Tennessee Valley Authority, 1101 Market Street, Chattanooga, TN 37402

CNL-17-089

July 19, 2017

10 CFR 52, Subpart A

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Clinch River Nuclear Site
NRC Docket No. 52-047

Subject: Response to Request for Additional Information RAI Number 3, eRAI-8893, Regarding Vibratory Ground Motion in support of Early Site Permit Application for Clinch River Nuclear Site

References:

1. Letter from TVA to NRC, CNL-16-081, "Application for Early Site Permit for Clinch River Nuclear Site," dated May 12, 2016
2. Letter from TVA to NRC, CNL-16-170, "Submittal of Supplemental Information Related to Vibratory Ground Motion in Support of Early Site Permit Application for Clinch River Nuclear Site," dated October 28, 2016
3. NRC Electronic Mail, "Issuance of RAI pertaining to Section 2.5.2, Vibratory Ground Motion, RAI Number 3, eRAI-8893," dated June 21, 2017

By letter dated May 12, 2016 (Reference 1), Tennessee Valley Authority (TVA) submitted an application for an early site permit for the Clinch River Nuclear (CRN) Site in Oak Ridge, TN. By letter dated October 28, 2016 (Reference 2), TVA submitted a proposed change to the CRN Site Safety Analysis Report (SSAR) regarding SSAR Subsections 2.5.2.5, "Seismic Wave Transmission Characteristics of the Site," and 2.5.2.6, "Site-Specific GMRS." By electronic mail dated June 21, 2017 (Reference 3), Nuclear Regulatory Commission (NRC) issued a request for additional Information (RAI) regarding vibratory ground motion associated with the CRN Site.

The Enclosure to this letter provides the response to the RAI including SSAR markups. The SSAR markups will be incorporated in a future revision of the early site permit application.

There are no new regulatory commitments associated with this submittal. If any additional information is needed, please contact Dan Stout at (423) 751-7642.

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 19th day of July 2017.

Respectfully,

Daniel P. Stout for

J. W. Shea
Vice President, Nuclear Regulatory Affairs and Support Services

Enclosure:

Response to NRC Request for Additional Information Number 3, eRAI-8893

cc: (Enclosure)

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cc: (without Enclosure)

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ENCLOSURE

Response to NRC Request for Additional Information Number 3, eRAI-8893

NRC RAI 02.05.02-01

Section 2.5.2.6 of the SSAR provides the results of a sensitivity study evaluating the potential impact of 2-D site effects on site response. This sensitivity study includes a comparison of the 2-D site response and a 1-D site response using a similar approach used for the 2-D results. However, the 1-D site response used in this comparison is not used for establishing the permit basis of the Clinch River site. The comparison presented in the SSAR does not currently show that the 1-D site response used for licensing adequately captures the 2-D site effects explored by the sensitivity study.

In order to satisfy requirements in 10 CFR 100.23(d)(1) as it relates to seismic hazard and for the staff to make a determination about the adequacy of the 2-D sensitivity study, please provide a comparison of the 2-D site response to the 1-D site response results used to establish the Clinch River site GMRS.

TVA RAI-02.05.02-01 Response

SSAR Subsection 2.5.2.6, "2D Sensitivity Analysis," is being revised to provide additional detail regarding the 1D amplification used in the development of the Clinch River GMRS as compared to the 2D sensitivity analysis. Additionally, Figures 2.5.2-107, 2.5.2-108, 2.5.2-109, and 2.5.2-110 are being added to detail the comparison of the 1D base case profiles to the 2D amplification factors for Locations A and B. The overall conclusions regarding 2D effects for the Clinch River Site have not changed. See the SSAR markups provided in Subsection 2.5.2.6 in Attachment 1.

NRC RAI 02.05.02.02 Question

Updated SSAR Section 2.5.2.5.1.1 discusses the approach used to model epistemic uncertainty at the CRN site. A site profile is developed by grouping all available site data (as well as information from TVA dam sites) and calculating a log-mean and standard deviation. This is then used to calculate upper and lower site profiles. This approach is expected to account for dip across the site through the use of the three profiles. However, there is no justification made for this assertion in the text of the SSAR. Specifically, the SSAR does not explain how this approach accounts for the dipping structure across the site. Because the site is underlain by multiple rock layers with a dip of 33 degrees, it is necessary to explain how the 1-D site response approach is expected to accommodate the 2-D nature of the site.

In order to satisfy requirements in 10 CFR 100.23(d)(1) as it relates to seismic hazard and for the staff to make a determination about the adequacy of the site response inputs, please explain how the use of a log-mean profile, combined with upper and lower profiles based on the statistical analysis, accounts for the dipping stratigraphy of the site.

TVA RAI 02.05.02.02 Response

The updated SSAR Subsection 2.5.2.5, “Seismic Wave Transmission Characteristics of the Site,” provided in Reference 1 is being revised with additional text to clarify how the use of a log-mean profile and the associated upper and lower profiles based on the statistical analysis account for the dipping stratigraphy of the site. In addition, a clarification is being made in the second paragraph of SSAR Subsection 2.5.2.5.1.1, “Epistemic Uncertainties in V_S,” regarding the dipping structure results. There are two 2D effects of the dipping structure. The first is due to the lateral changes in velocities due to the lateral changes in formations. The second effect is due to broad-band resonances from impedance contrasts. The analyses have demonstrated that the second effect is insignificant and only the lateral changes need to be accommodated by using three basecase profiles. The lateral variations in velocity have been treated as epistemic uncertainty as captured in the sigma computed from averaging all the velocity profiles. A correction to the definition of “COV” is also being made in this Subsection. See the SSAR markups provided in Subsections 2.5.2.5 and 2.5.2.5.1.1 in Attachment 1.

