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

Subject: Duke Energy Carolinas, LLC
William States Lee III Nuclear Station - Docket Nos. 52-018 and 52-019
AP1000 Combined License Application for the
William States Lee III Nuclear Station Units 1 and 2
Response to Request for Additional Information
(RAI No. 3621)
Ltr# WL12010.03-04

Reference: Letter from Brian Hughes (NRC) to Peter Hastings (Duke Energy), Request for Additional Information Letter No. 076 Related to SRP Section: 02.05.02 – Vibratory Ground Motion for the William States Lee III Units 1 and 2 Combined License Application, dated November 3, 2009

This letter provides the Duke Energy response to the Nuclear Regulatory Commission's request for additional information (RAI) included in the referenced letter.

The response to the NRC information request described in the referenced letter is addressed in a separate enclosure, which also identifies associated changes, when appropriate, that will be made in a future revision of the Final Safety Analysis Report for the Lee Nuclear Station.

If you have any questions or need any additional information, please contact Peter S. Hastings, Nuclear Plant Development Licensing Manager, at 980-373-7820.

Bryan J. Dolan

Bryan J. Dolan
Vice President
Nuclear Plant Development

D093
NRO

Enclosure:

1) Duke Energy Response to Request for Additional Information Letter 076, RAI 02.05.02-049

AFFIDAVIT OF BRYAN J. DOLAN

Bryan J. Dolan, being duly sworn, states that he is Vice President, Nuclear Plant Development, Duke Energy Carolinas, LLC, that he is authorized on the part of said Company to sign and file with the U. S. Nuclear Regulatory Commission this supplement to the combined license application for the William States Lee III Nuclear Station and that all the matter and facts set forth herein are true and correct to the best of his knowledge.

Bryan J. Dolan

Bryan J. Dolan

Subscribed and sworn to me on March 12, 2010

Phoebe P. Elliott

Notary Public

My commission expires: June 26, 2011

SEAL

xc (w/o enclosure):

Loren Plisco, Deputy Regional Administrator, Region II
Stephanie Coffin, Branch Chief, DNRL

xc (w/ enclosure):

Brian Hughes, Senior Project Manager, DNRL

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 076

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.02-049**

NRC RAI:

The response to RAIs 1292-4547 and 777-2507 indicated that since the volume of material under the northwest corner of the nuclear island is less than 3% of the total volume of the material beneath the Lee Unit 1, it does not require additional site response calculations. However, the staff is concerned about potential, localized, high-frequency amplification at the northwest corner. The staff performed initial confirmatory site response analysis using a modified subsurface profile B that included 21 ft of concrete replacing the upper part of the subsurface material for the northwest corner of the nuclear island. The staff's analysis found that between the frequencies of 20 and 30 Hz, the Foundation Input Response Spectrum (FIRS) at the northwest corner is about 20% higher than the WEC generic hard rock spectrum. Please comment on the significance of this high frequency exceedance.

Duke Energy Response:

The horizontal design response spectra described in this response serve as a site response sensitivity evaluation of the localized rock properties beneath the Lee Nuclear Station (Lee) Unit 1 northwest corner, and are intended to demonstrate the adequacy of Foundation Input Response Spectra Base Case Profile A1 (FIRS A1) at Lee Unit 1.

To conservatively estimate the potential effects of a two-dimensional wedge of material reflecting a maximum thickness of approximately 50 ft and an average shear-wave velocity of approximately 7,000 ft/sec (geometric mean) on the Unit 1 FIRS (FSAR Subsection 2.5.2.7), Duke performed a series of one-dimensional horizontal component site response analyses. In total, seven one-dimensional analyses are evaluated in this sensitivity evaluation. Six dynamic profiles (profiles B3-1 through B3-6) are developed using the modeled northwest corner geometry described in Duke Energy response to RAI 03.07.01-001 (Reference 1), and seismic velocity profiles illustrated in Smoothed Velocity Profile B (FSAR Figure 2.5.4-249) and Dynamic Profile - Base Case A1 (FSAR Figure 2.5.4-252). The seventh profile is Base Case A1 (FSAR Figure 2.5.4-252).

As illustrated in Figure 1 (green-shaded area), the plan view dimensions of the northwest corner are 56 ft in the east-west direction (cross section line U-U', FSAR Figure 2.5.4-245) and 61 ft in the north-south direction (along cross section line V-V', FSAR Figure 2.5.4-246). This triangular shape approximates an isosceles triangle; in consideration of this negligible difference in shape the site response sensitivity results would be similar in either direction. Therefore, the sensitivity analysis is conducted in the east-west direction.

For the analyses, the two-dimensional wedge of material reflecting shear-wave velocities lower than that of the reference hard rock value of approximately 9,300 ft/sec (2.83 km/sec; EPRI, 2004 (FSAR Reference 2.5.2-202)) was approximated with a series of one-dimensional slices.

The one-dimensional slices were taken along the plant east-west line (Figure 1) which reflects the thickness of the low velocity material across the wedge (Figure 2). The geometry of the wedge is discussed in detail in Duke Energy response to RAI 03.07.01-001 (Reference 1). The cross-section and profile locations are summarized in Figure 1, while Figure 2 shows the base-case shear-wave velocity profiles estimated at each profile location. As Figure 2 illustrates, profile location B3-2 is at the edge of the wedge material and is identical to the Unit 1 profile A1 (FSAR Figure 2.5.4-252) with approximately 20.5 ft of fill concrete with an engineered shear-wave velocity of 7,500 ft/sec overlying hard rock with a shear-wave velocity of approximately 9,300 ft/sec.

It is important to point out that the northwest corner wedge in its entirety underlies a maximum horizontal extent of about 61 ft of the nuclear island in the plant north-south and east-west directions and about only 41 ft diagonally (Figure 1). As Figure 2 and Figure 3 illustrate, the thickness of the material with shear-wave velocities of 5,348 ft/sec, less than that of the overlying fill concrete, has a maximum thickness of about 20 ft. The remainder of the wedge material which underlies the lowest velocity rock consists of a layer of relatively uniform thickness of about 10 ft with a shear-wave velocity of 7,575 ft/sec, near that of the fill concrete. Underlying that material is hard rock with a shear-wave velocity of 8,645 ft/sec, approaching that of the underlying reference hard rock at approximately 9,300 ft/sec (EPRI, 2004; FSAR Figure 2.5.4-249).

