Dominion Nuclear North Anna, LLC
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Dominion®

August 19, 2004

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 04-438
ESP/JDH
Docket No. 52-008

DOMINION NUCLEAR NORTH ANNA, LLC
NORTH ANNA EARLY SITE PERMIT APPLICATION
RESPONSE TO JULY 9, 2004 REQUEST FOR ADDITIONAL INFORMATION AND RAI 2.5.2-9

In its July 9, 2004 letter titled "Additional Information Needed With Regard to Request for Additional Information Letter No. 2," the NRC requested additional information regarding certain aspects of Dominion Nuclear North Anna, LLC's (Dominion) Early Site Permit application. This letter contains our response to the July 9, 2004 NRC letter.

Also included in this letter is our response to RAI 2.5.2-9 from the NRC's June 1, 2004 letter titled "Request for Additional Information Letter No. 5."

It is our intent to update the North Anna ESP application to reflect our responses to these and other RAIs to support issuance of the NRC staff's draft safety and environmental evaluations scheduled for later this year. Planned changes to the application are identified following the response to each RAI.

If you have any questions or require additional information, please contact Mr. Joseph D. Hegner at 804-273-2770.

Very truly yours,

Eugene S. Grecheck
Vice President-Nuclear Support Services

Enclosure: Response to July 9, 2004 Request for Additional Information and RAI 2.5.2-9

Commitments made in this letter:

1. Revise North Anna ESP application to reflect RAI responses.

D074

cc: U. S. Nuclear Regulatory Commission, Region II
Sam Nunn Atlanta Federal Center
61 Forsyth Street, SW
Suite 23T85
Atlanta, Georgia 30303

Mr. Michael Scott
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Washington, D.C. 20555

Mr. M. T. Widmann
NRC Senior Resident Inspector
North Anna Power Station

Serial No. 04-438
Docket No. 52-008
Response to 7/9/04 NRC Letter and RAI 2.5.2-9

COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President, Nuclear Support Services, of Dominion Nuclear North Anna, LLC. He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of Dominion Nuclear North Anna, LLC, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 19TH day of August, 2004.

My Commission expires: May 31, 2006

Vicki L. Hull
Notary Public

(SEAL)

Enclosure

Response to July 9, 2004 Request for Additional Information and RAI 2.5.2-9

RAI 2.5.2-9 (6/1/04 NRC Letter)

SSAR Subsection 2.5.2.6 describes an alternative approach to that recommended in Regulatory Guide 1.165 for determining the SSE ground motion spectrum. Please provide the following information regarding this approach:

RAI 2.5.2-9 2nd Paragraph

The approach described in SSAR Section 2.5.2 uses a Uniform Hazard Spectrum (UHS) at the mean 10^{-4} per year probability level as its starting point. Please justify the selection of mean 10^{-4} per year as the appropriate starting point.

Response to RAI 2.5.2-9 2nd Paragraph

NOTE: On July 22, 2004, a telephone conference was held between Dominion and the NRC staff to discuss the two approaches presented in SSAR Section 2.5.2: the reference probability approach and a performance-based approach. The analyses originally presented in the SSAR relied primarily on the performance-based approach. During the call, Dominion advised the NRC of its intent to revise SSAR Section 2.5.2 to base the selected safe shutdown earthquake ground motion on the reference probability approach in accordance with Regulatory Guide (RG) 1.165. The NRC staff indicated that such a revised approach would allow the staff to complete its review on the currently published schedule. Dominion further advised the NRC staff that the performance-based approach would be retained in the SSAR as alternate and further justification for the selected SSE ground motion and that responses to the NRC questions regarding the performance-based approach would be addressed.

For the performance-based approach, the ground motion level for the SSE spectrum is selected to ensure that the annual probability of seismic effects on the plant, measured in terms of seismically induced core damage, is as low as calculated at other nuclear plants in the U. S. designed to current standards. The selected SSE spectrum from this approach is characterized by horizontal and vertical free-field ground motion response spectra at the free ground surface. The quantitative goal of the performance-based approach is to achieve an annual frequency of seismically induced core damage that is 10^{-5} or lower, when conservatively estimated by calculating the annual frequency of onset of significant inelastic deformation (FOSID) of structures, systems, and components (SSCs). This quantitative goal is achieved by defining a design amplitude at each structural period, such that the response of generic SSCs would ensure that the annual FOSID would be less than 10^{-5}.

