Ofoegbu.

CHAIRMAN FARRAR: That is all, Ms. Nakahara?

MS. NAKAHARA: Yes.

JUDGE LAM: Dr. Ofoegbu, in your review of the Applicant's work, did you find any major deficiencies?

THE WITNESS: At first we did, but that resulted in the Nuclear Regulatory Commission issuing a series of requests for additional information, which were responded to by the Applicant, and they eventually, the site characterization was adequate.

JUDGE LAM: So your review had actually contributed to the actual evolution of the soil testing program?

THE WITNESS: That is what we believe, yes. There were changes, there were substantial changes from the time we started to the time it ended. Now, whether these were because of the questions we asked, or because of the second thoughts that the Applicant had, we can't say.

JUDGE LAM: Now, when you look at the final result of the soil testing program, your testimony is that they had been adequate.

Now, to help this Licensing Board to calibrate, what do you mean by adequacy? If I ask you to rate them on a scale of 1 to 10, 10 being the highest, on both the quantity and the quality of the work, how would you rate them?

THE WITNESS: A rating like that is not fair, I rather explain what adequacy means from a regulatory point of view.

Really what we are looking at is the parameters used for design calculation, whether they would be supported by the site characterization information obtained.

We look at those parameters one at a time, the shear strength used in the bearing capacity analysis. There isn't any disputes that the Applicant collected laboratory samples from the weakest soil layer, and the fact that that layer is the weakest is abundantly demonstrated by the cone penetrometer data presented in figure 2.6-5, 14 sheets, in the safety analysis report.

So that establishes, firmly, that this is the weakest layer. And if you look at how that data varies, find that the average shear strength over 30 feet depth, at each location, is greater than the shear strength that was actually used in design analysis.

There is an exhibit that the State has, here, I don't know if I'm permitted to use it to show you, because it shows a visual of what I'm talking about.

There is State's exhibit 59 taken during the deposition.

MR. TRAVIESO-DIAZ: Judge Lam, I intend to ask, in recross to Dr. Ofoegbu, some questions relating to what I believe he is talking about, which is exhibit 233.

So perhaps you may have more questions for him after asking those questions.

JUDGE LAM: That would satisfy my concern.

MR. TURK: Or we could just hand him the

exhibit and he could complete his answer.

MR. TRAVIESO-DIAZ: That would be acceptable to me, but I didn't want to speak out of turn.

THE WITNESS: Yes, that is the one I'm referring to, but I don't know if I'm allowed to use it.

MR. O'NEILL: Referring to State's exhibit, I believe, 100? Well, it was originally identified, I think, during the course of the deposition, as exhibit 59.

It contains several figures showing plots of CPT traces at tip stress, versus depth, something Dr. Bartlett had prepared. Exhibit 99, I think.

MR. TRAVIESO-DIAZ: Again, Mr. Chairman, Dr. Lam, that is an exhibit, State exhibit 99, which I intend to use later today, but I don't know if it is appropriate, at what point, to have the witness see it, since it is not my witness, and I'm not -- I don't know what the good way to go about it is.

JUDGE LAM: Well, you know, there is no need to go to a level of excruciating detail. The reason I asked the question is when I read something being labeled adequate, I need somehow to calibrate that.

Like my high school math teacher would have done an adequate job of teaching high school algebra. And Dr. Albert Einstein would also have done an adequate job of doing his relativity theory.

Adequacy means, could mean barely passing, or to a level of sophistication and comprehensiveness that would give us a great level of assurance that, indeed, the soils testing program is good.

I mean, that is the reason I asked that question. A simple answer would do.

THE WITNESS: What I would say is that the information they have is adequate. I was going to go into detail and explain, because given a number grade 1 to 10 is difficult.

I mean, that is -- it is -- there is something analysis (UDTA) I don't even know how to give a number to that. But there is abundant reasonable assurance that the work that the site characterization demonstrates, that the information used for design represents the properties of the soils that would affect the behavior of the structures, systems, and components important to safety at the site.

JUDGE LAM: Okay, thank you.

CHAIRMAN FARRAR: Any redirect by the

Staff?

MR. O'NEILL: Just give me a moment, Your Honor, please.

MR. TURK: May we talk to the witness also, for a moment?

CHAIRMAN FARRAR: Yes.

MR. TURK: Let's go off the record for about two minutes?

CHAIRMAN FARRAR: Yes, go ahead.

(Whereupon, the above-entitled matter went off the record at 2:19 p.m. and went back on the record at 2:21 p.m.)

MR. O'NEILL: We have no further questions, Your Honor, thank you.

CHAIRMAN FARRAR: All right.

MR. TRAVIESO-DIAZ: I have only one area, perhaps two or three related questions.

CHAIRMAN FARRAR: Okay, go ahead.

