NRC Audit at GE Office, San Jose, CA
June 5-8, 2006

GE Status of Remaining Responses to RAI 3.7

RAI Number	Question Summary	Full Text	Schedule	Status
3.7-5	Clarify the definition of the SSE used for the design, and justify the use of generic and North Anna ground motion will lead to acceptable design. (3.7.1)	In DCD Section 3.7.1, the applicant stated that seismic design parameters (including seismic ground motion response spectra) considered for the ESBWR seismic design comprise two site conditions, generic and North Anna early site permit (ESP) sites. It is not clear from the descriptions provided in DCD Section 3.7.1 if the intent of the DCD is to show that (a) the design is appropriate for the North Ana site and any other generic site for which the RG 1.60 response spectrum is the appropriate SSE; or (b) if the design is to be considered appropriate for any site whose design response spectrum falls below the envelope of the RG 1.60 and North Anna design spectrum. The applicant also stated on Page 3.7-1, that the SSE is based upon an evaluation of the maximum seismic potential at a site. The DCD indicates that the results from the two separate ground motion sets are considered in the plant evaluations and development of enveloped responses. If the envelope spectrum were to be specified as the SSE, then a single set of time histories appropriate for this envelope spectrum would be used to generate enveloped responses. The staff requests the applicant clarify the definition of the SSE being used for the plant design, and also justify that the enveloped responses from load cases using multiple time histories (generic and North Anna) in fact leads to a conservative result of responses that would be obtained from a single ground motion time history (envelope of generic and North Anna ESP sites).	6/30/06	The plan to address this RAI is to verify that the approach used is conservative by performing an additional response analysis using a single ground response spectrum (envelope of 0.3g RG 1.60 and North Anna high frequency spectra). However, due to some unexpected delay in the generation of spectrum-compatible artificial time histories, a complete response to this RAI may have to be postponed to the August 18 package.
3.7-7	Provide a detailed description of North Anna ESP site conditions (e.g., geotechnical properties, etc.) in the DCD. (3.7.1)	In DCD Section 3.7.1, the applicant stated that because the Clinton and Grand Gulf site conditions are bounded by the envelope of the generic site and North Anna site conditions, the North Anna ESP site is selected for further consideration in conjunction with generic sites for site enveloping seismic design of the ESBWR standard plant. In addition to the ground motion response spectra, and time histories provided in the DCD, the applicant is requested to include in the DCD a detailed description of the North Anna site conditions (e.g., geotechnical properties), including response spectra at various depths through the profile consistent with design spectra.	6/30/06	In progress. Pertinent information will be extracted from North Anna ESP application.

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3.7-8	Justify why the PGAs and ground response spectra are the same at two (2) different foundation elevations (3.7.1)	In DCD Section 3.7.1.1 and DCD Section 3.7.1.1.1, respectively, the applicant stated that for generic site (1) the peak ground acceleration (PGA) of the SSE is 0.3g at the foundation level, and (2) the design response spectra are specified at the foundation level in the free field. It is the staff's understanding that the foundation level of the reactor/fuel building is located at 20m (66.0 ft) below grade and the foundation level of the control building is located at 15.05 m (49 ft) below grade. The applicant is requested to provide its technical basis to justify why the PGAs and ground response spectra are the same at these two (2) different foundation elevations.	6/30/06	In progress. The use of same 0.3g RG 1.60 spectra at different foundation elevations is a conservative approach for developing site-envelop seismic loads for standard plant design. In COL a free-field site response analysis will be performed using the site-specific ground spectra defined at the ground surface or rock outcrop. The calculated free-field spectra at the foundation level will be compared to the standard plant foundation spectra as indicated in DCD Section 3.7.5.1.
3.7-11	Provide justification for the DCD conclusion and a comparison plot of two sets of ground response spectra. (3.7.1)	In the fourth sentence of the first paragraph of DCD Section 3.7.1.1.3 (Page 3.7-4), the applicant stated that, since the low frequency part of North Anna SSE ground response spectra are enveloped by the 0.3g RG 1.60 generic site response spectra with large margins, only the high frequency part needs to be explicitly taken into account. The staff requests the applicant to provide justifications for the conclusion drawn in the DCD and a comparison plot of these two sets of ground response spectra in Tier 2 DCD Section 3.7.1, "Seismic Design Parameters."	6/30/06	In progress. A comparison plot of the low frequency part of the North Anna spectra and 0.3g RG 1.60 will be provided.