With this velocity structure, the increased amplification at the surface of the fill concrete at locations over the wedge material is largely generated by the top two rock layers with shear-wave velocities of 5,348 ft/sec and 7,575 ft/sec and maximum thicknesses of about 20 ft and 10 ft, respectively. These two layers along with the overlying concrete fill are expected to control the one-dimensional amplification at locations along the surface of the fill concrete above the wedge (Figure 1). These locations are shown schematically on Figure 2 at B3-3, B3-6, B3-1, and 6 ft beyond the edge of the nuclear island location, B3-4. At location B3-5, the vertical extent of the lowest velocity wedge material has increased from zero at B3-2 to about 10 ft (Figure 2 and Figure 3), reaching a thickness at which one-dimensional analyses would result in some degree of amplification over a frequency range of significance to structures, systems, and components. As a result, the maximum horizontal extent of the wedge in the plant north-south and east-west directions which may impact the nuclear island is effectively reduced from about 60 ft to about 50 ft in Figure 3 and substantially less measured diagonally from the corner of the nuclear island (Figure 1).

Due to the fundamentally two-dimensional nature of the low velocity wedge and its limited lateral extent, site response analyses assuming a one-dimensional approximation and vertical wave propagation are considered to result in a conservative estimate of expected amplification. The one-dimensional analyses implicitly assume infinite lateral extent of the profile which allows the full impact of resonances or superposition of multiple reflected waves to constructively interfere at the surface. Additionally, vertically propagating waves result in the maximum one-dimensional amplification and waves with inclined incidence develop less amplification. Due to the very high shear-wave velocity of the reference rock, depending on earthquake source distance and depth, the assumption of normal incidence reflects an unquantified degree of conservatism in predicted amplification.

As a result of the assumptions of one-dimensional site response analyses and vertically propagating shear-waves, the amplification computed for the profiles in Figure 3 reflecting the wedge slices depicted in Figure 2 are considered to represent a conservative approximation to the actual motions which may be experienced at the northwest corner of the Unit 1 nuclear island. For each location, the median one-dimensional amplification is shown in Figure 4 along with a listing of the maximum amplification and its associated frequency. For profiles B3-1 to B3-6, with the exception of B3-2 (which is the same as profile A1 presented in FSAR Figure 2.5.4-252), the maximum median amplification is about 1.3 and occurs near 30 Hz. Profile B3-5, reflects the minimum thickness of the low velocity rock (5,348 ft/sec, Figure 2 and Figure 3), results in the lowest median amplification and the highest maximum amplification frequency, as expected. Profile B3-2, FIRS A1 (FSAR Figure 2.5.2-244) reflects only the effects of the fill concrete. To conservatively estimate the potential hazard at the surface of the fill concrete over the portion of the nuclear island underlain by the three-dimensional wedge of low velocity material (green triangle in Figure 1), equal weight (0.5) was given to the hazard computed for profile B3-2 and equal weight (0.5) to the hazard computed for the wedge profiles (B3-1, B3-3, B3-4, B3-5, and B3-6). Specifically the hazard computed for each wedge profile was given a weight of 0.1 for a combined relative weight of 0.5.

While there is no definitive analytical rationale for assessing the appropriate weights for approximating the effects of a two-dimensional wedge with one-dimensional analyses, the two-dimensional alluvial valley analyses of Bard and Gariel (1986) (Reference 2) provide some guidance. In their analyses of valley edge sites, which approximates the Unit 1 two-dimensional wedge (Figure 2), Bard and Gariel (1986) show that amplifications from the one-dimensional analyses exceeded the amplifications of the two-dimensional analyses for a dipping layer of wedge material of uniform velocity overlying material of higher velocity. This is especially the case for a low impedance contrast between the low velocity wedge material and the underlying basement material (e.g. Valley C; Figure 11 and Figure 14 from Bard and Gariel, 1986). In this case the one-dimensional analyses are predicted to exceed the two-dimensional analyses across the dipping interface or wedge, even at the location where the dip decreases to horizontal. These results suggest that averaging the one-dimensional amplification at sites across the wedge results in a conservative estimate of amplification for any site along the wedge. Averaging the hazard over exceedance frequency is necessary to maintain the desired exceedance frequency and likely results in additional conservatism in this application of approximating two-dimensional hazard with one-dimensional analyses.

A hard rock kappa value of 0.006 sec was used, consistent with that incorporated in the hard rock attenuation relations (EPRI, 2004) (FSAR Reference 2.5.2-202). With a hysteretic damping in concrete between 0.5% and 1.0% any additional damping in the shallow concrete profile and firm rock profiles, with Q_S values at or exceeding 25 (Silva and Darragh, 1995) (Reference 3) and total thickness less than about 50 ft (Figure 2), is neglected as its impacts on amplification will occur at frequencies greater than 50 Hz, which is beyond the frequency range of structural interest.

For the northwest corner analyses, each profile depth to the hard rock (9,300 ft/sec, 2.83 km/sec) was randomized ± 3 ft using a uniform distribution. The concrete and shallow rock velocities were randomized with a coefficient of variability (COV) of 0.1 about the base-case velocities. This is a smaller COV than observed for typical generic rock conditions which have COV estimates in the range of 0.25 to 0.35 and is appropriate for rock conditions covering a wide region (Silva et al., 1996 (FSAR Reference 2.5.2-288)). The restricted aleatory variability for the northwest corner analyses accommodates the very restricted region of the Unit 1 nuclear island and reflects the controlled placement of fill concrete as part of the construction Quality Assurance Program. Furthermore, the COV of 0.1 is consistent with that used for the fill concrete overlying the hard rock of the nuclear island (FSAR 2.5.2.7). To complete the analyses, the fully probabilistic Approach 3 (Reference 4) was used to develop hazard curves for each profile B3-1 to B3-6 and, finally, to calculate horizontal component design response spectra (DRS) at annual exceedance frequency (AEF) of 10^{-4} (FSAR Subsection 2.5.2.7.4; FSAR Figure 2.5.2-247). The full suite of DRS along with the weighted average (over exceedance frequency) are shown in Figure 5a and Figure 5b in both logarithmic (Figure 5a) and linear (Figure 5b) spectral acceleration (Sa) axes. Near 30 Hz, the DRS reflecting the one-dimensional approximation to the two-dimensional wedge (profiles B3-1 to B3-6) exceed the A1 FIRS (FSAR Figure 2.5.2-244) by about 20%. The weighted DRS, reflecting a conservative estimate of the motion on the nuclear island above the wedge (Figure 1), exceed the Unit 1 FIRS by about 10% near 30 Hz.

