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Task Order No. 6, Review of the Calvert Cliffs Application for Combined Operating License in the Areas Relating to Geology and Seismology
TAC No. RX0105
UniStar Nuclear Energy

USGS Reviews of Responses to Supplemental RAIs for Calvert Cliffs, Maryland site, Submitted February 15, 2011.

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This report contains the reviews of the U.S. Geological Survey (USGS) and its subcontractor (the University of Memphis) of the applicant's responses to several supplemental requests for additional information (RAIs). The Nuclear Regulatory Commission (NRC) sent the supplemental RAIs for seismology to the applicant as RAI 216, which contains several individual RAIs, in an email dated February 23, 2010. The supplemental RAIs for geology were sent as RAI 219 in a second email dated March 20, 2010.

On March 25, 2010, the applicant returned the seismology responses to RAI 216, Questions 02.05.02–15 through 21, as the applicant's document UN#10–075. On May 19, 2010, the applicant returned the geology responses to RAI 219, Questions 02.05.01–66 through 69, as the applicant's document UN#10–129.

Each RAI is repeated verbatim below, immediately following the RAI number and the question number. The first sentence of each of our response reviews places the response into one of three categories, according to our judgment of the importance of the requested information and the quality of the response:

(1) No additional information is needed (nine of the eleven responses);
(2) The COLA should be modified as recommended in the review to make the COLA's discussion of this topic scientifically convincing (two responses); or
(3) The COLA must be modified as recommended in the review to provide the foundation on which NRC can make a credible safety finding (no responses).

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Section 02.05.01: Basic Geologic and Seismic Information

RAI 219, QUESTION 02.05.01–66

"FSAR, Section 2.5.1.1.4.4.4.5, Hillville fault zone, refers to seismic reflection data to support the presence of the Hillville fault, within 5 miles of CCNPP. In RAI 02.05.01–18, the NRC staff asked for a copy of the seismic line St M–1 and asked about the fault possibly being captured in the extensive marine seismic data taken in the Chesapeake Bay, to the east of the land-based seismic reflection line.

"You responded by providing a segment of the seismic reflection line and an enlarged figure of the LiDAR data. You stated that the fault is seen on the St M–1 seismic reflection data but was not interpreted on the marine seismic reflection in the Chesapeake Bay. The fault is projected to the NE (placing the reflection profile west-southwest of CCNPP) based on coincidence with an aeromagnetic anomaly. In addition, a structure contour map published by the MD Geological Survey does not show offset on a regional recognized stratigraphic marker, the top of the Piney Point-Nanjemoy Aquifer.

"In your response, you stated that you plan no change to the FSAR. Please justify why the response figures and associated discussions should not be a part of the revised FSAR."

USGS review:
The COLA should be modified as recommended in the last paragraph of this review to make the COLA's discussion of this topic scientifically convincing.

Nearly all of the requested information has been provided. Below we argue that when this information is combined with other cited evidence that is already in the FSAR, together they make a sound case against young activity of a northeast-trending fault system as large as the one interpreted in the seismic-reflection profile. The young activity would be since the late Miocene (5.3–10.6 Ma: Gradstein, F., Ogg, J., and Smith, A., eds., 2004, A geologic time scale 2004: Cambridge, United Kingdom, Cambridge University Press, 589 p., folded plate).

Specifically, the new Figure 2.5–305 shows the requested seismic-reflection profile. It is southwest of the site, on the southwest side of the Patuxent River, and the profile trends northwest. The interpreted profile shows the Hillville fault zone in the form of a graben that offsets the top of basement approximately 250 ft vertically. The interpreted graben is roughly 3.3 mi wide. The interpretation of the reflection profile shows that the graben faults were active as recently as the Cretaceous Period.

The applicant provides four additional kinds of information that would reinforce the case against recent activity if the additional information were integrated better with the discussion of profile St M-1.

(1) The enlarged LiDAR image that replaces the original Figure 2.5–26 shows clearly the absence of any strong surface expression of the Hillville fault.

(2) That applicant reports that, closer to the site and on the northeast side of the Patuxent River, the elevations of exposed geologic contacts above the graben do not differ recognizably from elevations on either side of the graben. Figures 2.5–32 and 2.5–33 show two cross sections named AA' and BB' that trend at high angles to the graben and parallel to the reflection profile St M–1. AA' shows that the graben is centered near Island Creek. The 3.3-mi width of the graben indicates that it occupies about half the length of section AA'. At ground level above the

graben, AA' shows that the contact between undifferentiated upland deposits and the underlying St. Marys Formation is preserved and mapped on ten hills and ridges.

