Exelon Nuclear
200 Exelon Way
KSA3-N
Kennett Square, PA 19348

Telephone 610.765.5610
Fax 610.765.5755
www.exeloncorp.com

Exelon® Nuclear

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March 16, 2005

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Early Site Permit (ESP) Application for the Clinton ESP Site
Docket No. 52-007

Subject: Seismic Risk (Performance Goal) Based Approach Calculation (TAC No. MC1122)

Re: 1) ASCE Standard 43-05, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities,* American Society of Civil Engineers, 2005 (in publication)

2) Letter, Exelon Generation Company, LLC, (M. Kray), to U.S. Nuclear Regulatory Commission (Document Control Desk) dated November 19, 2004, Seismic Risk (Performance Goal) Based Approach Primer – Exelon Early Site Permit (ESP) Application for the Clinton ESP Site (TAC No. MC1122)

The subject application presents Exelon Generation Company, LLC's (EGC) seismic information pursuant to 10 CFR § 100.23 in terms of a risk-based approach premised on the referenced industry standard (the "ASCE Method" or "Standard" (Reference 1)). Additionally, at the request of the Nuclear Regulatory Commission (NRC) staff during a meeting on September 16, 2004, EGC submitted (Reference 2) additional material to summarize the performance-based methodology and its basis in a single compilation, titled "*Risk (Performance-Goal) Based Approach for Establishing the SSE Design Response Spectrum Used in Exelon Generation Company Early Site Permit Application,*" (Kennedy, 2004).

The results presented in Sections 7.2.2 and 8 of the Kennedy (2004) paper are based on generic seismic hazard information. The enclosed memo repeats these calculations using the EGC ESP site-specific hazard curves and the EGC ESP design response spectrum developed using the approach outlined in ASCE/SEI Standard 43-05. The results of these calculations indicate that the DRS defined on the basis of ASCE/SEI Standard 43-05 meets the stated

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target performance goal and that use of the ASCE/SEI Standard 43-05 to define the SSE ground motions are expected to result in an acceptable level of seismic safety; i.e., consistent with the target performance goal for a new Standard Plant at the EGC ESP site.

Please contact Eddie Grant of my staff at 610-765-5001 if you have any questions regarding this submittal.

Sincerely yours,

Marilyn C. Kray

Marilyn C. Kray
Vice President, Project Development

TPM/erg

cc: U.S. NRC Regional Office (w/ enclosure)
Mr. John P. Segala (w/ enclosure)

Enclosures

AFFIDAVIT OF MARILYN C. KRAY

State of Pennsylvania

County of Chester

The foregoing document was acknowledged before me, in and for the County and State aforesaid, by Marilyn C. Kray, who is Vice President, Project Development, of Exelon Generation Company, LLC. She has affirmed before me that she is duly authorized to execute and file the foregoing document on behalf of Exelon Generation Company, LLC, and that the statements in the document are true to the best of her knowledge and belief.

Acknowledged and affirmed before me this 16th day of March, 2005.

My commission expires 10-6-07.

Vivia V. Gallimore

Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Vivia V. Gallimore, Notary Public
Kennett Square Boro, Chester County
My Commission Expires Oct. 6, 2007
Member, Pennsylvania Association Of Notaries

Memo, Geomatrix Consultants (Bob Youngs) to CH2M HILL (Amy Lientz and Don Anderson) dated February 8, 2005, "Risk" Calculation for EGC ESP Site.

2101 Webster Street, 12th Floor
Oakland, CA 94612
(510) 663-4100 • Fax (510) 663-4141

GEOMATRIX

Date: February 8, 2005

To: Amy Lientz/CH2M HILL
Don Anderson/CH2M HILL

From: Bob Youngs/Geomatrix Consultants

Subject: **"Risk" Calculation for EGC ESP Site**

Executive Summary

The basis for the risk (performance-goal) based approach defined in ASCE/SEI Standard 43-05 and utilized in the Exelon Generation Company, LLC (EGC), Early Site Permit (ESP) application, has been presented in a "white paper" by Dr. Robert Kennedy (2004). The standard was constructed to produce designs that achieve a mean annual probability of unacceptable performance of 1×10^{-5} or less (i.e., the target performance goal). In terms of Seismic Category 1 Structures, Systems and Components, unacceptable performance is defined to be the "onset of significant inelastic deformation."