Reference 1. Letter from TVA to NRC, CNL-16-170, “Submittal of Supplemental Information Related to Vibratory Ground Motion in Support of Early Site Permit Application for Clinch River Nuclear Site,” dated October 28, 2016

Attachment 1
SSAR Subsections 2.5.2.5, 2.5.2.5.1.1, and 2.5.2.6 Markups

SSAR Subsection 2.5.2.5 is being revised as indicated. Underlines indicates text to be added. Strikethroughs indicates text to be deleted.

2.5.2.5 Seismic Wave Transmission Characteristics of the Site

This subsection describes the development of the site amplification factors that results from the transmission of the seismic waves through the site-specific geologic profile above the hard rock, which consists of various dipping rock formations as described in Subsections 2.5.4.2 and 2.5.4.7. The site amplification factors are used in determination of the UHRS and the GMRS for the site.

Due to the dipping stratigraphy beneath the CRN Site (about 33 degrees) potential two-dimensional (2D) effects on ground motions were evaluated using an expanded version of the computer code SASSI (System for Analysis of Soil Structure Interaction). The 2D effects were addressed through a sensitivity analysis (Subsection 2.5.2.6).

A geologic cross-section at the site that illustrates the depth to Precambrian rock, drawn perpendicular to the strike direction, is shown on Figure 2.5.1-63. Planned surface grade at the site is at Elevation 821 ft. The planned bottom of the foundation for Reactor Service Buildings (RSB) is taken at Elevation 683 ft. The top of competent rock varies across the areas of Locations A and B as shown on Figure 2.5.4-2. Based on the data to the top of unweathered rock from the suspension data, competent rock ranges from about Elevation 749 to 770 ft at Location A and Elevation 738 to 758 ft at Location B. Given that no specific technology has been selected, the elevation of the GMRS is chosen to be Elevation 683 ft corresponding to the bottom of the RSB foundations below the top of unweathered rock. All elevations cited in this subsection are based on the North American Vertical Datum of 1988 (NAVD88).

Recognizing the assessment of epistemic uncertainty must necessarily reflect a significant degree of judgment and the range in basecase shear-wave velocities (V_S) at CRN Site must necessarily accommodate two separate aspects of the site conditions:~~. For~~ (1) for the depth ranges for which measured velocities were available, the dipping structure (Figure 2.5.4-13) results in the same unit and associated dynamic material properties occurring at different depths across each site footprint~~.~~

~~Providing impedance contrasts are relatively small,~~ ; and (2) broad-band resonance or amplification effects due to the dipping structure, such as a basin edge.~~,~~ However, as discussed further, impedance contrasts beneath the CRN Site are small and so 2D resonance and amplification effects are not expected to significantly exceed ~~(Reference 2.5.2-169)~~ one-dimensional (1D) resonances (Reference 2.5.2-169), particularly if they are broadened through the use of multiple basecases. Extending epistemic uncertainty through the shallow portion of the profile (approximately 300 ft) where sufficient measurements exist to constrain a single basecase profile was considered essential to accommodate ~~the~~both potential effects of the shallow dipping structure.

For the deeper structure (Knox Group and below, Figure 2.5.4-13) uncertainty in V_S exists due principally to the limited site-specific measurements. Below the Knox group, 2D effects are expected to be less than the shallower structure, particularly at frequencies of interest (greater than 0.5 Hz), due to the smaller impedance contrasts and the shallowing of the dip and more uneven nature of the very deep structure (Figure 2.5.4-13) (Subsection 2.5.2.6). As a result the same relative factor expressing epistemic uncertainty was used for both the shallow structure with direct measurements as well as the deep structure lacking site-specific velocity measurements.

SSAR Subsection 2.5.2.5.1.1 is being revised as indicated. Underlines indicates text to be added. Strikethroughs indicates text to be deleted.

2.5.2.5.1.1 Epistemic Uncertainties in V_S

To address the epistemic uncertainty in the mean basecase profile, the uncertainties in the 25 V_S profiles measured within the CRN Site and at 18 TVA damsites (measured by Geovision Geophysical Services) were examined through a statistical analysis that looked at several aspects of the data. For the TVA dam V_S profiles, the material above rock (embankment material, alluvium, etc.) was removed and not considered in the statistical analysis. All V_S profiles were smoothed prior to performing the statistical analysis. First, the V_S profiles for each of the subunits of the CRN Chickamauga Group were compiled and the sigmas and ~~common offset vectors~~coefficients of variation (COVs) were computed (Figures 2.5.2-92 and 2.5.2-93). The right side of the figures show the number of profiles used to compute the statistics. The actual depths of the subunits were preserved. The sigmas and COVs average are relatively small and are fairly uniform with depth at about 0.08 and reflect within unit differences. In a similar fashion, the CRN Chickamauga Group was divided up by general rock type (dolomite, limestone, and siltstone) and Figures 2.5.2-94 and 2.5.2-95 show the trends. For the subunits that were a mix of dolomite and limestone, the dominant rock types were used. The dolomite and limestone showed smaller sigma and COVs than the shale (Figures 2.5.2-94 and 2.5.2-95). Finally, the sigmas and COV were computed for the CRN and TVA damsite V_S profiles (Figures 2.5.2-96 and 2.5.2-97). The sigma and COV average about 0.15 and 0.30, respectively, from 50 to 200 ft where there were a sufficient number of profiles. Not surprisingly, the sigma and COV were higher for the TVA dams because they were located on a wider range of geology covering three Appalachian states compared to the CRN profiles.