Finally, the weighted DRS and the Unit 1 FIRS are compared to the WEC hard rock horizontal spectrum in Figure 6a (logarithmic spectral acceleration (Sa) axes) and Figure 6b (linear spectral acceleration (Sa) axes). The weighted DRS very slightly exceeds (by a few percent) the WEC hard rock spectrum for frequencies between 30 and 40 Hz. Due to the conservatism inherent in the one-dimensional approximation of the two-dimensional wedge, which very likely exceeds a few percent (Valleys A and B in Figure 14 of Bard and Gariel, 1986), the design spectra for the northwest corner of Unit 1 are considered to be accommodated by the WEC hard rock spectrum and demonstrate the adequacy of FIRS A1 at the Lee Unit 1.

References:

1. Letter from Bryan J. Dolan (Duke Energy) to Document Control Desk, U.S. Nuclear Regulatory Commission, Response to Request for Additional Information (RAI Nos. 1003 and 1004), Ltr# WLG2008.12-25, dated December 17, 2008.
2. Bard, P.Y. and J. Gariel (1986). "The seismic response of two-dimensional sedimentary deposits with large vertical velocity gradients." Bulletin of the Seismological Society America, 76, 343-346.
3. Silva, W.J. and Darragh, R.B. (1995). "Engineering characterization of earthquake strong ground motion recorded at rock sites." Electronic Power Research Institute, Palo Alto, California; TR-102262.
4. Letter from Bryan J. Dolan (Duke Energy) to Document Control Desk, U.S. Nuclear Regulatory Commission, Transmittal of Unit 1 Foundation Input Response Spectra (FIRS) Horizontal and Vertical Component Analysis, Ltr# WLG2010.02-01, dated February 22, 2010.

Associated Revision to the Lee Nuclear Station Supplemental Technical Report:

None

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

None

Attachments:

1) Figure 1. Lee Unit 1 Northwest Corner Dynamic Profile Base Case Locations Used in Sensitivity Analysis
2) Figure 2. Lee Unit 1 Northwest Corner Shear-Wave Velocity Model, East-West Transect along Section U-U'
3) Figure 3. Lee Unit 1 Northwest Corner Analysis Shear-Wave Velocity Profiles
4) Figure 4. Lee Unit 1 Northwest Corner Median Horizontal Amplification Factors (Relative to Hard Rock)
5) Figure 5a. Horizontal Design Response Spectra (DRS) Computed for Lee Unit 1 Northwest Corner (Profiles Reflect Results from 1D Slices) (Logarithmic Sa axes)
6) Figure 5b. Horizontal Design Response Spectra (DRS) Computed for Lee Unit 1 Northwest Corner (Profiles Reflect Results from 1D Slices) (Linear Sa axes)
7) Figure 6a. Comparison of the Weighted Northwest Corner Horizontal Design Response Spectra with the Lee Unit 1 Horizontal FIRS (FSAR Figure 2.5.2-244) and the WEC Generic Hard Rock Horizontal Design Spectrum (Logarithmic Sa Axes)
8) Figure 6b. Comparison of the Weighted Northwest Corner Horizontal Design Response Spectra with the Lee Unit 1 Horizontal FIRS (FSAR Figure 2.5.2-244) and the WEC Generic Hard Rock Horizontal Design Spectrum (Linear Sa axes)

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.02-049

Figure 1. Lee Unit 1 Northwest Corner
Dynamic Profile Base Case Locations Used in Sensitivity Analysis

