2.5.4.7.5 Evaluation of Modulus Reduction and Damping Values

Testing of five intact samples using the RCTS method samples was conducted as described in Subsection 2.5.4.2.1.3.4. These tests are on materials from the Vincentown, Hornerstown and Navesink Formations. A discussion of data analysis methods and conclusions is located in Subsection 2.5.4.2.2.2. Damping ratio and the modulus reduction ratio results plotted on the generic EPRI curves for Eastern North America (Reference 2.5.4.7-3) are shown in Figures 2.5.4.7-17 through 2.5.4.7-20.

The plotted data are similar to the shape of the EPRI curves within the range of the test strains, but more linear. This is because the presence of the cemented layers within the formations and the dense consistency as described in Subsections 2.5.4.1.2.2.8, 2.5.4.1.2.3.1 and 2.5.4.1.2.3.2 created difficulties in obtaining intact samples resulting in some sample disturbance. Also, because of the existence of cemented layers, the intact samples obtained would represent the sands between cemented layers. Thus, the RCTS test results are not representative of the behavior of the formation itself.

Replace with "References 2.5.4.7-10 and 2.5.4.7-16" per RAI No. 61.

The plots of data from the tests conducted at four times the estim shown on Figures 2.5.4.7-19 and 2.5.4.7-20 show a closer match comparable to the sample depths, although the test data are still below the generic curves in most instances. Figure 2.5.4.7-20 also shows a wide scatter for the variation of damping with strain. The RCTS data were obtained on samples only from the Navesink Formation or higher. The RCTS test results were not used to predict modulus reduction and damping variation with shear strain because of the inconsistent RCTS test results compared to EPRI generic curves and because modulus reduction and damping curves are needed for materials deeper than the sampled depths. Computational techniques for modeling modulus reduction and damping variation related to shear strain, as described below, were used.

Work at the University of Texas (~~Reference 2.5.4.7-10~~) presents results of analysis of many RCTS tests on sandy and clayey soils to develop equations for modulus reduction and damping variation with shear strain as well as standard deviation. The equations, developed by Darendeli, use the confining pressure, plasticity index and overconsolidation ratio as inputs. For the PSEG Site, soils below the top of the competent layer and above the Potomac Formation were divided into four layers. Table 2.5.4.7-5 summarizes information about the layers.

For each layer, the effective confining pressure at the layer center was determined by using the depth of the layer below the top of the competent layer and soil unit weights. To account for the effects of materials above the competent layer, the confining pressure was increased to consider the weight of fill placed from the top of the competent layer to the new plant grade elevation. Stresses from removal of the existing materials were included. The curves computed using the data on Table 2.5.4.7-5 are shown in Figures 2.5.4.7-21 through 2.5.4.7-28. These curves provide input for the development of the GMRS as discussed in Subsection 2.5.2.5.

2.5.4.7.6 Development of Ground Motion Response Spectra

The GMRS for the ESPA is derived at the top of competent material. The average shear wave velocity seismic profile is shown on Figure 2.5.4.7-8a. Derivation of the GMRS based on this velocity profile is described in Subsection 2.5.2.5.

ADD "A range of overconsolidation ratios and associated K_o values was applied as shown on Table 2.5.4.7-5." per RAI No. 61.

2.5.4.7-12 Washington Savannah River Company, LLC, "Savannah River Site Probabilistic Seismic Hazard Assessment Update (U)," WSRC-TR-2006-00113, Rev. 0, p. 197, December, 2007.

2.5.4.7-13 Zapecza, O. S., "Hydrogeologic framework of the New Jersey coastal plain: USGS Professional Paper 1404-B", 1989.

2.5.4.7-14 Garrity, C.P. and D.R. Soller, "Database of the Geologic Map of North America," adapted from the map by J.C. Reed Jr. and others (2005): U.S. Geological Survey Data Series 424, Website, http://pubs.usgs.gov/ds/424/, accessed September 24, 2009.

2.5.4.7-15 MACTEC Engineering and Consulting Inc., "Geotechnical Exploration and Testing, PSEG Site ESPA Application, Lower Alloways Creek Township, New Jersey," Revision 0, July 10, 2009.

2.5.4.7-16 Darendeli, Mehmet B., "Development of a New Family of Normalized Modulus Reduction and Material Damping Curves", Dissertation, The University of Texas at Austin, August, 2001.