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3.7-12	Provide descriptions of North Anna ground motions and geotechnical information (3.7.1)	DCD Section 3.7.1.1.3 provides a description of the North Anna ESP design ground motion (5% damping design ground response spectra at different foundation levels, comparisons of response spectra calculated from the modified ground motion time histories with the ESP ground response spectra, etc.). In order for the staff to reach a safety conclusion regarding the design adequacy (based on the ESP ground motion) of the RB/FB and CB, the applicant is requested to provide the following information in the DCD: (a) Which of the ESP ground response spectra (target spectra or spectra/1.10 or spectra*1.30) to be used for the seismic analysis and design? (b) The ESP response spectra for 2%, 3%, 4%, and 7% damping ratios. (c) Definition of the "modified" ground motion time histories. (d) Demonstrate that the response spectra calculated from the modified ground motion time histories envelop the design ESP ground response spectra for all damping ratios to be used in the analyses. (e) Demonstrate that the modified ground motion time histories satisfy the PSD requirements (including how the target PSD was calculated). (f) Basis for the statement in the second paragraph of Page 3.7-4, "the cross-correlations between the three individual components are all less than the 0.3 requirement." (The staff's position for the cross-correlations between the three individual components is 0.16. This staff's position had been applied for other design certification review, such as AP600, AP1000, etc.)	6/30/06	In progress. . North Anna ESP application followed the more recent NUREG/CR-6728 guidelines, in lieu of SRP 3.7.1 requirements, for generation of time histories and the associated spectrum matching without the PSD check. GE intends to take exceptions to these SRP 3.7.1 requirements in the ESBWR application and will provide technical justification.
3.7-16	Address the limitation of the formulation of equations of motion described in Section 3.7.2.1.1. (3.7.2)	In DCD Section 3.7.2.1.1, the applicant presents the formulation of the equations of motion in terms of undamped eigenvalues and mode shapes, with solutions obtained by integration in the time domain. The applicant is requested to address the limitations of this formulation, particularly for the case of frequency-dependent SSI stiffness and damping coefficients.	8/18/06	In progress. For uniform sites the use of frequency-independent soil properties in the formulation is an acceptable approach in accordance with guidance of ASCE 4-98, Section 3.3.4.2.2. The effects of frequency-dependent SSI stiffness and damping coefficients will be evaluated for additional layered sites as shown on page 10.