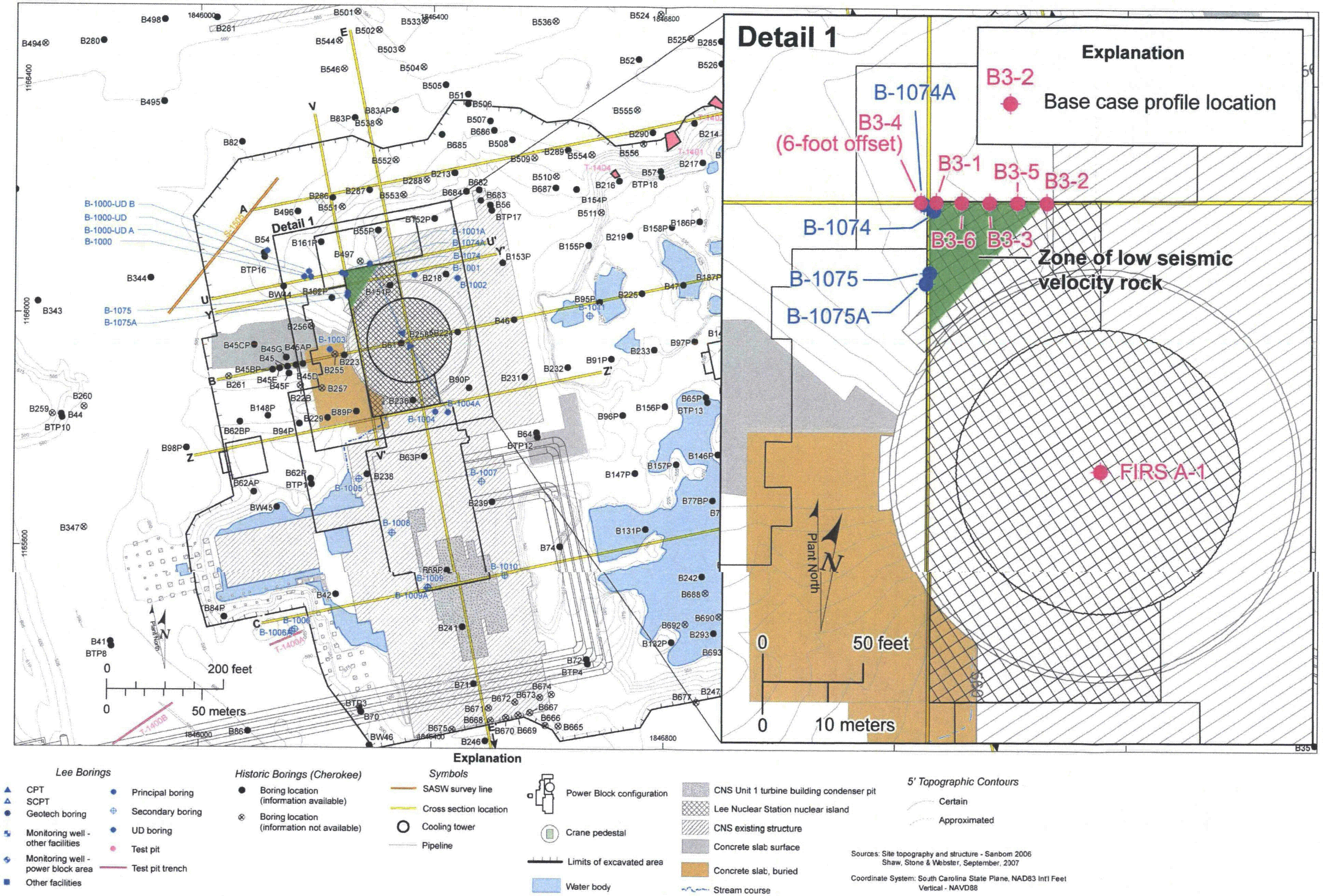

Figure 1. Lee Unit 1 Northwest Corner, Dynamic Profile Base Case Locations Used in Sensitivity Analysis

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.02-049

Figure 1. Lee Unit 1 Northwest Corner
Dynamic Profile Base Case Locations Used in Sensitivity Analysis

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.05.02-049

Figure 2. Lee Unit 1 Northwest Corner
Shear-Wave Velocity Model, East-West Transect along Section U-U'

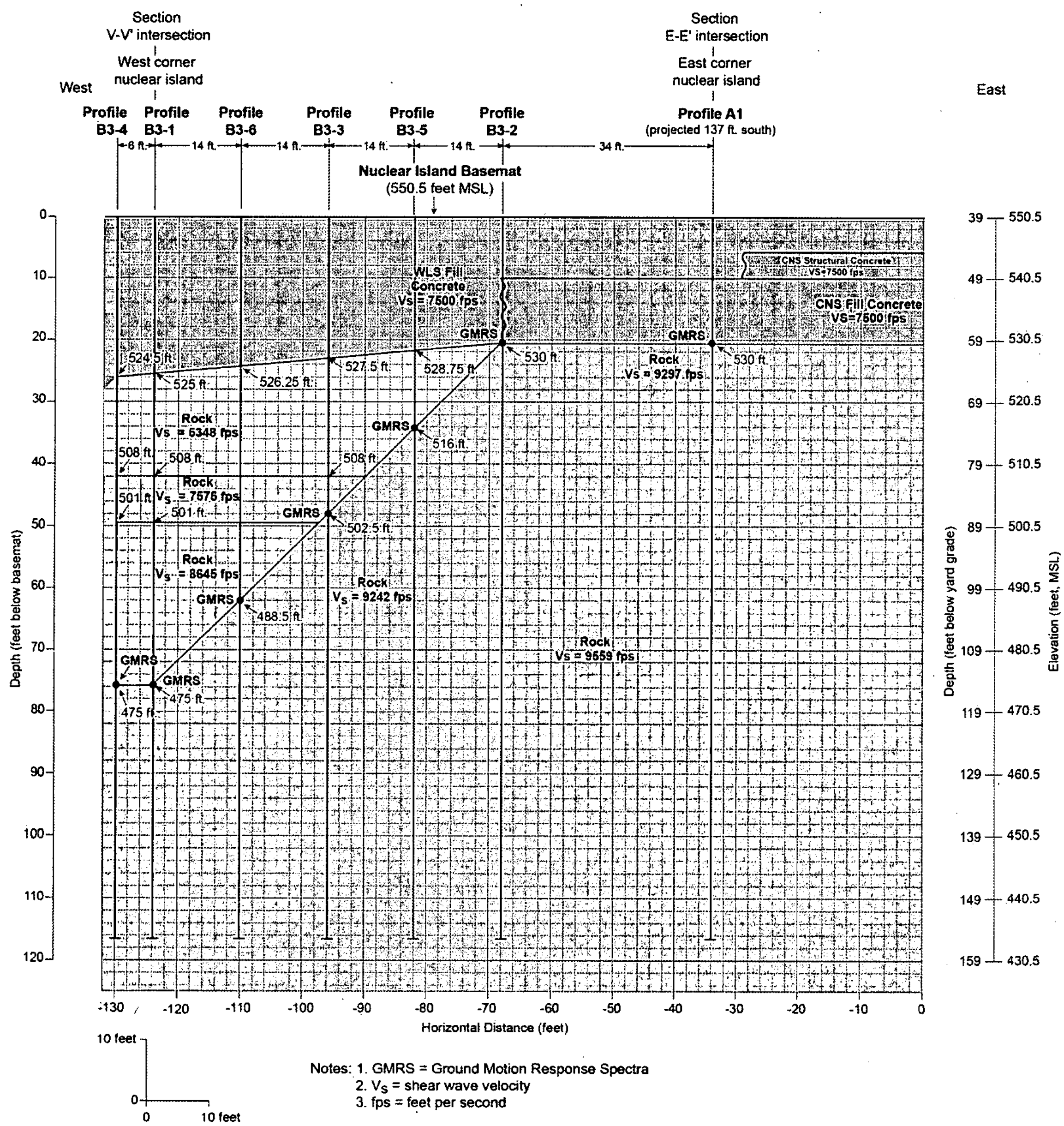

Figure 2. Lee Unit 1 Northwest Corner Shear-Wave Velocity Model, East-West Transect along Section U-U'.