ADD Reference
per RAI No. 61.

Table 2.5.4.7-5
Summary of Modulus Reduction and Damping Layer Information

~~Layer for Analysis~~	~~Related Dynamic Profile Layer(s) from Figure 2.5.4.7-8a~~[c]	~~Soil Type~~	~~Plasticity Index (PI)~~	~~Over-consolidation Ratio~~	~~Confining Pressure at Layer Center (ksf)~~[d] ~~Case 1~~
~~A~~	~~1~~	~~Sand~~	~~NA~~	~~NA~~	~~4.7~~
~~B~~	~~2, 3, 4 and 5~~	~~Sand~~	~~NA~~	~~NA~~	~~9.4~~
~~C~~	~~6, 7, and 8~~	~~Clay with some sand~~	~~30~~	~~2~~[a]	~~15.3~~
~~D~~[b]	~~9a and 9b~~	~~Sand~~	~~NA~~	~~NA~~	~~19.9~~

~~a) Overconsolidation ratio is estimated~~
~~b) Layers 9a and 9b are subdivision of Layer 9 with same properties – subdivided to accommodate geologic strata break.~~
~~c) Layer 10 shown on Figure 2.5.4.7-8a is combined with the Deep Profile~~
~~d) ksf = 1000 pounds per square foot~~

REPLACE with Insert 1 per RAI No. 61.

RAI No. 61, INSERT 1 for Table 2.5.4.7-5

Layer for Analysis	Related Dynamic Profile Layer(s) from Figure 2.5.4.7-8a[b]	Soil Type	Plasticity Index (PI)	Over-Consolidation Ratio (OCR)	K_o[c]	Confining Pressure, ksf[d]
A	1	Sand	NA	1	0.5	4.7
				2	0.6	5.1
				4	0.92	6.6
				6	1.17	7.8
B	2,3,4 and 5	Sand	NA	1	0.5	9.4
				2	0.83	12.5
				4	1.06	14.6
				6	1.21	16.0
C	6,7, and 8	Clay with some sand	30	2	0.5	15.3
				2	0.71	18.5
				4	1.0	22.9
				6	1.22	26.2
D[a]	9a and 9b	Sand	NA	1	0.5	19.9
				2	0.6	21.9
				4	0.92	28.3
				6	1.17	33.2

a) Layers 9a and 9b are subdivision of Layer 9 with same properties - subdivided to accommodate geologic strata break.
b) Layer 10 shown on Figure 2.5.4.7-8a is combined with the Deep Profile
c) Coefficient of lateral earth pressure at rest
d) ksf = 1000 pounds per square foot

Soil Classification System (USCS) designations shown on the test boring logs, and the results of Atterberg limit tests and grain size analysis tests performed on selected samples.

Based on their granular composition and position below the water table, the Vincentown, Hornerstown, Navesink, Mount Laurel, Wenonah, Marshalltown, Englishtown, Magothy and Potomac formations are potentially liquefiable. The Woodbury and Merchantville formations are clayey soils containing less than 50 percent sand and are not likely to liquefy.

The field SPT results (N-values) are corrected for field variables, sampling methods and effective overburden pressures. Based on the average corrected N-value of each formation, the Hornerstown, Wenonah and Englishtown formations are potentially liquefiable. The other formations have average corrected N-values equal to or greater than 30 blows per foot and are not likely to liquefy (Reference 2.5.4.8-2).

As discussed in Reference 2.5.4.8-2, resistance of soils to liquefaction increases with age – Pleistocene sediments are more resistant to liquefaction than younger sediments, and pre-Pleistocene sediments are generally not liquefiable. All formations below the top of the competent layer are pre-Pleistocene and are not likely to liquefy based on their age.

The results of the geologically based liquefaction screening evaluation are summarized on Table 2.5.4.8-1.

2.5.4.8.3 SPT-Based Liquefaction Assessment

A liquefaction assessment using a simplified SPT-based empirical procedure is performed for the geologic formations below the top of the competent layer using the methods described in Reference 2.5.4.8-2 and as described in RG 1.198. The liquefaction potential is presented as a

REPLACE with "Table 2.5.2-34 presents controlling earthquakes for high and low frequency earthquakes and for annual frequencies of exceedance of 10^{-4}, 10^{-5} and 10^{-6}. Because liquefaction assessment is based on the GMRS, and because the GMRS is computed using only the high frequency controlling earthquakes for 10^{-4} and 10^{-5} annual frequencies of exceedance, only the values in Table 2.5.2-34 for those events are applicable for selecting the controlling earthquake. The applicable values in Table 2.5.2-34 are magnitude 6 or less, therefore magnitude 6 is used in the liquefaction analysis." per RAI No. 61.