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3.7-24	Provide a description of how the mass modeling criteria were applied. (3.7.2)	The last two sentences in the second paragraph on page 3.7-10 (DCD Section 3.7.2.3) state that the number of masses or dynamic degrees of freedom is considered adequate when additional degrees of freedom do not result in more than a 10% increase in response. Alternatively, the number of dynamic degrees of freedom is no less than twice the number of modes below the cutoff frequency. The staff generally agrees with this criteria, but it is not clear how the criteria has been implemented in the development of the seismic structural models. The applicant is requested to include in the DCD specific information on how these criteria were satisfied for each seismic structural model.	8/18/06	In progress. The criterion "the number of dynamic degrees of freedom is no less than twice the number of modes below the cutoff frequency" is met for the RB/FB model but not for the CB. The CB model is being refined to show conformance with the criterion "number of masses or dynamic degrees of freedom is considered adequate when additional degrees of freedom do not result in more than a 10% increase in response." See 3.7-57.
3.7-25	Provide a description of how the heavy cranes were included in the seismic model of the RB/FB complex. (3.7.2)	For the development of the RB/FB seismic model, the staff requests the applicant to specify in the DCD where the heavy crane (with trolley) is to be parked during plant operation. This information is needed to properly locate the mass and assess the effects of mass eccentricity in the seismic analysis. This information also needs to be identified as an interface item for the COL applicant.	6/30/06	In progress. Sensitivity analysis is being performed for the worst parked location to demonstrate the effects of mass eccentricity are negligible.
3.7-26	Provide information of how the effects of out-of-plane vibration of floors and walls were considered. (3.7.2)	For seismic subsystem analysis, accurate in-structure response spectra are needed at the subsystem support points. The staff requests the applicant to describe in the DCD how it has considered the effects of out-of-plane vibration of floors and walls in the seismic structural models and the development of in-structure response spectra.	6/30/06	In progress. Walls are being evaluated to show the out-of-plane frequencies are higher than building frequencies.
3.7-27	Include dimensions in the figures and consider them as Tier 1 information. (3.7.2)	In DCD Tier 1 Figures 2.17.5-1 through 2.17.5-11 and Tier 2 Figure 1.2-1, the applicant did not provide the foundation dimensions for the RB/FB and the CB, nor the distance from the center of the reactor vessel to the edge of the RB/FB foundation. Because this information is important for the structural modeling and the seismic response of seismic Category I structures, the staff requests the applicant to include these dimensions in the above figures and to consider them as DCD Tier 1 information.	8/18/06	In progress.

RAI Number	Question Summary	Full Text	Schedule	Status
3.7-29	Clarify the definition of the SSE. (3.7.2)	The first sentence of DCD Appendix 3A, Section 3A.1 states that this appendix presents SSI analysis performed for two site conditions, generic site and North Anna ESP site-specific, adopted to establish seismic design loads for the RB, FB, and CB of the ESBWR standard plant under SSE excitation. The definition of the SSE is not clear to the staff: is it both the 0.3g RG 1.60 ground motion response spectra and the North Anna ESP ground motion response spectra, or is it a combination (envelop) of these two spectra? The staff requests the applicant to clarify the definition of the SSE used for the ESBWR standard plant design in the DCD.	6/30/06	Same as 3.7-5.
3.7-30	Include, in the DCD, the limitation of using uniform site impedance function for the ESBWR design. (3.7.2)	The last part of the second paragraph on page 3A-4 of DCD Section 3A.3.1 states that three subsurface conditions (soft, medium, rock and hard rock sites) are considered to be uniform half-space, as provided in Table 3A.3-1 for SSI analyses. According to the staff's review experience, there are a number of sites composed of layered materials that should be considered for siting of nuclear plants. Such sites may have significant variation of shear wave velocity with depth, leading to potentially significant impedance mismatches between layers. Such profiles can have effective impedance functions that are significantly different from those associated with a uniform half-space. (See for example, "Handbook of Impedance Functions" by Sieffert and Cevaer). These sites are typically characterized by impedance functions that are highly frequency-dependent, particularly those associated with radiation damping. The approach of using a frequency-independent assumption for both stiffness and damping in SSI may lead to significantly different computed responses. The behavior (or response) of a massive structure (such as RB/FB or CB) may be significantly influenced by these variations due to site conditions. For the design of a standard plant such as ESBWR, the DCD should address the limitations on site layering that will be required, to ensure the applicability of the ESBWR design, which is based on the assumption of uniformity. The staff requests the applicant to include this information in the DCD, and also identify it as a COL interface item.	8/18/06	Same as 3.7-16.
3.7-32	Clarify, in the DCD, how the material damping and SSI radiation damping were considered in the seismic analyses. (3.7.2)	DCD Appendix 3A, Tables 3A.3-1 and 3A.3-2, indicate material (hysteretic) damping values assumed for foundation soils for the various uniform site cases. However, no mention is made in the SSI description of how these damping parameters are combined with the SSI radiation damping values listed in Tables 3A.5-1 and 3A.5-2. The staff requests the applicant clarify in the DCD how these properties (material damping and radiation damping) were considered in the SSI calculations and how significant they are to facilitate responses.	8/18/06	In progress. The SSI radiation damping values listed in Table 3A.5-1 and 3A.5-2 are the only damping considered in the SSI calculations. Soil material damping values listed in Tables 3A.3-1 and 3A.3-2 are conservatively neglected.