The approach outlined in ASCE/SEI Standard 43-05 uses a simplified seismic risk equation to develop the appropriate design response spectra (DRS) from the mean probabilistic seismic hazard results for the site. In Section 7.2.2 of the white paper, Dr. Kennedy demonstrates that numerical convolution of the complete site hazard curves with plant fragilities derived from the ASCE/SEI Standard 43-05 based DRS produces estimates of the mean annual frequency of onset of significant inelastic deformation (FOSID) that meet or exceed the target performance goal. Furthermore, in Section 8 of the white paper, Dr. Kennedy shows that convolution of site hazard curves with plant fragilities derived from the ASCE/SEI Standard 43-05 based DRS produces estimates of Core Damage Frequency (CDF) for the new Standard Plant designs that are in the low range of CDF values reported for existing plants.

The results presented in Sections 7.2.2 and 8 of Kennedy (2004) are based on generic seismic hazard results. The purpose of this memo is to repeat these calculations using the EGC ESP site-specific hazard curves and the EGC ESP design response spectrum developed using the approach outlined in ASCE/SEI Standard 43-05. Two sets of calculations were performed. The first set computed the mean values of the FOSID for spectral frequencies of 1, 2.5, 5 and 10 Hz. The results of these calculations, presented in Tables 1 and 2, indicate that the DRS defined on the basis of ASCE/SEI Standard 43-05 meets the stated target performance goal. The second set of calculations was performed to estimate the mean annual core damage frequency (CDF) for a new Standard Plant design. The estimated values (Tables 3 and 4) lie in the lower range of reported core damage frequencies obtained from probabilistic risk assessments (PRAs) of commercial nuclear power plants. These results indicate that use of the ASCE/SEI Standard 43-05 to define the SSE ground motions are expected to result in an acceptable level of seismic safety; i.e., consistent with the target performance goal for a new Standard Plant at the EGC ESP site.

GEOMATRIX

Approach

The approach used to perform the risk calculation for the EGC ESP site is described in Kennedy (2004), Section 3.1 and Appendix A. The risk of adverse consequences, P_F, is computed using Equation 3.1a of Kennedy (2004):

$$P_F = -\int_0^\infty P_F(a)\left(\frac{dH(a)}{da}\right)da \quad (1)$$

where $P_F(a)$ is the conditional probability (annual frequency) of "failure" (adverse consequences) given the level of spectral acceleration equals a, which by definition is the mean fragility curve, and $H(a)$ is the mean annual frequency of exceeding spectral acceleration level a. In implementation, the integral Equation (1) is replaced by the summation:

$$P_F = \sum_i P_F(a_i) \times [H(a_i - \Delta a) - H(a_i + \Delta a)] \quad (2)$$

where Δa is chosen as a suitable small increment of spectral acceleration and the derivative of the hazard curve is replaced by the difference $[H(a_i - \Delta a) - H(a_i + \Delta a)]$.

The probability of "failure" is computed using a lognormal distribution from the expression:

$$P_F(a) = \Phi\left[\frac{\ln(a) - \ln(C_{50})}{\beta}\right] \quad (3)$$

where C_{50} is the median capacity of the system (the median spectral acceleration level required to cause "failure"), β is the standard deviation of the natural log of the failure level (controlling the shape of the fragility curve), and $\Phi[\,]$ is the normal distribution cumulative probability function. The median capacity is given by:

$$C_{50} = DRS \times F_{1\%} \times \exp(2.326\beta) \quad (4)$$

where DRS is the design response spectral level and $F_{1\%}$ is the seismic margin factor at 1% of the median capacity.