The design amplitude required to achieve this quantitative goal at each structural period can be calculated starting from the 10^{-4} annual probability level, from the 10^{-5} annual

probability level, or from some other annual probability level. The scale factor on each of these probability levels would be different, but they would all lead to the same selected SSE design level. However, starting from this level has precedent as described in Reference 1.

RAI 2.5.2-9 Part b)

The performance-based approach described in SSAR Section 2.5.2 starts with the risk equation and ends with a scale factor multiplier that is used to achieve the target performance goal. Please provide the details of the derivation of this approach and describe how the use of the scale factor achieves the target performance goal. In addition please provide the details (beyond those provided in NUREG/CR-6728 and the ASCE Draft Standard, SSAR References 118 and 119) of the assumptions made for each of the key parameters such as the seismic margin ratio, combined standard deviation, amplitude ratio, and hazard curve slope.

Response to Part b)

The performance-based approach uses a simple recommended scale factor (SF) to scale a mean 10^{-4} spectral amplitude (the "starting spectral amplitude") to achieve a selected design amplitude (the selected SSE). The recommended SF is based only on the hazard curve slope (using factor A_R). It is in fact a close approximation to a more detailed calculation of the required value of the SF necessary to achieve a reduction from the 10^{-4} annual frequency of exceedance of the hazard to a desired FOSID. This required SF is a function of a different measure of the hazard curve slope K_H, the logarithmic standard deviation of fragility β, the probability ratio R_P, and the conservatism in design F_P as follows:

$$\text{required SF} = [R_P \exp\{-x_p K_H \beta + \tfrac{1}{2}(K_H \beta)^2\}^{1/K_H}]/F_P \qquad (1)$$

where:

R_P is the probability ratio between the frequency of exceedance of the starting spectral amplitude (10^{-4}) and the desired FOSID for generic SSCs. In the application of the performance-based method, the target FOSID is 10^{-5}, so R_P is 10.

x_p=2.326 for a standard HCLPF defined as a 1% probability of failure (Reference 3).

K_H is the negative logarithmic slope of the seismic hazard curve, and is related to A_R by the relation $K_H=[\log_{10} A_R]^{-1}$. For the hazard curves at North Anna, A_R ranges from 2.81 to 3.39 for different oscillator periods (see SSAR Table 2.5-28).

β is the logarithmic standard deviation of fragility. Nuclear SSCs typically have β in the range 0.3 to 0.6 (see Reference 3).

F_P is the additional safety margin for design, above the design spectral acceleration, implied by the conservatisms in applicable seismic codes and

standards. An F_P value of 1.0 is a conservative estimate applicable to nuclear SSCs designed to modern standards to describe the safety margin between design levels and levels of response that cause significant inelastic deformation. An F_P value of 1.67 is applicable to nuclear SSCs designed to modern standards to describe the safety margin between design levels and levels of response that cause unacceptable performance.

The five parameters above are the key parameters of the performance-based method. Equation (1) can be derived from Equations 7.16 and 7.17 in NUREG/CR-6728 (Reference 4) by combining these two equations and solving for SF.

As stated above, it is conservative to assume that the design level exactly corresponds to the onset of significant inelastic deformation, i.e., that F_P=1.0 and that there is no conservatism inherent in modern design procedures. Under this conservative assumption, Figure 1 shows with symbols the required scale factor SF necessary to achieve an annual FOSID of 10^{-5} (i.e. R_P=10) for A_R values ranging from 2.8 to 3.6. This range of A_R values encompasses the hazard curves calculated for North Anna, as reported in SSAR Table 2.5-28. Figure 1 shows results for β=0.3, 0.4, 0.5, and 0.6.