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3.7-33	Justify that the use of the ASCE 4-98 approach to calculate the lateral soil pressure will result in a conservative design. (3.7.2)	DCD Section 3A.5 indicates that the use of lateral pressures computed from the equivalent static pressure analysis listed in ASCE 4-98 is conservative. Based on reviews of a number of facilities, it is known that actual pressures computed from detailed SSI evaluations of embedded foundations are directly influenced by the characteristics of the foundation response spectrum used to define the ground motions as well as the relative stiffness (shear wave velocity) of the soils above the basemat level. The staff requests the applicant clearly indicate in the DCD either (1) the technical basis for the statement that these static pressures are conservative for any site, or (2) any limitations that need to be incorporated into the acceptable site profile characteristics to limit the actual dynamic pressures anticipated.	8/18/06	One of the objectives of the additional SASSI analyses mentioned in 3.7-16 is to obtain seismic lateral pressures. These SASSI calculated pressures will be compared with the pressures calculated using the AISC 4-98 approach.
3.7-34	Provide a technical basis to demonstrate that the input design ground motion time histories meet the guidelines specified in the SRP Section 3.7.1. (3.7.2)	In the seismic analysis of the RB/FB and CB for the North Anna site conditions (ground motion and local geotechnical properties), the staff identified the following concerns: a. As indicated in DCD Figures 3.7-24 through 3.7-35, the North Anna ground motions at the base of the RB/FB are different from those at the CB base. The staff's concern is whether these ground motions are treated as design ground motions. If yes, it implies that the design ground motion is not uniquely defined (RG 1.60 ground motion and North Anna ground motions at the foundation base of the RB/FB and CB). The staff requests the applicant (1) clarify the definition of design ground motion in the DCD, and (2) define the design site parameters (Tier 1 information) in Tier 1 Table 5.1-1. b. Do the ground motion time histories generated for the North Anna ground response spectra satisfy the response spectrum enveloping requirements for all damping ratios to be used for the seismic design? If yes, the staff requests that the comparison plots be provided in the DCD. If not, the staff requests the applicant to provide, in the DCD, technical basis for not satisfying these SRP guidelines. c. Do the ground motion time histories generated for the North Anna ground response spectra satisfy the PSD enveloping guidelines? If yes, the staff requests that a detailed description showing how the target PSDs were developed, and showing the comparison, be provided in the DCD. If not, the staff requests the applicant provide, in the DCD, a technical basis for not satisfying these SRP guidelines.	6/30/06	In progress. Similar to 3.7-8 and 3.7-12.