Two definitions of "failure" level are presented in Kennedy (2004). One is the onset of significant inelastic deformation. For this definition, the seismic margin factor $F_{1\%}$ is taken to be 1.0 to 1.1, depending on β, when computing the median capacity, C_{50}, using Equation (4). The second "failure" definition is the core damage in which the seismic margin factor $F_{1\%}$ is taken to be 1.67 when computing the median capacity, C_{50}. For both cases, the design response level, DRS, is given by Equations 1.1, 2.3, and 2.4 of Kennedy (2004):

$$DRS = DF \times SA_{10^{-4}}$$

$$DF = \max\left[1.0,\ 0.6(A_R)^{0.8}\right] \tag{5}$$

$$A_R = \left(\frac{SA_{10^{-5}}}{SA_{10^{-4}}}\right)$$

where $SA_{10\text{-}4}$ and $SA_{10\text{-}5}$ are the spectral accelerations with mean frequency of exceedance of 10^{-4} and 10^{-5}, respectively

Development of Soil Hazard Curves

The PSHA for the EGC ESP developed mean hazard curves for rock conditions. These were converted into approximate soil hazard curves by multiplying by the mean soil amplification developed using method 2B of NUREG/CR-6728. Appendix B of the EGC ESP SSAR describes the method used to develop mean site amplification functions at rock hazard levels of 10^{-4} and 10^{-5}. This process was repeated to develop mean site amplification functions at rock hazard levels of 10^{-3} and 10^{-6}.

Deaggregation of the hazard was used to define reference earthquakes (RE) and Deaggregation Earthquakes (DEL, DEM, and DEH) at each hazard level. Rock site time histories were then scaled to approximately match the spectra for the DEL, DEM, and DEH events. Site response analyses were conduced to develop mean site amplification functions for each DEL, DEM, and DEH, and a weighted mean amplification function was computed for 5-10Hz motions and 1-2.5Hz motions at each hazard level. Two sets of amplification functions were computed: one using no limit on the soil damping level in the site response analyses, and one imposing an upper limit of 15% on the soil damping level. The 15% limit on soil damping was identified by NRC as an issue in the first set of RAIs for the EGC ESP SSAR, and therefore, the limit was included in this analysis to evaluate its effect. The results show that imposing a upper limit of 15% on soil damping only affects the response analyses for ground motions with annual exceedance frequencies less than 10^{-5}, as shown in Figures 1 through 4. As a result, there is little impact of this limit on the computed risk values (Tables 1 through 4).

The weighted mean soil amplification functions were used to scale the rock mean hazard curves to produce approximate mean soil hazard curves. Figures 1 though 4 show the computed soil hazard curves. The hazard curves were conservatively extrapolated linearly in log-log space to lower frequencies of exceedance for the risk calculation.