MR. TRAVIESO-DIAZ: If Mr. Turk could lend Dr. Ofoegbu his copy of exhibit 233? That is the foundation profile.

MR. TURK: I've handed the witness a copy of Figure 2.6-5, which I believe is PFS proposed exhibit 233.

MR. TRAVIESO-DIAZ: I will identify it for the record. As I said earlier, this exhibit 233 is sheet 7 of 14 of the Foundation Profiles included in figure 2.6-5 of the PFS SAR.

CROSS EXAMINATION

BY MR. TRAVIESO DIAZ:

Q Is this one of the sheets to which you were referring, Dr. Ofoegbu, in talking, in previous testimony's response to Ms. Nakahara's questions?

A Yes, this is one of the sheets.

Q Could you, just very briefly, tell us, by reference to this figure, how can you correlate the cone penetration readings to shear strength, both vertically and horizontally across the site?

A Okay. EaCh of the -- this is black and white photocopy, so it is not exactly as good as the color copies in the SAR. But the dark lines represent the tip resistance.

It is usually given in tons per square foot. It is not a direct shear strength value, but it is proportional to the shear strength at each location.

Q Dr. Ofoegbu, pardon me, so the record is clear.

A Okay.

Q When you say that line, do you mean the wiggly vertical lines across each of the profiles?

MR. TURK: I thought he said dark lines?

THE WITNESS: Yes, they are dark, but they are --

MR. O'NEILL: Dr. Ofoegbu -- I'm sorry, I apologize for interrupting. Would it be helpful to have a color version?

THE WITNESS: Yes, a color version would be much better for me, because I have looked at them more.

MR. TURK: I would ask, as you do that, because the rest of us have black and white, look at both the color version and the black and white, so you can help us understand, when we see our black and white copies, what we are looking at.

Or we could ask the Applicant, perhaps you could get us some color copies later?

MR. TRAVIESO-DIAZ: Well, I have at least one. I apologize. When I was trying to get copies made, black and white is the best that we can do. Dark solid lines that show, each of them runs from the top -- they start from the point letter CPT- a number, then the dark line runs down vertically, going way down, until it goes down to about elevation 4440, on the first --

MR. TURK: May I ask, just so we are clear in following you, Dr. Ofoegbu, I think you are looking at the first vertical column, the thick, in your black and white it looks like a thick grey vertical column?

THE WITNESS: Yes.

MR. TURK: Within which there is a line drawn that wiggles?

THE WITNESS: Yes.

MR. TURK: And when you refer to the dark line, you are talking about the wiggly line that appears going down through that vertical column, and at some point going outside the dark grey wide vertical column. On paper it appears to be about a half inch wide vertical column.

THE WITNESS: Yes. And the horizontal distance of that line, from the part of the rectangular column, indicates the magnitude of the tip resistance.

MR. O'NEILL: So you are referring to the left edge of the rectangular column?

THE WITNESS: Yes, the left edge of the rectangular column is like zero of the wiggly line, and then the farther the wiggly line is from that left edge, the greater the tip resistance.

MR. TURK: I ask you, also, to explain --

there appear to be two wiggly lines in that first strong vertical column.

And if you notice, for instance, at elevation 4455, it is fairly pronounced. You see there is one wiggly line that goes to the center of the column, and one that goes far off to the right?

THE WITNESS: Yes.

MR. TURK: When you are talking about the wiggly line, which wiggly line are you referring to?

THE WITNESS: Well, actually it is the one that is farther to the right, because that is the one that shows tip resistance. The other one is the sleeve resistance.

The cone penetrometer measures two types of resistance. It measures resistance to the tip of the cone, which is really the more useful one. And then it measures resistance to the cylindrical body of the rock. The penetrometer is a rock, cone down.

MR. TRAVIESO-DIAZ: May I resume?

THE WITNESS: Yes.

(Laughter.)

MR. TRAVIESO-DIAZ: I greatly appreciate the clarifications, but I'm missing my train of thought.

BY MR. TRAVIESO DIAZ:

Q Dr. Ofoegbu, let's just try to, first of all, to make it clear. Do you see, in the extreme right-hand column, a quarter of the drawing, something called cone penetration tests?

A Yes.

Q And there are zigzag lines there?

A Yes.

Q Are just a representation of the same zigzag lines that you see on each of the six vertical shafts on the figure?

A That is correct.

Q And you were saying that the right-hand most of the two set of lines in the legend represents the value of cone penetration tip resistance that we are interested in?

A Yes, the tip resistance.

Q All right. Now, if you will look, just so that we all focus in the same place, at the first of this vertical shaft, the one that is marked CPT32 on the left?

A Yes.

Q Do you see that?

A Yes.

Q Now, is it your understanding that what this profile represents is the variation with depth, as you go down on the profile of the tip resistance registered by the cone penetrometer?