Cross-section of the northwest corner of Unit 1 illustrating the wedge of material between hard rock with a shear-wave velocity of approximately 9,300 ft/sec and below the fill concrete with an engineered shear-wave velocity of 7,500 ft/sec. Representative 1D velocity profiles are at locations B3-1, B3-3, B3-4, B3-5, and B3-6. B3-2 reflects the edge of the wedge and is identical to the Unit 1 A1 profile (FSAR Figure 2.5.4-252).

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.05.02-049

Figure 3. Lee Unit 1 Northwest Corner
Analysis Shear-Wave Velocity Profiles

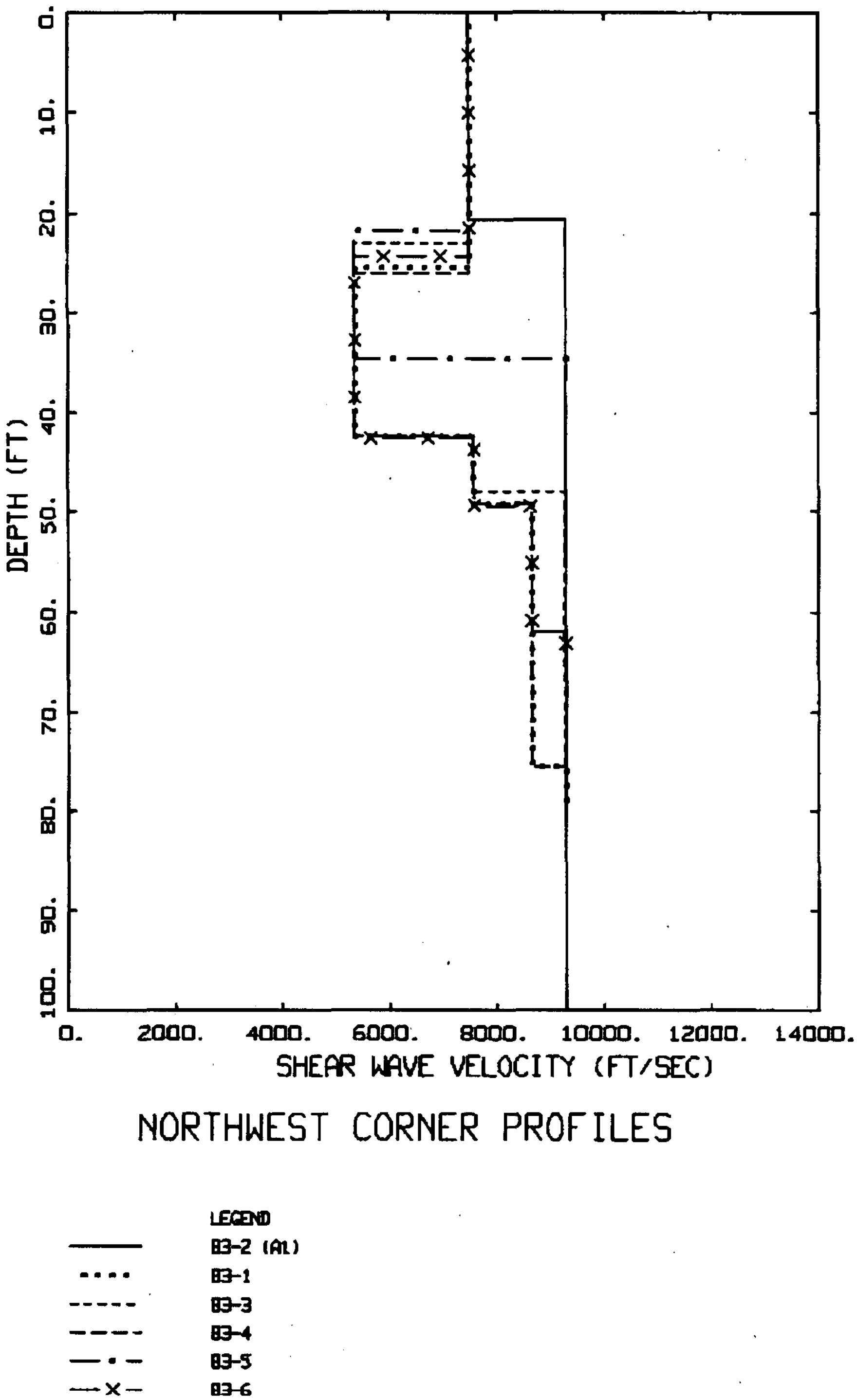

Figure 3. Unit 1 Northwest Corner Analysis Shear-Wave Velocity Profiles.

The locations of the profiles are illustrated in Figure 1. Profile B3-2 reflects the edge of the wedge material and is identical to the Unit 1 Profile A1 (FSAR Figure 2.5.4-252).

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 4 to RAI 02.05.02-049

Figure 4. Lee Unit 1 Northwest Corner
Median Horizontal Amplification Factors (Relative to Hard Rock)