Using these results as well as the sigma across units at the CRN Site in Figure 2.5.2-96 to inform judgment in developing depth-independent epistemic uncertainty, a standard deviation of 0.15 was selected. This standard deviation accommodates ~~to accommodate~~ potential 2D effects in the top 300 ft where ~~2D~~the effects of the dipping structure resulting in the same velocity at different depths may be expected to be the strongest, ~~in the shallow strata but~~ albeit still minor~~,~~. The standard deviation also accommodates the ~~as well as~~ lack of site-specific measurements below a depth of about 300 ft. Considering a three-point approximation to the distribution weights of 0.2, 0.6, and 0.2 for lower (P2)-, middle (P1)-, and upper (P3)- range estimates results in a velocity scale factor of approximately 1.25, a ± 25 percent variation about the mean (best estimate) basecase. The resulting base-case (P1) as well as lower-range (P2) and upper-range (P3) basecases are illustrated in Figure 2.5.4-20 and 2.5.4-21 for Locations A and B, respectively. The resulting range in V_S from the lower- to upper- base-cases is about 1.6 and well within the range for such materials (Reference 2.5.2-208), acknowledging a portion of the range was taken to accommodate the dipping structure in terms of lateral variations in velocities. The lateral changes in velocities have been treated as epistemic uncertainty.

Basecase profiles (P1) for Locations A and B, illustrated in Figures 2.5.4-20 and 2.5.4-21, reflect high V_S throughout, particularly within the Knox Group and below. The limestones as well as some of the shales exceed at depth the V_S (2.83 km/s) of the top layer of the generic Midcontinent crustal model (Subsection 2.5.2.5.5). As a result, to accommodate a more realistic crustal profile, the roughly 12,000 ft (3.6 km) of the CRN Site profile was taken to replace the top layer of the Midcontinent crust, with the second layer at a V_S of 3.52 km/s (11,550 ft/s) assumed to effectively reflect basement conditions (Figure 2.5.4-13). The assumed basement condition is depicted in Figures 2.5.4-20 and 2.5.4-21 as the deepest layer. The upper-range base-case profiles (P3) within the Knox Group and Rome and Pumpkin Valley Units were truncated at the assumed basement V_S of 3.52 km/s.

SSAR Subsection 2.5.2.6 is being revised as indicated. Underlines indicates text to be added.

2.5.2.6 2D Sensitivity Analysis

Due to the dipping nature of the underlying stratigraphy beneath the CRN Site (approximately 33 degrees) (Figure 2.5.4-12), potential 2D effects on earthquake ground motions were evaluated. In the development of the GMRS using Approach 3 from NUREG/CR-6728, a 1D equivalent-linear site response approach was used. Potential~~, and potential~~ 2D effects, due to the same geologic unit and associated velocity occurring at different depths across each site as well as broad-band amplification (basin edge) effects resulting from dipping impedance contrasts, were initially addressed by evaluating the epistemic uncertainty in V_S beneath the CRN Site.

The objectives of the 2D sensitivity analysis were to: (1) evaluate how simplifying the dipping stratigraphy beneath the CRN Site to a 1D model for site response impacts the GMRS, and (2) assess whether sufficient epistemic uncertainty had been incorporated into the 1D analysis to address potential 2D effects. A 2D model of the site was developed which included both Locations A and B (Figure 2.5.4-13). The amplification between Precambrian basement rock (where V_S exceeds about 11,500 ft/s) and the surface of the model was then computed. The influence of the dipping stratigraphy was evaluated by comparing the amplification computed by the 2D analysis with that from the 1D analysis. The 2D effects were analyzed at three points across Locations A and B to allow averaging across both locations. The three points at each location that were analyzed were center, left (updip of center), and right (downdip of center).

The computational zone for the 2D modeling, defined as the area shown in the geologic cross-section (Figure 2.5.4-12), and was approximately 20,000 ft wide by 14,800 ft deep and consisted of multiple layers having interfaces at various dip angles (Figure 2.5.2-80). The depth of the mesh to the top of the basement hardrock is about 12,600 ft with 2200 ft of basement rock included in the mesh. All properties of the rock layers were assumed to be linear-elastic. The computational zone was represented by a 2D finite element (FE) mesh, having the capability to transmit 50 Hz frequency response (Figure 2.5.2-81). This 50 Hz frequency requirement is consistent with the NRC recommendations provided in NUREG-0800 for site response analysis. The element sizes were determined using the standard criterion of $f = V_S/5d$, where V_S is the material shear-wave velocity, d is the largest dimension of the element and f is the passing frequency.