A That is correct.

Q Thank you. And now, look, for example you see a series of dotted lines that go across from the left to the right of the drawing, do you see those?

A Yes.

Q What do those dark dotted lines represent?

A Actually there are two sets of dotted lines. The thick ones --

Q Yes, I mean the thick ones.

A Okay. The thick ones, I believe, represents (UDTA) interfaces. It is bounded between different layers, based on the interpretation of these cone tip resistance. Is that correct?

Q So, for example, if you take a look at the first dotted line that is between 4465 and 4470, would that be your understanding, that that is the line of demarcation between the eolian silt layer on top, and the silty clay dash, or slash, clayey silt below?

A That is correct, yes.

Q And that second layer is called silty clay/clayey silt, is what we have been talking about as layer 1B, or layer 2, or upper Lake Bonneville deposits?

A That is correct. They are 1B in the safety evaluation report.

Q So if I want to use this figure to determine how the cone penetration tip resistance varies from one layer to another, and within one layer I would just start to follow the zigzag line?

A Yes.

Q Okay. Now, tell me, concentrating just on the second layer, the one that is layer 2, or layer 1B, do you see, at the top of that layer, at approximately between the boundary at 4468, or so, and 4466, that there is like a peak in computation tip resistance?

A Yes.

Q Do you have any explanation for that tip, for that -- sorry.

A Well, I believe that this is the kind of hard crust that is usually found on the top of a soil profile. That is one possible explanation.

It is really the explanation that we are interested in here is that this is, that the top of the silty clay, clayey silt, has higher shear strength than the underlying part of the silty clay/clayey silt.

Q Now, let me ask you a couple of other

things. The rectangles that are on the very top of the, that have a caption called storage pads?

A Yes, I see those.

Q Would those be the storage pads that we have been talking about, throughout this hearing?

A That is a representation of the storage pads, yes.

Q Would your understanding be that the cement treated soil layer that has been discussed about, would be immediately below those storage pads?

A That is what we understand, yes.

Q Would your understanding be that the soil, the cement treated soil layer would be in close proximity to that area that you said that could be the crust of the layer 2, layer 1-B?

A That would be the assumption, yes. Unless they remove that layer.

Q Unless they remove it. But if they don't remove the layer, would the cement treated soil layer rest on top of that you call crust?

A That would be correct, yes.

Q And that is the area within this layer 2 that has the greatest strength?

A That is correct.

Q Now, you would take a look within the

layer 2, or layer 1B, and you get past that peak, and move down, say closer to 465, does it look to you like the cone penetration tip resistance is fairly uniform from there to near the boundary with the next layer?

A Okay, now let me describe the tip resistance. It starts from that high value that we just described, and then decreases and tends to stay uniform. Well, relatively uniform, until it hits the next layer dotted line, more or less.

Q And the next layer of the line would be the next soil layer, is that right?

A Yes, the next soil layer, yes.

Q That would no longer be layer 2, is that right?

A That would no longer be layer 1-B.

Q Right.

A Yes, let's not get into this confusion, okay? The initial classification of the soil at the site identified two layers. Layer 1, the 25 to 30 feet that we are looking at right now, and layer 2, the material lies underneath.

So when cone penetrometer led to a final classification of the top layer, instead of calling those layer 1, 2, we said we called them 1A, 1B, and so on. That is why we have this nomenclature difference.

Q All right. Let's just call it layer 1B for the rest of the discussion, so that we are on the same page.

A Okay.

Q Is it your understanding, then, that the readings of cone penetration resistance, once you get past that crust are fairly uniform, going down vertically, in layer 1B?

A It is relatively uniform, yes. It is fairly uniform compared to the rest of the soil profile.

Q And, in fact, the variations in cone penetration tip resistance within that layer 1B are much less pronounced than they are, for example, in the next layer, is that right?

A That is correct.

Q And any other layer for the rest of the profile, is that right?

A That is correct.

Q Now, you read from left to right, and you compare the distribution of cone penetration tip resistance values, going from the first shaft to the second, to the third.

Do you consider those to be uniform? Or

should I clarify?

A Yes, because the word uniform could be --

MR. TURK: Excuse me one second. Uniform from shaft to shaft, or uniform within each shaft?

MR. TRAVIESO-DIAZ: From shaft to shaft.

BY MR. TRAVIESO DIAZ:

Q If I were to look at, for example, the layer 1B cone penetration resistance for the first shaft, and I were to go to the second and the third, would the behavior of the cone penetration tip resistance, going from the top of the shaft, to the bottom, be similar?

In other words, you have a crust on top, and relatively uniform throughout?

A That pattern is uniform throughout.

Q It is uniform throughout all the six shafts?

A Yes.

Q And now tell us, again, based with all this background, how do you extrapolate from these values to shear strength?