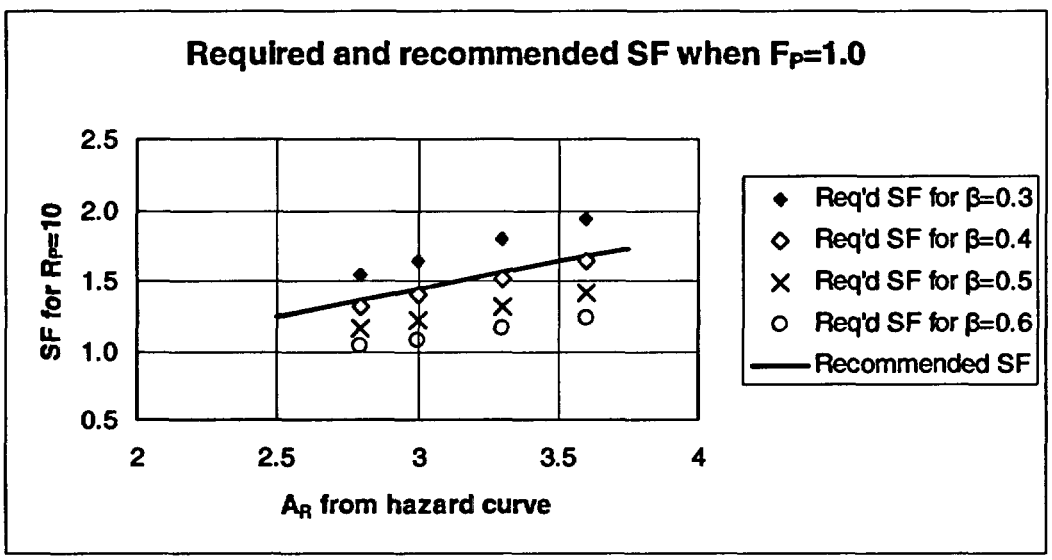

Figure 1. Required SF to achieve a probability ratio of 10 when F_P=1.0, compared to recommended SF.

The recommended value of SF for use here is calculated as the following:

recommended SF = max(1.0, 0.6 $A_R^{0.8}$) (SSAR Equation 2.5.2-3)

Assumptions inherent in this equation for the five key parameters discussed above are as follows:

R_P is assumed to be 10

x_p=2.326

K_H is directly accounted for by $A_R=10^{1/KH}$

β is assumed to be 0.4

F_P is conservatively assumed to be 1.0, i.e. that there is no seismic margin between seismic design level and onset of significant inelastic deformation implied by the applicable codes and standards

This equation assumes that a single SF applies to all fragility β values. Figure 1 shows the recommended SF from SSAR Equation 2.5.2-3 as a black line.

The recommended SF would achieve a probability ratio of 10 and hence a FOSID even less than 10^{-5} for all SSCs with β of 0.4 or greater. This includes the large majority of SSCs; very few have β less than 0.4. Figure 1 above is consistent with Figure 1 in the response to RAI 2.5.2-1 (Reference 2), which shows FOSIDs for F_P=1.0 ranging from about 5×10^{-6} to 1.5×10^{-5}, i.e. R_P values from 20 to 6.7, depending on the value of β. Figure 1 also illustrates how SSAR Equation 2.5.2-3 (the recommended SF) was derived. It was an empirical fit to required SF values for $\beta\simeq0.4$, which includes most but not all SSCs, assuming (conservatively) that F_P=1.0 for the onset of significant inelastic deformation. Note that SSAR Equation 2.5.2-3 was recommended in the ASCE draft standard (Reference 1), but its derivation originated in the 1990s (Reference 5).

Additional perspective can be gained if we use Equation (1) to calculate the required SF to achieve a 10^{-5} frequency of unacceptable performance (FUP) for nuclear SSCs. (The FUP is an alternative conservative proxy for the frequency of core damage, because not all events that lead to unacceptable performance of one or more SSCs would lead to core damage.) For unacceptable performance, F_P=1.67 applies, and Figure 2 shows with symbols the required scale factor SF necessary to achieve a FUP of 10^{-5} (i.e. R_P=10) for A_R values ranging from 2.8 to 3.6. This range of A_R values encompasses the hazard curves calculated for North Anna for different oscillator periods, as reported in SSAR Table 2.5-28. Figure 2 shows results for β=0.3, 0.4, 0.5, and 0.6.