The 2D mesh included the Precambrian basement with a V_S of about 11,500 ft/s, consistent with the V_S used in the GMRS (Figure 2.5.2-82; Subsection 2.5.2.5.8). The V_S values for the geologic formations represented in the mesh were adopted from the 1D V_S profiles used in calculating the GMRS presented in Subsection 2.5.2.5.8. The damping was taken as the average of the six sets of profiles (Figure 2.5.2-82).

The 2D analyses were performed using SDE-SASSI Version 2.0. 1D analyses were performed to compare against the 2D model. The 1D analysis used the validated equivalent-linear site response analysis program CARES Version 2.0. SDE-SASSI is an expanded and fully validated version of the SASSI computer code, which includes a transmitting boundary at the base (Figure 2.5.2-80). The model also includes transmitting boundary elements on both vertical sides of the finite element mesh. The side transmitting boundary elements were located at each node of the mesh boundary and are defined by spring/dashpot elements for both normal and shear motions at the boundary node. The purpose of these boundary elements is to minimize the effects of the numerical boundaries on the computed response in the central region of the mesh. The input motion was assumed to be located at the top of the basement rock and is an outcrop motion (Figure 2.5.2-80).

The best estimate V_S profile used in the GMRS was run in the 2D analysis. Other pertinent data on rock properties (Poisson's ratio, unit weight, and hysteretic material damping ratio) used in the 2D computational zone were also adopted from the GMRS analysis. Poisson's ratio was required in the 2D analysis. A value of 0.25 was used, which is a typical value for hard rock, and was measured in dynamic laboratory tests of rock samples from the same formation located approximately 30 mi southwest of the CRN Site. It was not necessary to run the lower-range and upper-range V_S profiles considered in the GMRS 1D analysis in the 2D analysis because both profiles were developed to accommodate 2D effects.

A basement outcrop horizontal time history, spectrally-matched to the enveloped GMRS, was used as input to both the 1D and 2D calculations. Because the 2D analysis was a linear analysis, the results are not sensitive to control motion spectral shapes provided it has sufficient amplitude across spectral frequency to excite the 5 percent-damped oscillators. The smooth GMRS reflects design levels of motion over a wide bandwidth and was selected to reflect control motions for the 2D analyses. The seed time history was the Pacoima Kagel Canyon record of the 1994 **M** 6.7 Northridge, California earthquake (Figure 2.5.2-83). The spectral matching meets the applicable criteria from NUREG-0800. The 5-95 percent Arias intensity was 21.79 m/s. The 5 percent-damped response spectra for this time history record as computed by both the CARES and RASCALS programs are very similar (Figure 2.5.2-84).

The 1D site profiles (velocity and hysteric material damping) used in the 1D CARES calculations were then used in the 2D/1D spectral comparisons. The response calculations, 1D and 2D, were performed using linear properties, with no strain iteration considered in the computations.

Figure 2.5.2-80 presents a schematic diagram of the 2D SASSI model used to evaluate site effects. The CRN Site is represented by 2D triangular and quadrilateral finite elements generated throughout the zone of influence, considered from the surface down to and into the basement rock and from the left to right boundary (Figure 2.5.2-82). As previously stated, results were calculated at three points for both Locations A and B.

For the 2D calculations, the input horizontal time history is defined at the top of basement as a normally (vertical) incident outcrop motion applied in the plane of the figure; that is, the problem considered is SV wave (vertically-polarized shear-wave) transmission (Figure 2.5.2-80). Vertical input and corresponding surface output motions were not considered in the 2D analysis because potential effects on the vertical component are expected to be less than the horizontal as the compressional-wave velocities are significantly greater than the shear-wave velocities. No horizontal wave passage effects are considered in the calculations. Transmitting boundary conditions are assumed along the two vertical side boundaries in the form of both horizontal and vertical dashpots applied at each node along the vertical boundaries, which accommodate approximate normal wave incidence. The purpose of these boundary elements is to minimize the energy feedback off these computational boundaries back into the large 2D mesh. The lack of usage of such elements may lead to significant increase in mesh response, particularly at relative low frequency (between 1 and 5 Hz for such a site profile). The transmitting boundary formulation used in these calculations is based on the simple viscous Lysmer-Kuhlemeyer

(References 2.5.2-170 and 2.5.2-171) model, and has been long used in such wave transmission calculations in both finite-element and finite-difference wave propagation.

The semi-infinite half-space at the base of the 2D SASSI model consists of two parts: (1) the addition of 20 layers having a total depth of 1.5 V_Sb / f (where 'V_Sb' is the V_S of the basement half-space and 'f' is the frequency of the analysis) and (2) the addition of horizontal and vertical dashpots applied at the base of the extended layered site model. This modeling approach is inherent within the SASSI code and is intended to minimize any reflections off the bottom boundary of the model. The transmitting boundary models have been found to be an important component of these large half-space problems.

For the CRN Site calculations, two finite element meshes were developed for the 2D calculations, a fine and coarse mesh, established throughout the computational zone (20,000 ft wide by 14,800 ft deep) (Figure 2.5.2-80). The fine mesh described earlier with a 50 Hz transmission capability is computationally very large, resulting in a mesh having about 500,000 finite elements (with over 1,000,000 degrees-of-freedom, two at each node) and requires large computer capacity along with modern matrix solvers. Figure 2.5.2-81 presents a snapshot of the fine mesh in the CRN Site. For the firm and hard rocks in the fine mesh, the resulting element dimensions are on average about 28 ft.