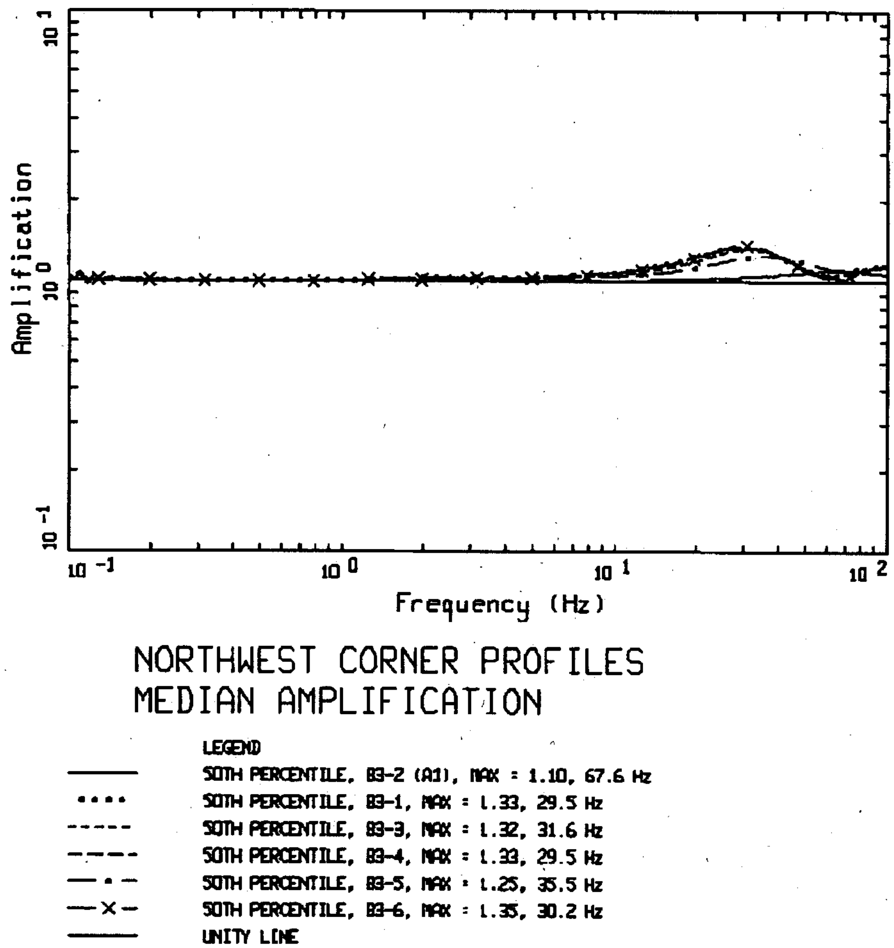

Figure 4. Lee Unit 1 Northwest Corner Median Horizontal Amplification Factors (Relative to Hard Rock).

The locations of the profiles are illustrated in Figure 2 and the analyzed shear-wave velocity profiles are shown in Figure 3. Median amplification for Profile B3-2 reflects the edge of the wedge material and is identical to the Unit 1 Profile A1 (FSAR Figure 2.5.4-252) and Unit 1 amplification (FSAR Figure 2.5.2-241).

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 5 to RAI 02.05.02-049

**Figure 5a. Horizontal Design Response Spectra (DRS)
Computed for Lee Unit 1 Northwest Corner
(Profiles Reflect Results from 1D Slices) (Logarithmic Sa axes)**

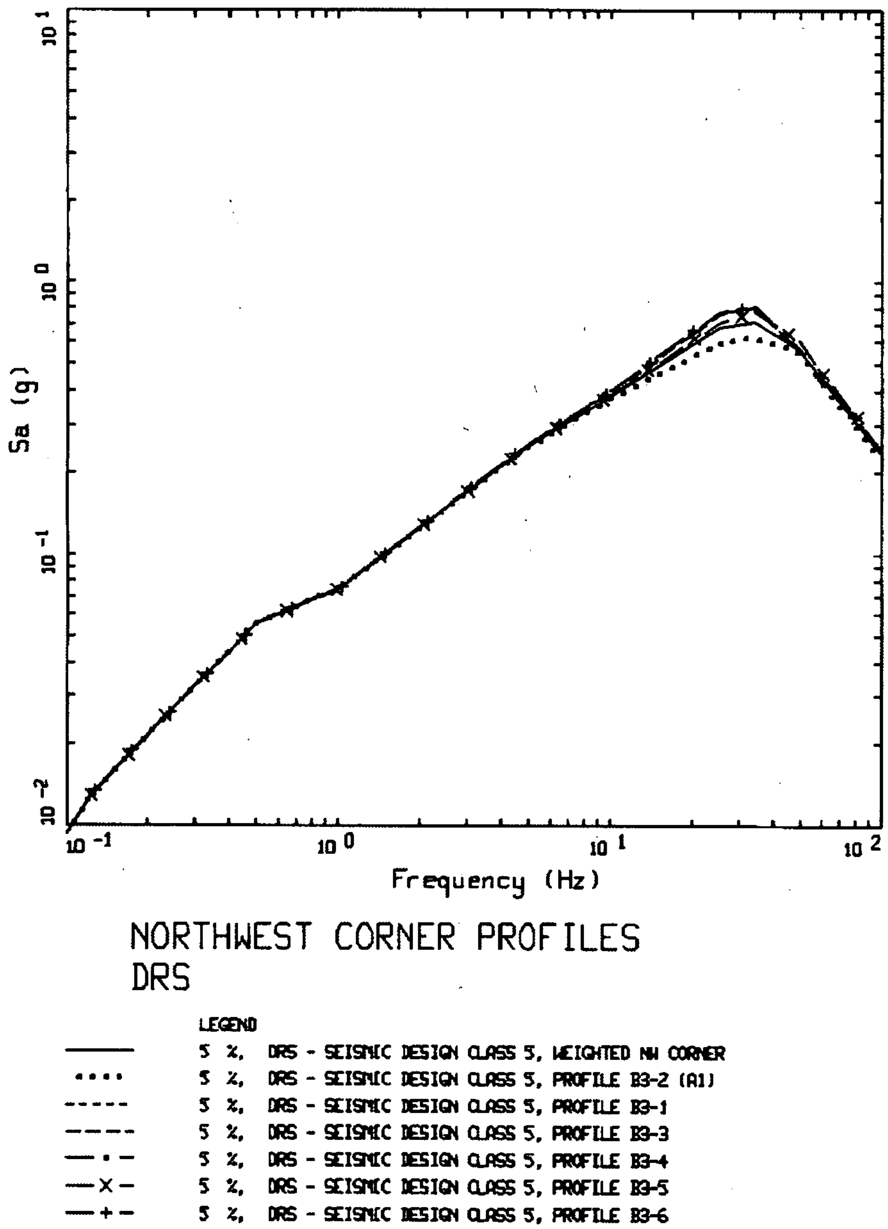

Figure 5a. Horizontal Design Response Spectra (DRS) Computed for Lee Unit 1 Northwest Corner (Profiles Reflect Results from 1D Slices).

The DRS for each 1D profile is shown along with the weighted average (over exceedance frequency) compared to the Lee Unit 1 horizontal FIRS (Profile A1) based on Profile B3-2. (Logarithmic Sa axes).