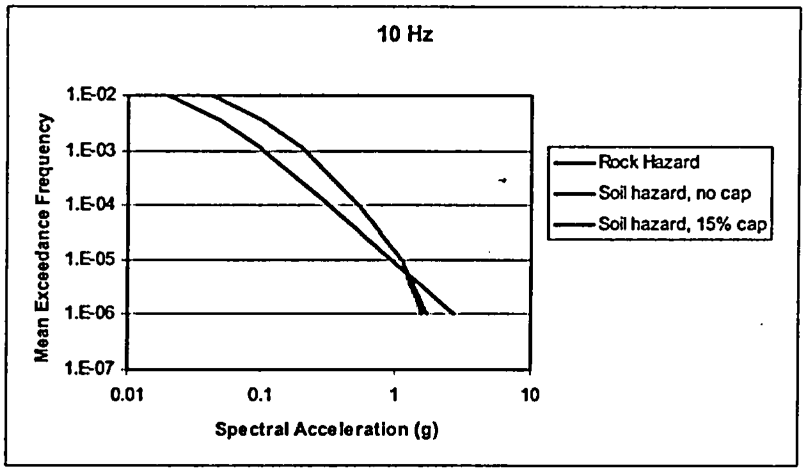

Figure 1, 10-Hz soil hazard curves

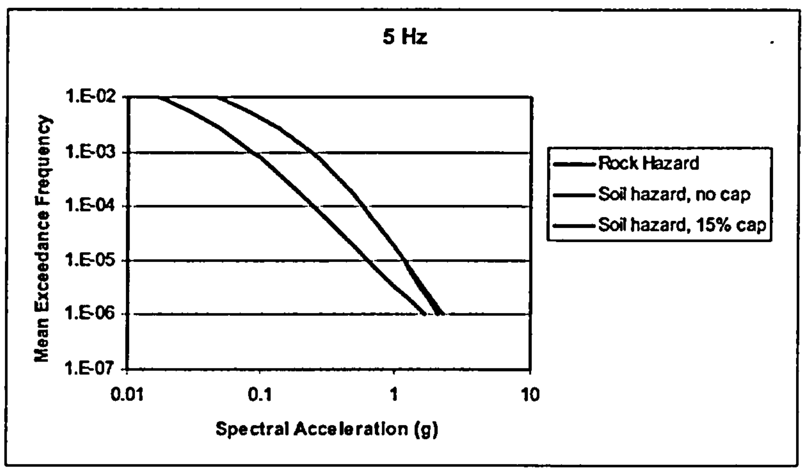

Figure 2, 5-Hz soil hazard curves

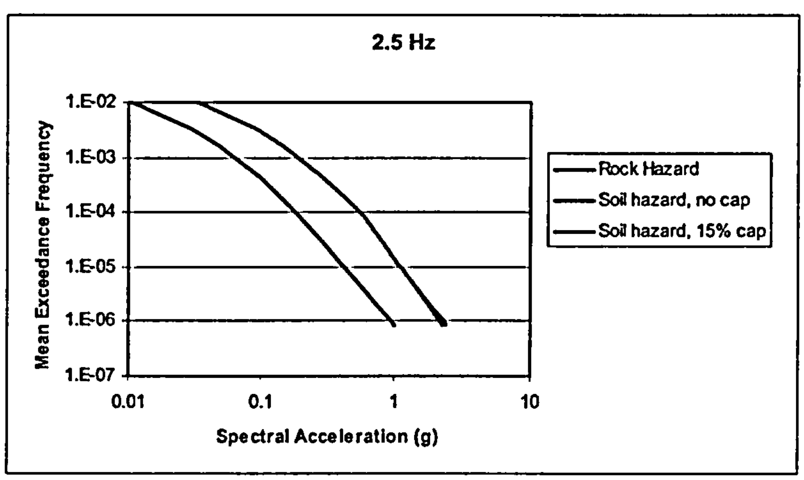

Figure 3, 2.5-Hz soil hazard curves

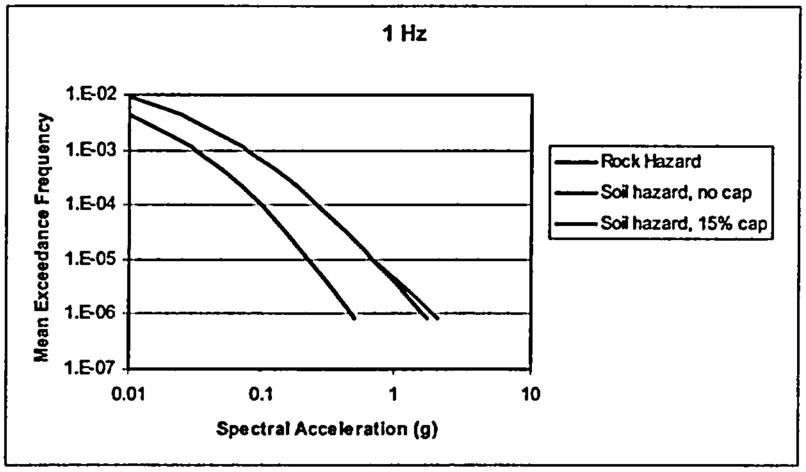

Figure 4, 1-Hz soil hazard curves

Results of "Risk" Calculations

Tables 1 through 4 present the results of applying Equations (2) through (5) to the soil hazard curves shown in Figures 1 through 4. Results are presented for both soil hazard obtained using unrestricted soil damping and for soil damping limited to a maximum of 15%. Use of the restricted soil damping produces approximately a 10% increase in the calculated risk levels.

The frequency of the onset of significant inelastic deformation (FOSID) risk levels are in the range of 0.5 to 1.1 × 10^{-5}, consistent with the target goal of 1 × 10^{-5}. The CDF risk levels are in the range of 0.7 to 4 × 10^{-6}. The CDF values for 25 operating plants are listed in Table 4.1 of Kennedy (2004). The CDF values for the operating plants range from 1.9× 10^{-7} to 2.3× 10^{-4}, with a median value of 1.2× 10^{-5}. The CDF values obtained in this EGC ESP-specific analysis lie in the lower range of the values for the operating plants.