A coarse mesh model was developed to have a transmission capability limited to about 10 Hz. The average element size for the coarse mesh is about five times larger than those of the fine mesh, or about 125 ft. The coarse mesh model results in a much smaller (as compared to the fine model) complex dynamic matrix to be solved at each frequency of interest, and allows the solutions to be obtained much more efficiently. The comparisons of results at low frequency (less than 10 Hz) are used to provide support and verification to the fine mesh solutions. This coarse mesh calculation is especially appropriate where the most significant 2D effects are expected to be most pronounced at low frequencies (below 10 Hz).

Figures 2.5.2-85 and 2.5.2-86 present the results of the horizontal surface response spectra for Locations A and B, respectively, from the 2D calculations for the fine mesh. The 2D spectra generated at the sites in Locations A and B span a distance of about 400 ft from the left to the right side. The lognormal mean of the three spectra for each site was also computed and is plotted in the figures. The three 2D spectral results show the scatter expected for three different locations in each area.

Figures 2.5.2-87 and 2.5.2-88 present the lognormal-mean horizontal 2D surface spectra for Locations A and B, respectively, as compared to the resulting 1D surface spectra. The 2D effect of the rock layering essentially eliminates the higher frequencies (above about 5 to 6 Hz) from the response; that is, the 2D response spectra fall off rapidly from the 1D response spectra at the higher frequencies. This is primarily due to the scattering of the high-frequency responses caused by the non-horizontal layer interfaces. Figures 2.5.2-89 and 2.5.2-90 present the same spectra as in Figures 2.5.2-87 and 2.5.2-88, but after smoothing with a seven-point averaging window. To achieve statistical stability of the spectral ratios, both the numerator (2D) and denominator (1D) were smoothed separately prior to taking the ratios.

Figure 2.5.2-91 presents the corresponding 2D/1D effect on smoothed surface spectral response for Locations A and B, in terms of response spectral ratios. The spectral ratios are all below 1 except for one small exceedances at Location B (less than 10 percent). The 2D scattering effect removes the higher frequency responses (above about 5 to 6 Hz). At lower frequencies, the 2D scattering effect can cause the response to increase but the ratios are still below 1 (Figure 2.5.2-91).

In calculating the GMRS, best-estimate base-case 1D profiles were developed representative of slices taken through the midpoints of Locations A and B extending to basement rock conditions (Section 2.5.2.5.1). To accommodate epistemic uncertainty in velocity, upper- and lower-range profiles and associated amplification factors were developed for Locations A and B for a total of six sets of profiles and associated amplification factors. For each location, hazard was developed as a weighted average of hazard computed for the best-estimate as well as lower- and upper-range profiles. The epistemic uncertainty in Vs at each location was considered sufficient to accommodate both the occurrence of the same unit and dynamic material properties at different depths as well as broad-band amplification due to the dipping structure. The final GMRS was taken as an envelope of the hazard developed for Locations A and B (Section 2.5.2.5.8) (Reference 2.5.2-210).

Figure 2.5.2-107 compares the 1D amplification used in developing the GMRS with the 2D sensitivity analysis for Location A. In Figure 2.5.2-107 the 1D amplification factors shown are for the base-case profile and reflects the median estimate over 60 realizations. Since the 2D sensitivity calculation represents only a single analysis or realization, it has been smoothed using the Konno and Ohmachi algorithm (Reference 2.5.2-211) to reflect similar resolution as the 1D median estimate.

As Figure 2.5.2-107 illustrates, the 1D amplification factors significantly exceed the smoothed 2D factors computed in the sensitivity analysis across all frequencies except for a narrow frequency range around 2 Hz. Figure 2.5.2-108, illustrates the broadening of the 1D amplification by including the median amplification for the lower- and upper-range profiles.

For Location B, Figures 2.5.2-109 and 2.5.2-110 show the analogous plots comparing the 1D and 2D amplification factors. As with Location A, the 1D median estimate significantly exceeds the smoothed 2D factors except over a narrow frequency range near 2 Hz.

The 1D and 2D comparisons confirm that 2D effects were not expected to be a significant factor at the CRN site due to the high Vs and small impedance contrasts between dipping rock units.