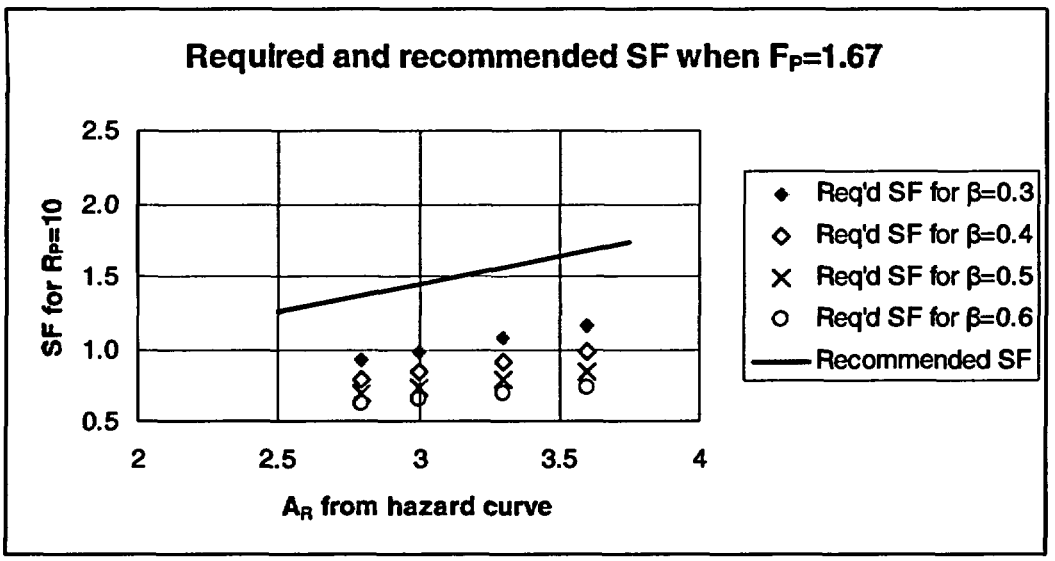

Figure 2. Required SF to achieve a probability ratio of 10 when F_P=1.67, compared to recommended SF.

The recommended SF in Figure 2 is the same line shown in Figure 1, calculated from SSAR Equation 2.5.2-3. It shows that the recommended SF is significantly above the required SF necessary to achieve a FUP of 10^{-5}. This means that using the recommended SF will achieve a probability ratio R_P greater than 10. This is why Figure 1 of the response to RAI 2.5.2-1 shows frequencies for F_P=1.67 ranging from 1.6×10^{-6} to 4.4×10^{-6}, i.e. R_P values from 62.5 to 22.7, depending on β. This is an additional indication that the recommended SF values, and the recommended ground motion spectrum derived from them, are appropriate and conservative.

References

1. American Society of Civil Engineers, *Seismic design criteria for structures, systems, and components in nuclear facilities and commentary*, ASCE draft standard, July 25, 2003, (Reference 118 of SSAR Section 2.5).

2. June 11, 2004 Letter from Eugene S. Grecheck, Vice President-Nuclear Support Services, Dominion, to U. S. Nuclear Regulatory Commission, Document Control Desk, "Dominion Nuclear North Anna, LLC, North Anna Early Site Permit Application, Response to Request for Additional Information No. 2 and Corrected Seismic Hazard Deaggregation Results."

3. Kennedy, R.P. (1999). "Overview of methods for seismic PFA and margin analysis including recent innovations", Proc of the OECD-NEA Workshop on Seismic Risk, Tokyo, Japan, August 10-12.

4. Risk Engineering, Inc. *Technical basis for revision of regulatory guidance on design ground motions: hazard- and risk-consistent ground motion spectra guidelines*, USNRC, Report NUREG/CR-6728, October 2001 (Reference 119 of SSAR Section 2.5).