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3.7-35	Clarify, in the DCD, (1) what soil damping was used in the SSI analysis, and (2) how the embedded effects were considered in the SSI analysis. (3.7.2)	As stated in DCD Appendix 3A, Section 3A.7, the elastic half-space theory was used for modeling the soil foundation for both the generic site condition and the North Anna site condition. The staff identified the following issues in need of clarification: (1) what soil damping (material damping and energy loss due to wave propagation) was assigned for the SSI analyses, and (2) how the embedment effects (especially at relatively soft soil sites) were considered in the analysis. The applicant is requested to address these clarifications, and also describe how the elastic half-space theory was applied to the North Anna site, in the DCD.	8/18/06	In progress. The embedment effects will be addressed by the SASSI analyses mentioned in 3.7-16.
3.7-37	Provide a description, in the DCD, of how to calculate the frequency-dependent and frequency-independent soil stiffness. (3.7.2)	In the third paragraph of DCD Appendix 3A, Section 3A.5, the applicant discussed how to use the frequency-independent soil-spring Kc, and damping coefficient Cc to represent the soil foundation in the SSI analysis of the RB/FB and CB. DCD Tables 3A.5-1 and 3A.2 provide tabulated numerical values of Kc and Cc for the RB/FB and CB. However, the applicant did not describe in the DCD how the frequency-dependent soil-springs (real and imaginary parts of the soil stiffness) were calculated, and how these frequency-dependent soil-springs were converted to frequency-independent soil-springs and damping ratios. The staff requests the applicant provide a detailed description in the DCD.	8/18/06	In progress. Response will be similar to the response to RAI 3.7-49, item 7.
3.7-38	Provide a description, in the DCD, of theory and method for calculating soil stiffness. (3.7.2)	It is stated in DCD Appendix 3A that the shear wave velocities and material damping ratios are strain compatible. The staff requests the applicant provide the following information in the DCD: (1) the theory (methods or formula) for calculating all soil springs, (2) the method (or formula) for calculating damping ratios, and 3) a clear description how the strain dependency of these values is accounted for in the soil-springs used in the SSI analyses.	8/18/06	In progress. Response to (1) and (2) will be similar to the response to RAI 3.7-49, item 7. For (3) the spring values are assumed to be at seismic strain level.
3.7-39	Describe how the structure-to-structure interaction effects were considered in the DCD. (3.7.2)	For the SSI analyses that were performed, the staff requests the applicant to describe in detail in the DCD how it considered the effect of structure-to-structure interaction through the soil between the RB/FB and CB. The staff considers this a potentially significant effect, especially for the response of the CB.	8/18/06	Structure-to-structure interaction effects will be addressed as part of the SASSI analyses mentioned in 3.7-16.
3.7-50	Provide a detailed description of the method applied to determine the cracked concrete stiffness. (3.7.2)	DCD Section 3.7.2.3, "Procedures Used for Analytical Modeling," does not address the method used to develop stiffness values (uncracked concrete sections versus cracked concrete sections) for concrete structural elements for the seismic analysis models. The staff requests the applicant include in the DCD a detailed description of the method applied to determine the stiffness values for both cracked concrete sections and uncracked concrete sections in the seismic analysis models.	8/18/06	The effect of concrete cracking will be addressed as part of the SASSI analyses mentioned in 3.7-16.

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3.7-52	Provide a description of the analysis method and acceptance criteria for the design of "auxiliary systems." (3.7.3)	DCD Section 3.7.3.13 does not provide any detail about the methods of analysis employed or the acceptance criteria used to determine structural design adequacy of buried conduits, tunnels, and auxiliary systems. In addition, the applicant did not provide the definition for the term "auxiliary systems." The staff requests the following additional information to complete its review: (a) a description of the types of SSCs that are included under the category "auxiliary systems;" (b) a description of the analysis method and acceptance criteria for buried conduits; (c) a description of the analysis method and acceptance criteria for tunnels; (d) a description of the analysis method and acceptance criteria for auxiliary systems.	6/30/06	In progress.
3.7-54	Specify the lower bound of the soil shear wave velocity to be 1000 ft/sec in the DCD. (3.7.5)	In DCD Section 3.7.5, the applicant indicated that the COL applicant needs to confirm that the site-specific shear wave velocity is no less than 1,000 fps in order to confirm the design adequacy of the plant. However, in following the guidance of the SRP for an individual site evaluation, the COL applicant needs to perform site-specific response calculations, reducing the low-strain shear-wave velocity profile from the Best Estimate (BE) to a Lower Bound (LB) value, defined as the BE divided by the square root of 2. DCD Section 3.7.5 needs to indicate that 1,000 fps is a LB velocity and not a BE velocity, or, as an alternative, the minimum acceptable BE velocity can be specified. In addition, since all design analyses were performed for assumed uniform velocity profiles, the site acceptance criteria needs to include information on what degree of variation from the uniform velocity profile is acceptable for the design.	8/18/06	Response to RAI 3.7-31 has clarified that 1000 ft/sec is the LB velocity after taking into account uncertainties. To enhance site suitability for the ESBWR standard plant, additional SASSI analyses are performed for layered sites as described in 3.7-16.
3.7-55	Provide the computer code validation packages, in English, for review. (3.7.2)	To facilitate the staff's evaluation of the adequacy of computer codes used for design and analysis of the ESBWR Seismic Category I structures, the staff requests the applicant submit validation packages, translated into English, for the following computer codes listed in DCD Appendix 3C: SSDP-2D TEMCOM2 DAC3N	6/30/06	In progress.