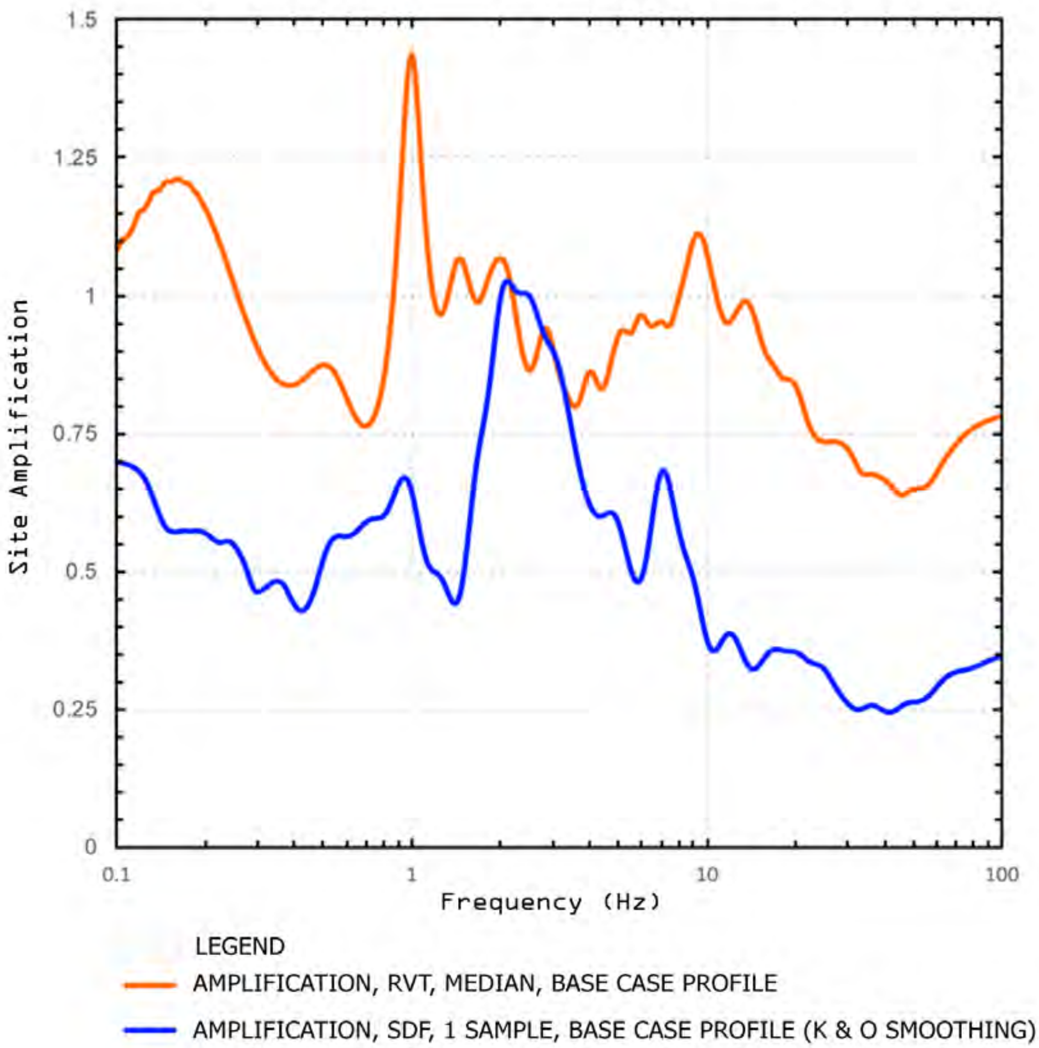
In summary, in this sensitivity analysis, the resulting 2D response for the best-estimate profile properties indicates no significant exceedance of the 1D response. This is due to the site V_S being high for this site and the differences in velocities between rock layers not being significant, reducing the magnitude of the 2D effects at lower frequencies of interest. As stated in Section 2.5.2.5.1, the use of multiple basescase velocity profiles in calculating the GMRS is expected to accommodate potential 2D effects from dipping layers. Also in examining the FAS of the small earthquakes recorded at Tellico Dam as part of the kappa evaluation, no broadband resonances were observed suggesting that 2D effects are not present at the site. Tellico Dam has a similar dipping structure beneath it as does the CRN Site. Hence no adjustment of the GMRS for 2D effects is required based on the implementation of multiple basecase V_S profiles in the site response analysis and the results of the 2D sensitivity analysis.

The following references are being added to Subsection 2.5.2:

2.5.2-210. W. Silva, B. Darragh, and I. Wong, "Comparison of 2D and 1D Site Response Analyses at the Clinch River Nuclear Site," December 6, 2016.