Section 2.5.2 of NUREG-0800 states that if the controlling earthquakes for a site have magnitudes less than 6, the time history selected for the evaluation of liquefaction potential must have a duration and number of strong motion cycles corresponding to at least a magnitude 6 event. ~~As presented in Subsection 2.5.2.6.1.2, the controlling earthquake magnitude is less than 6; therefore magnitude 6 is used in the analysis.~~

The CSR is a function of the maximum acceleration at the foundation level, the total and effective overburden pressures at the sample depth, and a stress reduction factor. A stress reduction factor is used because the soil column is not rigid but deformable, and shear stresses at depth are less than at the foundation level. The Ground Motion Response Spectrum (GMRS) is developed for the top of the competent layer (Vincentown Formation) and has a mean elevation of -67 ft. Therefore, the maximum acceleration is applied at the top of the competent

0.225

layer and the stress reduction factor is referenced to the top of the competent layer in the evaluation. The GMRS is shown on Figure 2.5.2-54. The maximum ground acceleration used in the analysis, ~~0.18~~ g, is the point at which the GMRS intersects the 100 Hz frequency. The use of 100 Hz to determine peak ground acceleration is standard practice and has been used on other soil sites.

Subsection 2.5.2.6 of the Hope Creek Generation Station (HCGS), UFSAR (Reference 2.5.4.8-1) presents the Safe Shutdown Earthquake (SSE) and peak acceleration for the HCGS site. Design acceleration of 20% g is recommended at the foundation level resulting from the occurrence of the SSE of Intensity VII (M ~ 5.7). These values are very comparable to the earthquake magnitude and peak acceleration used in this liquefaction evaluation.

The safety factor against liquefaction is computed for each SPT sample of granular soil obtained in borings NB-1 through NB-8 from the top of the competent layer at elevation -67 feet to the depth explored in the boring. Table 2.5.4.8-2 shows the minimum, maximum and average factors of safety against liquefaction and the distribution of safety factors for each geologic formation at the PSEG Site, based [illegible]or.

225 ADD "in general" per RAI No. 61. 15

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RG 1.198 states that factors of safety less than or equal to 1.1 against liquefaction are low, factors of safety between 1.1 and 1.4 are considered moderate, and factors of safety greater than or equal to 1.4 are considered high. A total of 257 SPT N-values are analyzed. There are ~~three~~ calculated liquefaction safety factors less than 1.1, ~~nine~~ safety factors between 1.1 and less than 1.4, and ~~245~~ safety factors greater than 1.4. The results represent isolated pockets. ~~Based on the results of the calculation of factors of safety, liquefaction of granular soils below the top of the competent layer is not likely to occur.~~

The existing total and effective overburden pressures are used in computing the safety factor against liquefaction. The Artificial and Hydraulic Fill, Alluvium and Kirkwood Formation soils will be removed and replaced with controlled fill such as concrete or compacted fill having a unit weight greater than the existing soils. The higher unit weight materials will increase the total and effective overburden pressures and will result in higher safety factors against liquefaction. Therefore the computed liquefaction safety factors shown on Table 2.5.4.8-2 are conservative using existing total and effective overburden pressures.

2.5.4.8.4 Liquefaction Outside the Safety-Related Structure Area

Replace with "The SPT-based screening calculation results indicate potentially liquefiable soils in the Vincentown Formation are isolated pockets surrounded by denser materials, not a continuous layer. Thus, liquefaction of granular soils below the top of the competent layer is not likely to occur." per RAI No. 61.