5. Kennedy, Robert C., and Stephen A. Short. *Basis for seismic provisions of DOE-STD-1020*, LLNL Rept. to U.S. Department of Energy, Report UCRL-CR-111478, April 1994. R. C. Kennedy and S. A. Short (1994). *Basis for seismic provisions of DOE-STD-1020*, Lawrence Livermore Nat. Lab Rept. UCRL-CR-111478, Brookhaven Nat. Lab. Rept. BNL-52418 (Reference 128 of SSAR Section 2.5).

Application Revision

SSAR Section 2.5.2 will be revised to reflect the RAI responses contained in this letter.

July 9, 2004 NRC Letter

By letter dated March 25, 2004, the U.S. Nuclear Regulatory Commission (NRC) staff provided you a list of requests for additional information (RAIs) regarding the application submitted by Dominion Nuclear North Anna, LLC (Dominion) for an early site permit (ESP) for the North Anna ESP site. By letter dated June 11, 2004, Dominion submitted responses to the RAIs in the NRC's March 25 letter. After evaluating Dominion's responses, the NRC staff has concluded that additional information is required regarding RAI 2.5.2-1. The staff discussed these information needs with your staff via a telephone conference on June 23, 2004, and requests that Dominion address the following points:

1. How Dominion's approach to determining the Safe Shutdown Earthquake (SSE) for the site addresses 10 CFR 100.23(c), given that Dominion's approach uses generic design characteristics not addressed in the regulation.

2. How Dominion's approach addresses 10 CFR 100.23(d)(1), given that the scale factor used in Dominion's approach results in an SSE that is not characterized by a free-field ground motion response spectrum.

3. How Dominion's approach incorporates unique local site conditions into the uniform hazard spectrum (UHS), or how site-specific geology is otherwise factored into determination of the SSE.

4. How Dominion's use of a higher reference probability than that specified in Regulatory Guide 1.165 would be justified, based on current seismic hazard analyses.

In summary, Dominion should demonstrate that its SSE for the ESP site is characterized by a free-field ground motion response spectrum at the free ground surface, for which certain structures, systems, and components must be designed to remain functional.

Response

The response to each RAI is provided on the following pages.

RAI 1 (NRC 7/9/04 Letter)

1. How Dominion's approach to determining the Safe Shutdown Earthquake (SSE) for the site addresses 10 CFR 100.23(c), given that Dominion's approach uses generic design characteristics not addressed in the regulation.

Response

NOTE: On July 22, 2004, a telephone conference was held between Dominion and the NRC staff to discuss the two approaches presented in SSAR Section 2.5.2: the reference probability approach and a performance-based approach. The analyses originally presented in the SSAR relied primarily on the performance-based approach. During the call, Dominion advised the NRC of its intent to revise SSAR Section 2.5.2 to base the selected safe shutdown earthquake ground motion on the reference probability approach in accordance with Regulatory Guide (RG) 1.165. The NRC staff indicated that such a revised approach would allow the staff to complete its review on the currently published schedule. Dominion further advised the NRC staff that the performance-based approach would be retained in the SSAR as alternate and further justification for the selected SSE ground motion and that responses to the NRC questions regarding the performance-based approach would be addressed.

Table 1 describes the conformance of the performance-based approach and the reference probability approach with the requirements of 10 CFR 100.23(c).

Table 1. Conformance of Performance-Based Approach and Reference Probability Approach with the Requirements of 10 CFR 100.23(c)

10 CFR 100.23(c)	Conforms.
(c) *Geological, seismological, and engineering characteristics.* The geological, seismological, and engineering characteristics of a site and its environs must be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site, to provide sufficient information to support evaluations performed to arrive at estimates of the Safe Shutdown Earthquake Ground Motion, and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. The size of the region to be investigated and the type of data pertinent to the investigations must be determined based on the nature of the region surrounding the proposed site. Data on the vibratory ground	▪ The seismic sources used to establish the SSE ground motion were investigated in accordance with Appendix D of Regulatory Guide 1.165, which establishes three areas corresponding to radii of 320 km (regional-level investigations), 40 km (reconnaissance-level investigations), and 5 km (detailed investigations) from the site. Additionally, the region within 1 km of the site was investigated in more detail than the other regions. ▪ The seismic source models used in the investigation are those described in Reference 1, updated with additional geological, seismological, and engineering