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 6 to RAI 02.05.02-049

Figure 5b. Horizontal Design Response Spectra (DRS) Computed for Lee Unit 1 Northwest Corner (Profiles Reflect Results from 1D Slices) (Linear Sa axes)

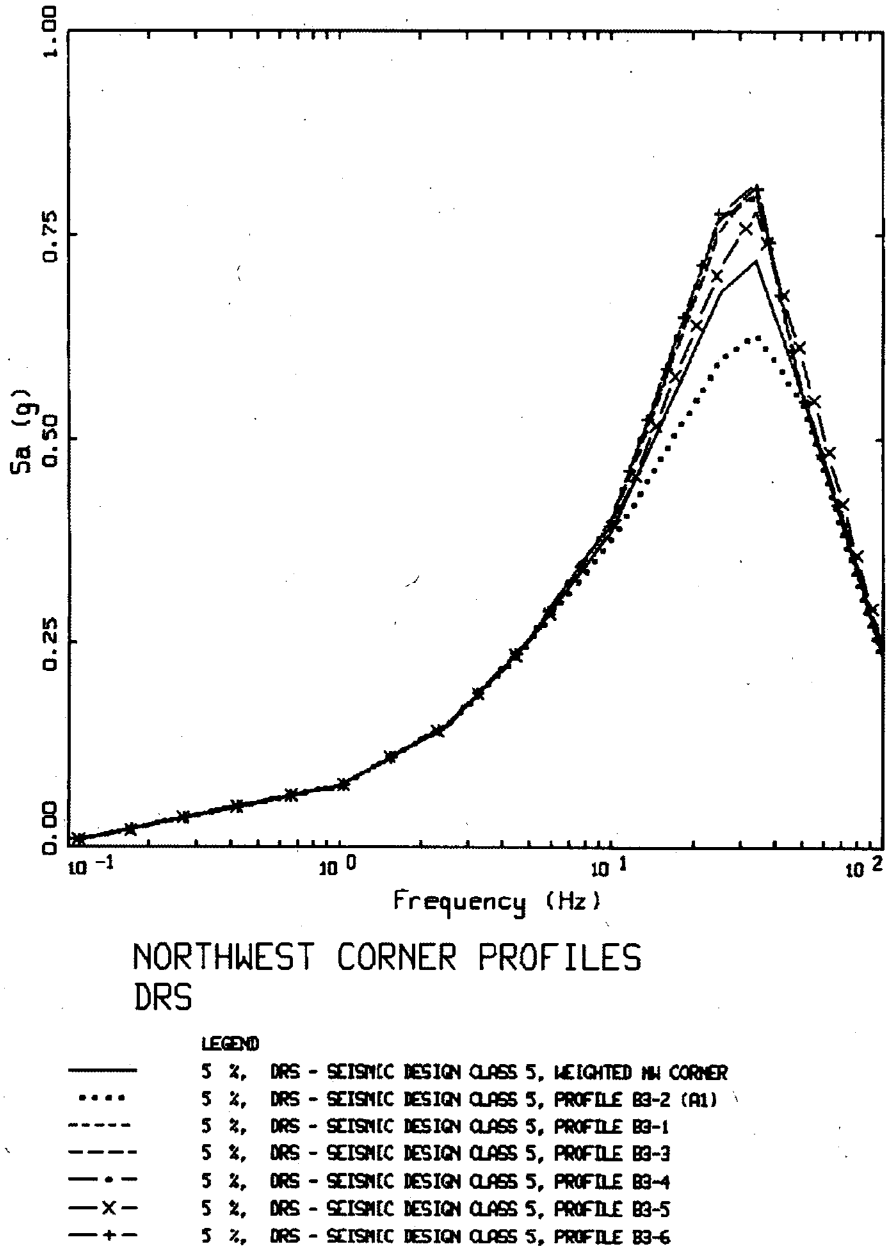

Figure 5b. Horizontal Design Response Spectra (DRS) Computed for Lee Unit 1 Northwest Corner (Profiles Reflect Results from 1D Slices).

The DRS for each 1D profile is shown along with the weighted average (over exceedance frequency) compared to the Lee Unit 1 horizontal FIRS (Profile A1) based on Profile B3-2. (Linear Sa axes).

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 7 to RAI 02.05.02-049

Figure 6a. Comparison of the Weighted Northwest Corner Horizontal Design Response Spectra with the Lee Unit 1 Horizontal FIRS (FSAR Figure 2.5.2-244) and the WEC Generic Hard Rock Horizontal Design Spectrum (Logarithmic Sa Axes)