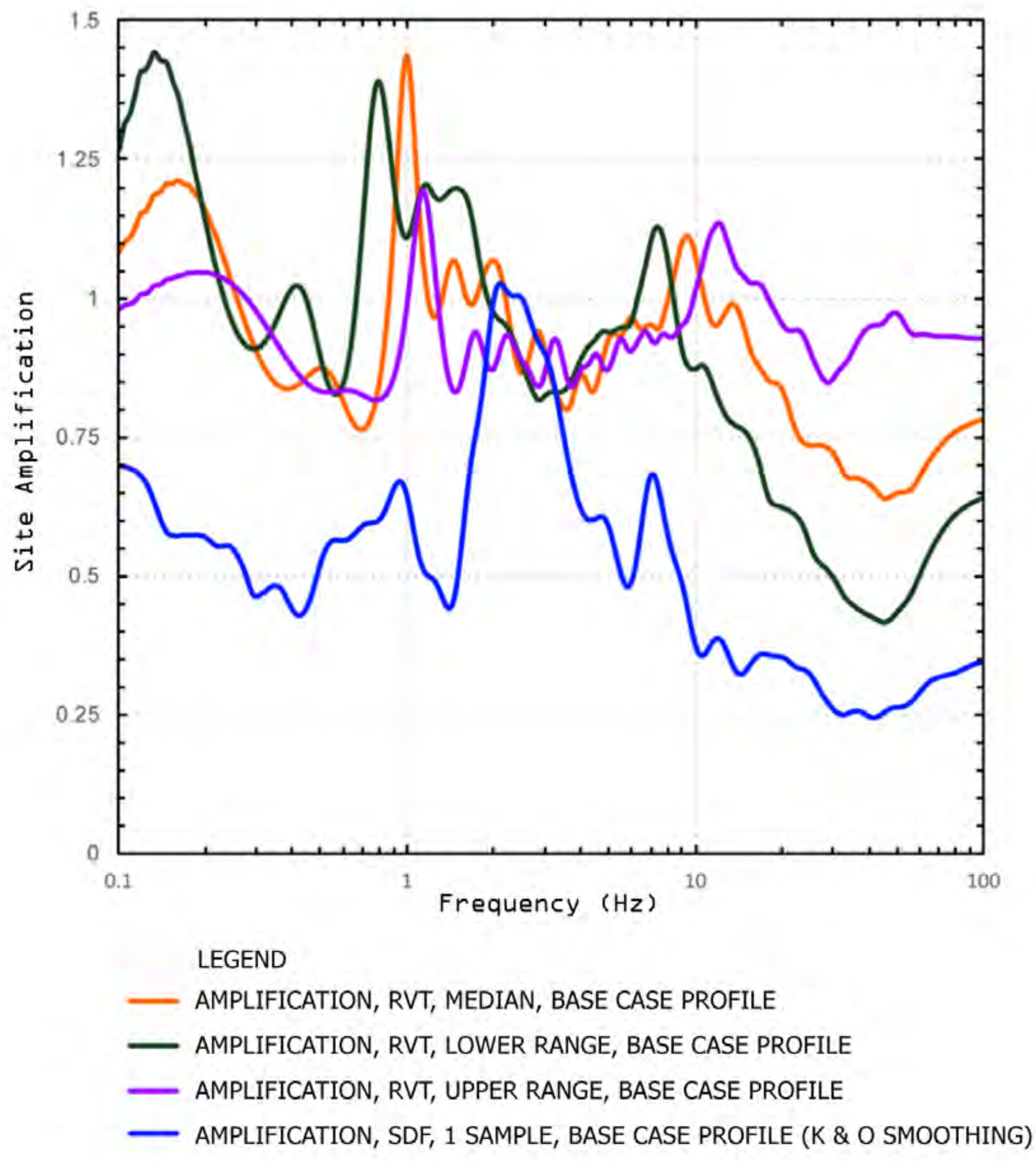
2.5.2-211. Konno, K. and T. Ohmachi (1998). "Ground motion characteristics estimated from spectral ratio between horizontal and vertical components of microtremor," Bulletin of the Seismological Society of America, Vol. 88, pp. 228-241, February 1998.

The following figures are being added to Subsection 2.5.2:



Reference 2.5.2-210, Figure 1

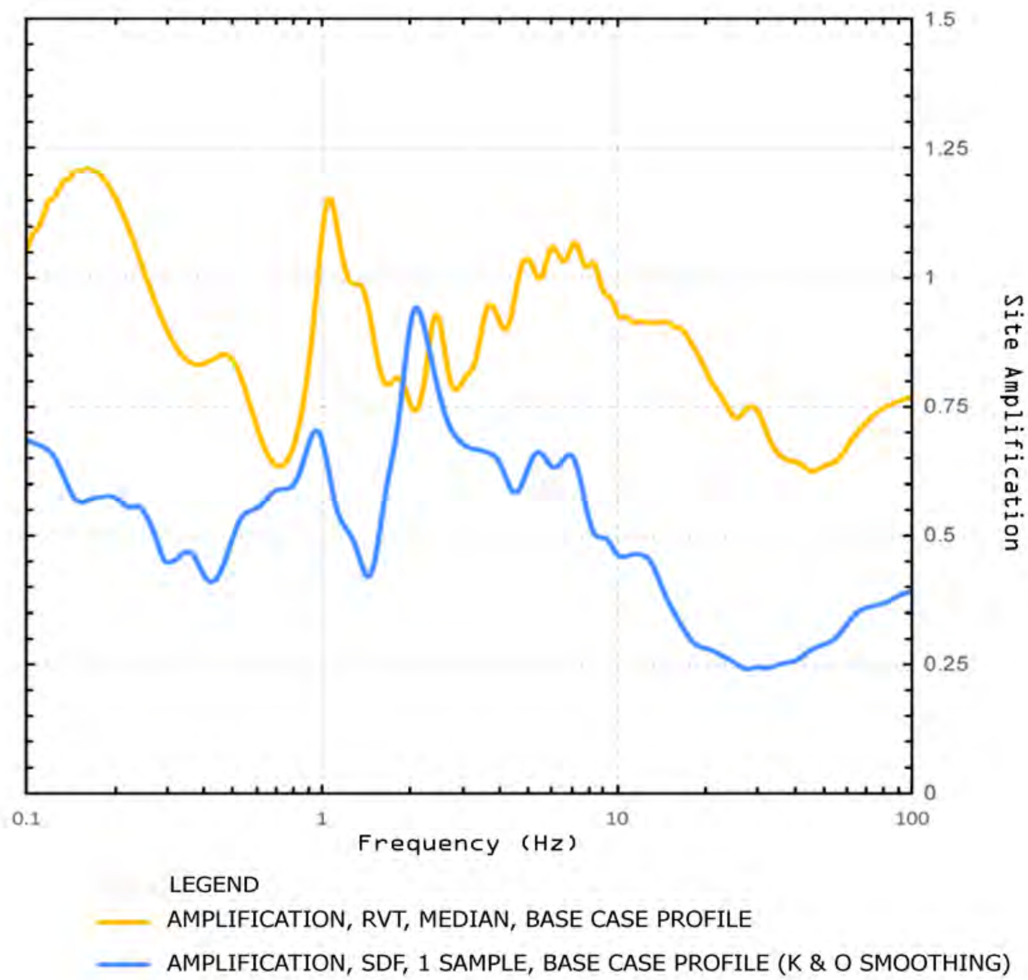
Figure 2.5.2-107. Comparison of 1D (Base-Case Profile) and 2D Amplification Factors (PSA, 5% Damping) for Location A