Table 1. Conformance of Performance-Based Approach and Reference Probability Approach with the Requirements of 10 CFR 100.23(c)

motion, tectonic surface deformation, nontectonic deformation, earthquake recurrence rates, fault geometry and slip rates, site foundation material, and seismically induced floods and water waves must be obtained by reviewing pertinent literature and carrying out field investigations. However, each applicant shall investigate all geologic and seismic factors (for example, volcanic activity) that may affect the design and operation of the proposed nuclear power plant irrespective of whether such factors are explicitly included in this section.	investigations as described in SSAR Section 2.5. ▪ The ground motion models are those described in Reference 2.

Thus, both the performance-based approach and the RG 1.165 reference probability approach to determining an SSE conform to the requirements of 10 CFR 100.23(c) regarding the investigations to be conducted and the size of the region to be investigated. For the performance-based approach, the use of generic design characteristics is made in relation to a scale factor used to select the appropriate level of ground motion amplitude at each structural period. The use of the scale factor is addressed in the response to RAI 2.

References

1. Rept. NP-6395-D, *Probabilistic seismic hazard evaluations at nuclear plant sites in the central and eastern United States: resolution of the Charleston earthquake issue.* EPRI, April 1989 (Reference 115 of SSAR Section 2.5).

2. EPRI 1008910, *CEUS ground motion project—model development and results,* EPRI, August 2003 (Reference 116 of SSAR Section 2.5).

Application Revision

SSAR Section 2.5.2 will be revised to reflect the RAI responses contained in this letter.

RAI 2 (7/9/04 NRC Letter)

2. How Dominion's approach addresses 10 CFR 100.23(d)(1), given that the scale factor used in Dominion's approach results in an SSE that is not characterized by a free-field ground motion response spectrum.

Response

Table 2 describes the conformance of the performance-based approach and the reference probability approach with the requirements of 10 CFR 100.23(d)(1).

Table 2. Conformance of Performance-Based Approach and Reference Probability Approach with the Requirements of 10 CFR 100.23(d)(1)

10 CFR 100.23(d)(1)	Conforms.
(d) *Geologic and seismic siting factors.* The geologic and seismic siting factors considered for design must include a determination of the Safe Shutdown Earthquake Ground Motion for the site, the potential for surface tectonic and nontectonic deformations, the design bases for seismically induced floods and water waves, and other design conditions as stated in paragraph (d)(4) of this section. (1) Determination of the Safe Shutdown Earthquake Ground Motion. The Safe Shutdown Earthquake Ground Motion for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface. The Safe Shutdown Earthquake Ground Motion for the site is determined considering the results of the investigations required by paragraph (c) of this section. Uncertainties are inherent in such estimates. These uncertainties must be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis or suitable sensitivity analyses. Paragraph IV(a)(1) of appendix S to part 50 of this chapter defines the minimum Safe Shutdown Earthquake Ground Motion for design.	▪ The performance-based approach and the reference probability approach both result in an SSE spectrum for the site that is characterized by horizontal and vertical free-field ground motion response spectra at the free ground surface. ▪ The investigations required by 10 CFR 100.23(c) were performed as described in Table 1. ▪ Uncertainties have been addressed by conducting a probabilistic seismic hazard analysis. ▪ The selected SSE ground motion exceeds the minimum safe shutdown earthquake ground motion defined in paragraph IV(a)(1) of 10 CFR 50 Appendix S.