The excavation for the power block will be bounded by a structural support system located approximately 850 ft. from the centerline of the nuclear island structures depending on the technology selected. Outside of the structural support system, the Artificial and Hydraulic Fill, Alluvium, and Kirkwood Formation soils will remain in place. Liquefaction of these soils could result in settlement and lateral spread outside the excavation support structure. As a worst

1 | 0

15 | 13 | 48
1 | 2 | 30

Table 2.5.4.8-2
Summary of Liquefaction Safety Factors (FS) for each Geologic Formation

Formation No.	Formation Name	Safety Factor[(a), (b)]			Distribution of Safety Factors		
		Minimum	Maximum	Average	FS<1.1	1.1<=FS<1.4	1.4<=FS
4	Vincentown	0.9	12.5	4.6	~~3~~	~~7~~	~~66~~
5	Hornerstown	1.3	10.2	4.6	~~0~~	~~1~~	~~32~~
6	Navesink	3.5	26.9	10.2	0	0	44
7	Mount Laurel	1.9	13.8	11.1	0	0	90
8	Wenonah	1.2	3.0	2.1	~~0~~	~~1~~	1
9	Marshalltown	1.9	9.3	5.7	0	0	5
10	Englishtown	2.7	2.7	2.7	0	0	1
11	Woodbury	NL	NL	NL	0	0	0
12	Merchantville	NL	NL	NL	0	0	0
13	Magothy	7.6	8.4	8.1	0	0	3
14	Potomac	7.3	7.5	7.5	0	0	3
				Total =	~~3~~	~~9~~	~~245~~

a) NL = Non-liquefiable silts and clays (USCS designations CL, CH, ML, MH, CL-ML, CH-MH)
b) Safety Factors based on lower bound Magnitude Scaling Factor

Revise numbers on table as shown per RAI No. 61.

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Replace with "Central and Eastern United States (CEUS)." per RAI No. 61.

2.5.4.9 Earthquake Design Basis

This subsection briefly summarizes the derivation of the site-specific GMRS and SSE as detailed in Subsection 2.5.2.6.

The PSEG Site is in the ~~area designated by the EPRI-SOG (Reference 2.5.4.9-1) as the CEUS.~~ The CEUS, as discussed in Subsection 2.5.1.1.4, is a stable continental region characterized by low rates of crustal deformation and no active plate boundary conditions.

A performance-based, site-specific GMRS is developed in accordance with the methodology provided in RG 1.208. The PSEG Site is a deep soil site, therefore excavation is required to reach a competent layer. The GMRS is developed at the top of the competent layer as provided in Section 5.3 of RG 1.208. A site dynamic properties profile, developed as described in Subsection 2.5.4.7, and based on soil properties described in Subsections 2.5.4.2 and 2.5.4.4, forms the basic description of the site conditions used in developing the GMRS. The GMRS and the methodology for developing it are provided in Subsection 2.5.2.6. The GMRS satisfies the requirements of 10 CFR 100.23 for development of a site-specific SSE ground motion.

The approach to developing the GMRS follows the recommended steps in RG 1.208, as briefly described below:

- ~~Review the EPRI-SOG seismic source model for the PSEG Site region (200-mile radius) (Reference 2.5.4.9-1). No new information was found post-1986 on any tectonic feature within the PSEG Site region that caused a significant change in the EPRI source zone model. Thus, an update of the EPRI 1986 model was not necessary (Subsection 2.5.2.2).~~
- Perform sensitivity studies and an updated probabilistic seismic hazard analysis (PSHA) to develop rock hazard spectra and define the controlling earthquakes (Subsection 2.5.2.4).
- Develop the site dynamic soil properties (Subsections 2.5.4.2, 2.5.4.4, and 2.5.4.7).
- Derive performance-based GMRS from the updated PSHA at a free field hypothetical outcrop at the top of the competent material beneath the site (defined as the upper portion of the Vincentown Formation) as described in Subsection 2.5.2.6.

The resulting GMRS is presented in Subsection 2.5.2.6.

2.5.4.9.1 References

2.5.4.9-1 ~~Electric Power Research Institute, "Seismic Hazard Methodology for the Central and Eastern United States," EPRI Report NP-4726, 10 vols, vol 1-3 & 5-10, 1986-1989.~~

REPLACE with "The seismic source characterization model used for the PSEG Site region (200-mile radius) is the Central and Eastern United States Seismic Source Characterization (CEUS SSC) contained in NUREG-2115. As discussed in Subsection 2.5.2.2, no alterations to the CEUS SSC were necessary, except to include the Atlantic Highly Extended Crust - East seismic source." per RAI No. 61.

REPLACE with " Not Used" per RAI No. 61.