Reference 2.5.2-210, Figure 2

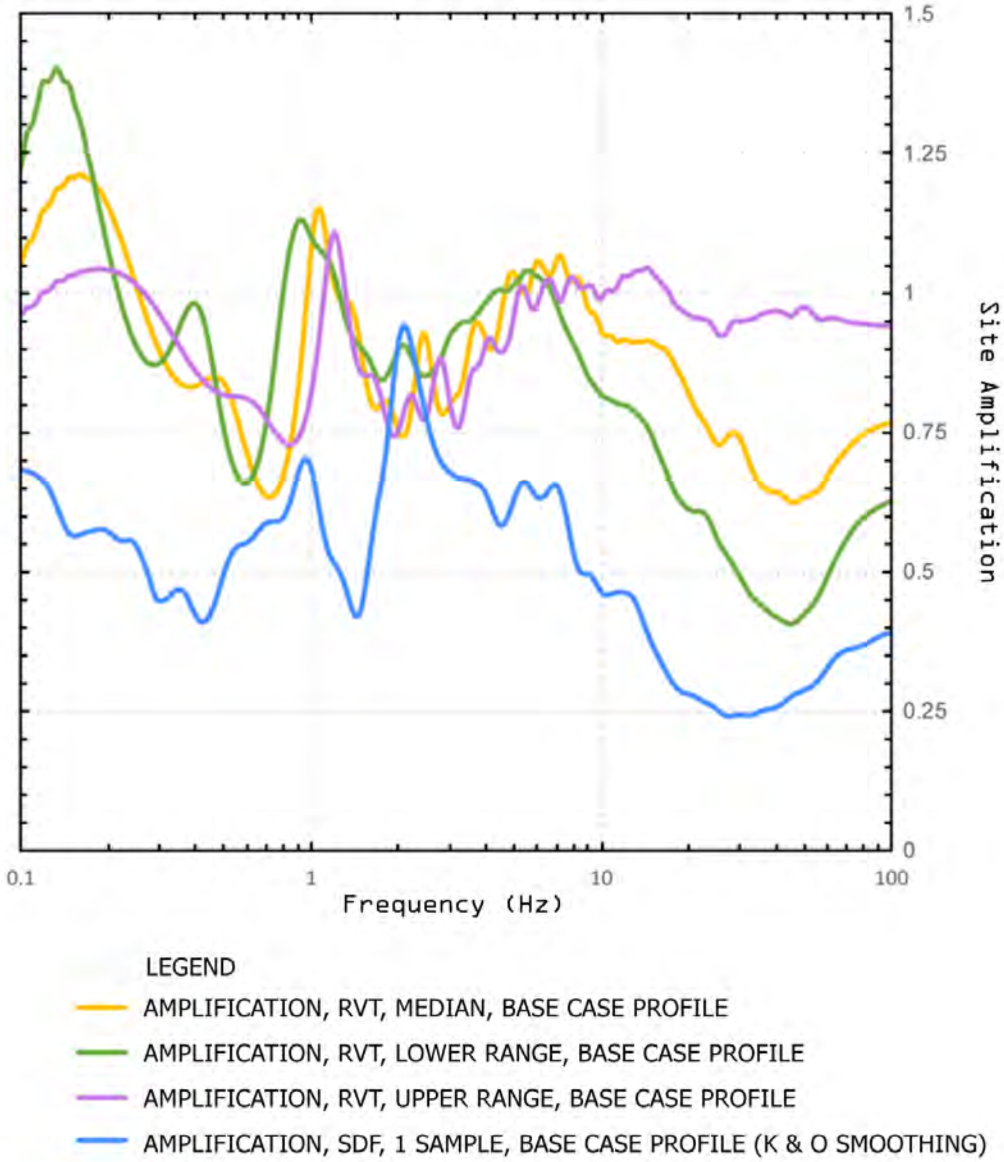
Figure 2.5.2-108. Comparison of 1D (Base-Case, Upper-, Lower-Range Profiles) and

2D Amplification Factors (PSA, 5% Damping) for Location A



Reference 2.5.2-210, Figure 3

Figure 2.5.2-109. Comparison of 1D (Base-Case Profile) and 2D Amplification Factors (PSA, 5% Damping) for Location B



Reference 2.5.2-210, Figure 4

Figure 2.5.2-110. Comparison of 1D (Base-Case, Upper-, Lower-Range Profiles) and 2D Amplification Factors (PSA, 5% Damping) for Location B