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3.7-57	Demonstrate that the stick structural models developed based on the process described in the DCD can transmit frequencies up to 50 Hz and be able to capture the responses resulting from the high frequency components of North Anna input ground motions. (3.7.2)	DCD Tier 2, Section 3.7.2.3 indicates that the mathematical model of the structural system is constructed either as a stick model or a finite element model. These models are used in the soil-structure interaction (SSI) response analyses to determine seismic response of the soil structure system as indicated in DCD Section 3.7.2.4 and described in Appendix 3A to DCD Section 3.7. The free-field ground motions used as input to the plant analysis and design are described in DCD Section 3.7.1 and are ground motions that envelope either the RG 1.60 low frequency response spectrum or the high frequency ground motion developed for the North Anna early site permit site. DCD Figure 3.7-30 presents a plot of the North Anna design ground response spectrum and indicates a response spectrum that possesses its primary spectral accelerations in the frequency range from about 10 Hz to 50 Hz with a peak spectral acceleration at a frequency of about 20 Hz for the horizontal response spectrum and about 30 to 50 Hz for the vertical response spectrum. Appendix 3A to DCD Section 3.7 presents descriptions of the stick models developed for use in SSI analyses for the primary structures and internals of the plant. DCD Tables 3A.7-5 through 3A.7-14 present the results of eigenvalue analyses that are carried to frequencies as high as 27 Hz. These indicate participation factors of 0.28 at frequencies as high as about 25 Hz. The staff requests that the applicant demonstrate that the stick structural models developed based on the process described in the DCD can transmit frequencies up to 50 Hz and be able to capture the responses resulting from the high frequency components of North Anna input ground motions.	8/18/06	In progress. The CB stick model is being refined by adding additional mass points with the objective to show that the resulting responses are no more than 10% increase of the responses predicted from the original model.

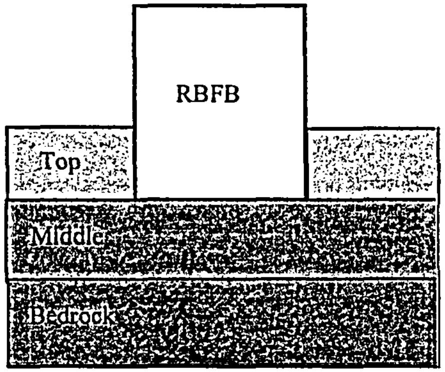

Figure1.1 RB/FB model

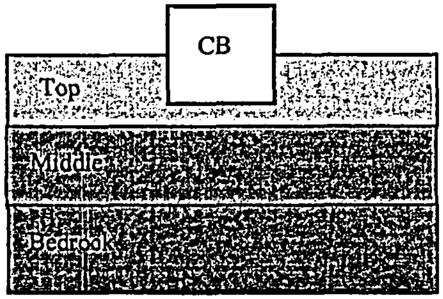

Figure1.2 CB model

Layered Site cases

Layer	Shear Wave Velocity(m/s)/Depth(m)			
	CASE1	CASE2	CASE3	CASE4
Top	300/20	300/20	300/20	300/20
Middle	300/20	800/20	300/40	800/40
Bedrock	1700	1700	1700	1700

Note that the 20m depth of the middle layer corresponds to the embedded depth of the RB/FB and 40mm depth corresponds to about one-half the largest plan dimension of the RB/FB foundation.