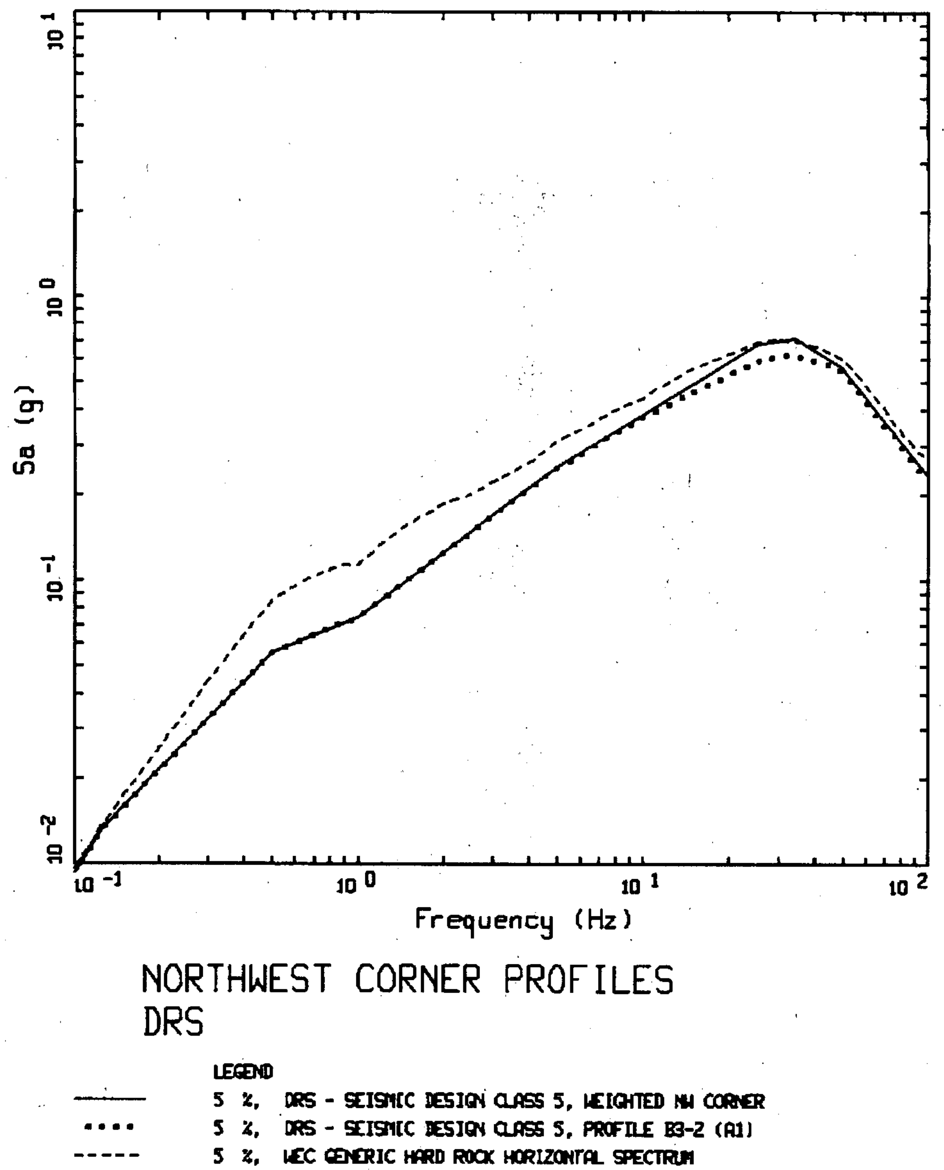

Figure 6a. Comparison of the Weighted Northwest Corner Horizontal Design Response Spectra (DRS) with the Lee Unit 1 Horizontal FIRS (FSAR Figure 2.5.2-244) and the WEC Generic Hard Rock Horizontal Design Spectrum (Logarithmic Sa Axes).

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 8 to RAI 02.05.02-049

Figure 6b. Comparison of the Weighted Northwest Corner Horizontal Design Response Spectra with the Lee Unit 1 Horizontal FIRS (FSAR Figure 2.5.2-244) and the WEC Generic Hard Rock Horizontal Design Spectrum (Linear Sa axes)

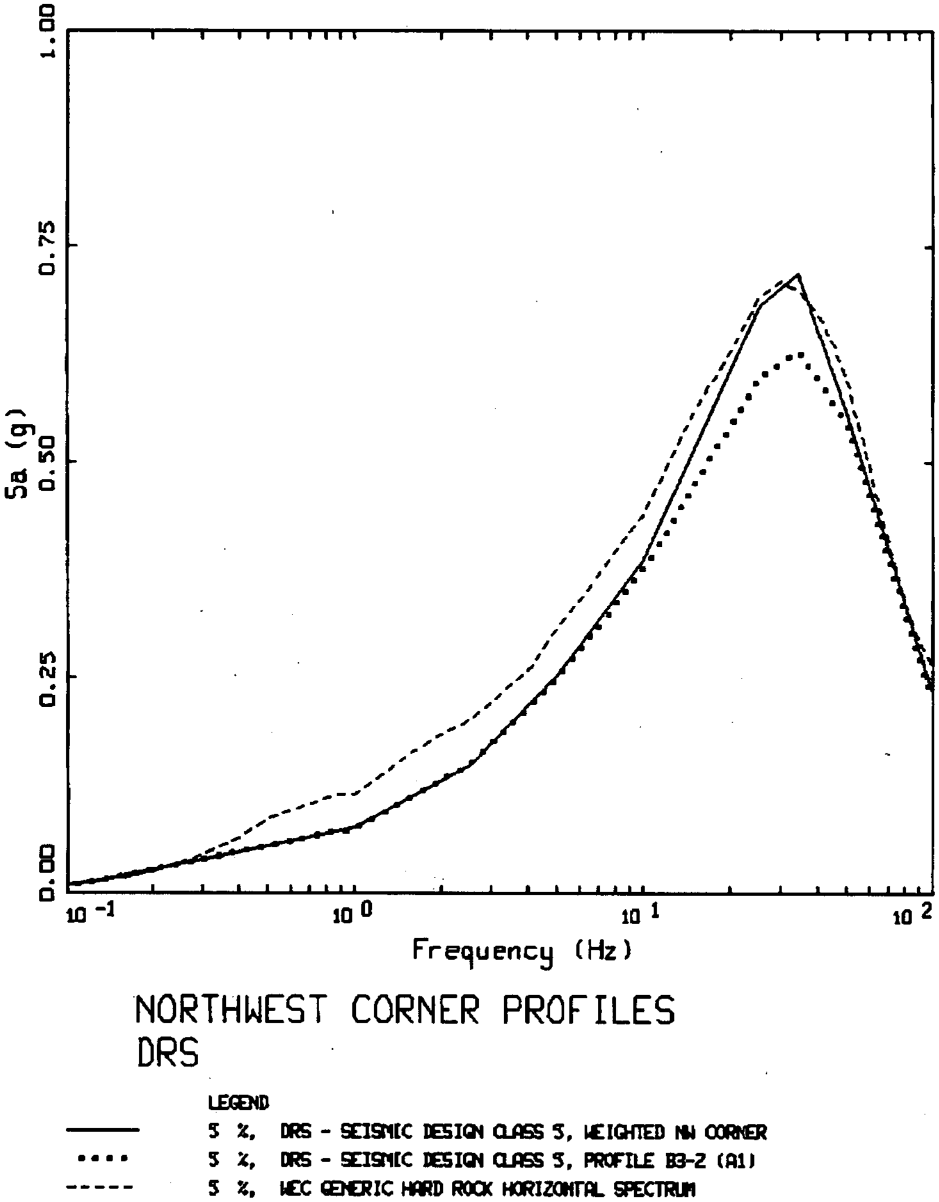

Figure 6b. Comparison of the Weighted Northwest Corner Horizontal Design Response Spectra (DRS) with the Lee Unit 1 Horizontal FIRS (FSAR Figure 2.5.2-244) and the WEC Generic Hard Rock Horizontal Design Spectrum (Linear Sa Axes).