These results indicate that use of the ASCE/SEI Standard 43-05 to define the SSE ground motions are expected to result in an acceptable level of seismic safety, i.e., consistent with the target performance goal for a new Standard Plant at the EGC ESP site.

Table 1 Seismic Risk in Terms of FOSID Using Soil Hazard

Hazard Curve:	SA_{10-4}	A_R	DF	DRS	Seismic Risk (FOSID) for: $F_{1\%} = 1.1$, $\beta = 0.3$	$F_{1\%} = 1.0$, $\beta = 0.4$	$F_{1\%} = 1.0$, $\beta = 0.5$	$F_{1\%} = 1.0$, $\beta = 0.6$
10 Hz	0.533	2.082	1.079	0.575	8.7E-06	7.9E-06	5.7E-06	4.6E-06
5 Hz	0.587	1.995	1.043	0.612	9.7E-06	9.0E-06	6.6E-06	5.4E-06
2.5 Hz	0.549	2.023	1.054	0.579	1.0E-05	9.2E-06	6.8E-06	5.4E-06
1 Hz	0.264	2.635	1.302	0.344	1.1E-05	9.0E-06	6.5E-06	5.1E-06

Table 2 Seismic Risk in Terms of FOSID Using Soil Hazard with 15% Damping Limit

Hazard Curve:	SA_{10-4}	A_R	DF	DRS	Seismic Risk (FOSID) for: $F_{1\%} = 1.1$, $\beta = 0.3$	$F_{1\%} = 1.0$, $\beta = 0.4$	$F_{1\%} = 1.0$, $\beta = 0.5$	$F_{1\%} = 1.0$, $\beta = 0.6$
10 Hz	0.533	2.082	1.079	0.575	9.1E-06	8.2E-06	5.9E-06	4.8E-06
5 Hz	0.587	1.995	1.043	0.612	1.0E-05	9.2E-06	6.8E-06	5.6E-06
2.5 Hz	0.549	2.023	1.054	0.579	1.0E-05	9.4E-06	6.9E-06	5.6E-06
1 Hz	0.264	2.635	1.302	0.344	1.1E-05	9.4E-06	6.9E-06	5.4E-06

Table 3 Seismic Risk in Terms of CDF Using Soil Hazard

Hazard Curve:	SA_{10-4}	A_R	DF	DRS	Seismic Risk (CDF) for: $F_{1\%}=1.67$, $\beta = 0.3$	$F_{1\%}=1.67$, $\beta = 0.4$	$F_{1\%}=1.67$, $\beta = 0.5$	$F_{1\%}=1.67$, $\beta = 0.6$
10 Hz	0.533	2.082	1.079	0.575	1.3E-06	8.9E-07	7.2E-07	6.7E-07
5 Hz	0.587	1.995	1.043	0.612	2.0E-06	1.4E-06	1.1E-06	9.1E-07
2.5 Hz	0.549	2.023	1.054	0.579	2.4E-06	1.6E-06	1.2E-06	1.0E-06
1 Hz	0.264	2.635	1.302	0.344	3.3E-06	2.2E-06	1.7E-06	1.3E-06

Table 4 Seismic Risk in Terms of CDF Using Soil Hazard with 15% Damping Limit

Hazard Curve:	SA_{10-4}	A_R	DF	DRS	Seismic Risk (CDF) for: $F_{1\%}=1.67$, $\beta = 0.3$	$F_{1\%}=1.67$, $\beta = 0.4$	$F_{1\%}=1.67$, $\beta = 0.5$	$F_{1\%}=1.67$, $\beta = 0.6$
10 Hz	0.533	2.082	1.079	0.575	1.6E-06	1.1E-06	8.4E-07	7.5E-07
5 Hz	0.587	1.995	1.043	0.612	2.3E-06	1.6E-06	1.2E-06	1.0E-06
2.5 Hz	0.549	2.023	1.054	0.579	2.6E-06	1.8E-06	1.4E-06	1.1E-06
1 Hz	0.264	2.635	1.302	0.344	3.8E-06	2.6E-06	2.0E-06	1.6E-06

Reference

Kennedy, R.P., 2004, Risk (performance-goal) based approach used in Exelon Generation Company Early Site Permit Application for establishing the SSE design response spectrum: Document prepared for Exelon Generation Company, LLC, December 10, 2004.