Each approach results in an SSE spectrum for the site that is characterized by horizontal and vertical free-field ground motion response spectra at the free ground surface. For the reference probability approach, the ground motion level for the SSE spectrum is selected by considering the annual probabilities of exceedance of seismic

design levels at other nuclear plants in the U. S. designed to current standards. This ensures that the seismic design is equivalent, in terms of annual probability of exceedance, to other plants. For the performance-based approach, the ground motion level for the SSE spectrum is selected to ensure that the annual probability of seismic effects on the plant, measured in terms of seismically induced core damage, is as low as calculated at other nuclear plants in the U. S. designed to current standards. Each approach results in an SSE characterized by a free-field ground motion response spectra at the free ground surface.

As shown in SSAR Figure 2.5-51, both approaches result in approximately the same SSE spectrum. This is not surprising because both approaches are calibrated to the seismic designs of existing plants. The scale factor used in the performance-based approach is simply a means of determining what free-field ground motion amplitude at each structural period should be selected for design, in order to achieve a performance goal (in this case related to seismically induced core damage).

Application Revision

SSAR Section 2.5.2 will be revised to reflect the RAI responses contained in this letter.

RAI 3 (7/9/04 NRC Letter)

3. How Dominion's approach incorporates unique local site conditions into the uniform hazard spectrum (UHS), or how site-specific geology is otherwise factored into determination of the SSE.

Response

The new reactor buildings would be founded on Zone III-IV or Zone IV bedrock, along with the majority of the other major safety-related structures. This material is consistent with the hard rock assumption of the EPRI 2003 ground motion models (Reference 1). Therefore, site-specific materials are factored into the determination of the SSE by recognizing that the hazard analysis performed to develop the SSE uses attenuation relations that are directly applicable to specific subsurface conditions at the North Anna ESP site.

Some safety-related structures (diesel generator building, certain pump structures, tanks, etc.) would be founded on strata above the bedrock, i.e., on the Zone III weathered rock, or the Zone IIA or Zone IIB saprolite. (Note that the Zone IIA saprolite would be improved prior to any safety-related structures being founded on that stratum.) Once the locations of structures to be founded on improved Zone IIA saprolite, Zone IIB saprolite, and Zone III weathered rock are known during detailed engineering, structure-specific subsurface investigations would be performed to determine actual strata thickness at each location, and confirm the material properties. Soil column amplification/attenuation analyses would be performed for the structure-specific locations and described in the COL application. For example, NUREG/CR-6728 (Reference 3) recommends methods for developing ground motion spectra on soil that are consistent (in terms of seismic hazard) with spectra on rock.

References

1. EPRI 1008910, *CEUS ground motion project—model development and results*, EPRI, August 2003 (Reference 116 of SSAR Section 2.5).

2. Risk Engineering, Inc. *Technical basis for revision of regulatory guidance on design ground motions: hazard- and risk-consistent ground motion spectra guidelines*, USNRC, Report NUREG/CR-6728, October 2001 (Reference 119 of SSAR Section 2.5).

Application Revision

SSAR Section 2.5.2 will be revised to reflect the RAI responses contained in this letter.

RAI 4 (7/9/04 NRC Letter)

4. How Dominion's use of a higher reference probability than that specified in Regulatory Guide 1.165 would be justified, based on current seismic hazard analyses.

Response

Three factors in current seismic hazard analyses justify an increase in the reference probability over that developed in RG 1.165:

(1) The 2003 EPRI ground motion models (Reference 2) indicate generally higher ground motions and aleatory uncertainties at high frequencies than previous models.

(2) Shorter recurrence interval estimates for the New Madrid and Charleston earthquakes will increase the hazard for plants affected by those events. Additional seismic sources in the central U. S. will also increase hazards.

(3) Use of the mean hazard instead of the median hazard will imply a higher reference probability for a fixed ground motion level, since the mean hazard curve lies above the median hazard curve.

The combined effect of these 3 factors could increase the reference probability by a factor of 5 or more, i.e. the reference probability for the mean hazard may be 5×10^{-5} or higher. Thus, for the reference probability approach applied at the North Anna ESP site, an SSE ground motion spectrum consistent with a mean hazard of 5×10^{-5} is justified.

Application Revision

SSAR Section 2.5.2 will be revised to reflect the RAI responses contained in this letter.