A Okay. Well, one way is to do it explicitly (UDTA). Another way is to say, look, this indicates the variation at the sites, and I have established abundantly that this layer 1B soil is the weakest soil layer, and I'm going to test samples from that layer, and measure, and use that information in my stability calculation.

And that is what PFS did. If you look at, in fact, the one that is measure C, D, B, CPT8, that is the last, I mean, the second last column, going left to right.

It shows the sample location (UDTA), and going down there you see one of the samples marked, that they actually tested in the lab.

Now, in the test result of this sample can be used if you want numerical correlation to calculate the actual shear strength represented by each of those penetrometer profiles.

Q Thank you very much, Dr. Ofoegbu, for the explanation.

MR. TRAVIESO-DIAZ: That is all I have. by the way, I would commend anybody, if you have access to a copy of this, and the other profiles, they contain a lot of information that is far more evident if you look at it in color.

MR. TURK: Could we ask that the Applicant simply provide a color copy as their exhibit? You can go to Kinko's across the street, and --

MR. TRAVIESO-DIAZ: If the Board will

allow, I will be prepared to substitute, as expeditiously as possible, color copies of exhibit 233 that, as I said, I think are far more informative.

CHAIRMAN FARRAR: Let's do that at your earliest opportunity. Any recross by the State?

MS. NAKAHARA: No, Your Honor, thank you.

MR. O'NEILL: None for the staff, Your Honor.

CHAIRMAN FARRAR: All right, then we are finished with this witness, in slightly more than an hour. We are getting better, an hour and a half, hour. As the Board looks at Mr. Travieso-Diaz.

MR. TRAVIESO-DIAZ: Well, I can talk fast.

CHAIRMAN FARRAR: All right, thank you, Dr. Ofoegbu, for your testimony. And --

MR. TRAVIESO-DIAZ: Should we take a short break?

CHAIRMAN FARRAR: Yes. Next we are going to do --

MR. TRAVIESO-DIAZ: Dr. Bartlett.

CHAIRMAN FARRAR: All right. So we had the PFS witness, and the Staff witness, now we will do Dr. Bartlett. Should we -- it is a little early to take a break, but would that be useful now?

MR. TRAVIESO-DIAZ: Yes, ten minutes would be enough.

CHAIRMAN FARRAR: It is 20 of, let's be back at 10 of, and let's see if we could all be back here on time.

(Whereupon, the above-entitled matter went off the record at 2:39 p.m. and went back on the record at 2:50 p.m.)

CHAIRMAN FARRAR: State witness Dr. Bartlett, the soils portion of Section C.

Whereupon,

STEVEN BARTLETT

was called as a witness by Counsel for the State and, having been previously duly sworn, assumed the witness stand, was examined and testified as follows:

DIRECT EXAMINATION

BY MS. CHANCELLOR:

Q Dr. Bartlett, you have in front of you testimony dated way back from April 1, 2002, entitled: State of Utah's Testimony of Dr. Steven F. Bartlett on Unified Contention Utah L/QQ (Soils Characterization)?

A Yes, I do.

Q Are there any corrections that need to be made to this testimony?

A Yes, a few misspellings. Shall I just go ahead and point to those corrections?

Q Yes. The corrections have been, there are just a couple of typos, and they have been marked on the copy that has been given to the Reporter.

CHAIRMAN FARRAR: But the copy we have was given to us some time ago.

MS. CHANCELLOR: You will need to make the hand corrections, Your Honor.

CHAIRMAN FARRAR: Okay. Where are they, Dr. Bartlett?

THE WITNESS: On page 2, under answer 3, first, second, third, fourth, fifth, sixth line down, beginning with analysis, and it should be its, not it.

CHAIRMAN FARRAR: Right.

THE WITNESS: And then on page 11 the last paragraph on that page, beginning with the Applicant, a word is used twice in that, anisotropy. Anisotropy is misspelled. It is A-N-I-S-O-T-R-O-P-Y.

CHAIRMAN FARRAR: So the O is missing?

THE WITNESS: Yes.

CHAIRMAN FARRAR: All right.

THE WITNESS: That is it, I believe that is it.

CHAIRMAN FARRAR: Okay.

BY MS. CHANCELLOR:

Q With those three corrections to your

testimony -- was this testimony prepared under your direction and control?

A Yes, it was prepared by me.

Q And with those corrections, do you adopt this testimony as your sworn testimony in this Proceeding?

A I do.

MS. CHANCELLOR: Your Honor, I request that the testimony be entered into the record.

CHAIRMAN FARRAR: Any objection?

MR. TRAVIESO-DIAZ: No objection.

MR. O'NEILL: No objection.

CHAIRMAN FARRAR: Then the Reporter will bind this testimony into the record at this point, as if read.

(Prefiled testimony of Dr. Steven Bartlett inserted here.)