The section's depiction of the elevations of the contact in these ten exposures and in the nearby exposures outside the graben indicates to us that any elevation difference larger than about 40 ft (12 m) between adjacent exposures should have been revealed by the mapping of the contact. No such elevation difference is shown in the cross section. The top of the St. Marys Formation is of late Miocene age (http://ngmdb.usgs.gov/Geolex/NewRefsmry/sumry_3942.html, accessed June 22, 2010). An upper limit of 40 ft (12 m) of vertical movement since the late Miocene implies an average vertical slip rate on the Hillville fault of no more than 10^{-3} mm/yr (about 10^{-5} in/yr), which we consider negligible for hazard-computation purposes.

Note that the seismic-reflection profile cannot constrain the amount of strike slip on the Hillville fault. However, even if the horizontal separation on the graben was several times as large as 40 ft (12 m), the three-dimensional separation would still be small. As noted earlier in (1), no strong LiDAR signature was seen. We do not know of any data that might characterize the amount of possible strike slip.

(3) At and near the site, a structure contour map made from well logs shows elevations of the top of the middle Eocene Nanjemoy Formation (Figure 2.5–14). The Nanjemoy Formation is approximately 40 million years old. One well location is shown near the Hillville fault. The well penetrated the top of the Nanjemoy Formation at an elevation of -165 ft. The structure contours were drawn with a 50-ft contour interval. As noted earlier, the interpretation of the reflection profile implies that the graben has a structural relief of about 250 ft at the top of basement. The spacing and shapes of the structure contours near the Hillville fault preclude the existence of a graben several miles wide with a structural relief as small as 100 ft at the Nanjemoy stratigraphic level. The contours make structural relief as small as 50 ft improbable. Thus, the structure contours restrict any late Eocene or younger faulting to have been less than about one-fifth of the vertical offset of the basement. Additionally, the late Eocene top of the Nanjemoy Formation is approximately four to eight times as old as the late Miocene top of the St. Marys Formation. The age difference implies that any slip rate calculated for the top of the Nanjemoy Formation would be very small.

(4) A detailed stratigraphic traverse along the sea cliffs at the site and several tens of miles farther northwest and southeast along the coast did not detect evidence of the Hillville fault (Figure 2.5–30; Kidwell, S.M., 1997, Anatomy of extremely thin marine sequences landward of a passive-margin hinge zone — Neogene Calvert Cliffs succession, Maryland, U.S.A.: Journal of Sedimentary Research, v. 67, no. 2, p. 322–340). Kidwell speculated a fault, but field investigations before and during the site audit showed that the evidence for a fault is better explained by a gentle, unfaulted warp like two that Kidwell reported. Pre-Pleistocene units exposed in the sea cliffs are as young as the St. Marys Formation of late Miocene age. The close spacing of the measured stratigraphic sections and their continuity across the projected location of the fault indicate that probably vertical offsets of approximately 30 ft would have been detected; none were reported. Thus, any post-late Miocene faulting has totalled about 30 ft or less of vertical movement. As explained earlier in (2), such slow accumulation of fault offset would pose negligible hazard.

The RAI requested several marine seismic-reflection profiles along the northeast projection of the Hillville fault beneath Chesapeake Bay. These profiles were not provided. The profiles are part of a bay-wide network (Figure 2.5–29A), but only four or five of the line segments are likely to cross the projection of the fault. The marine profiles are 1–10 mi offshore from Kidwell's onland stratigraphic traverse.

In summary, the evidence presented in the response and the FSAR demonstrates the absence of recognized evidence for recent activity on the Hillville fault, particularly if it has the inferred northeast strike. For completeness suitable for a scientific journal, the marine profiles should be provided. However, we judge that the amount and variety of information already presented by the applicant are sufficient to provide NRC with a sound foundation for a safety finding.

RAI 219, QUESTION 02.05.01–67

"In RAI 2.5.1–19 and –48, NRC staff asked for additional information about an unnamed fault in the northern portion of the Chesapeake Bay interpreted by Dr. F. Pazzaglia (Pazzaglia, 1993a, 1993b, 2006) (FSAR Subsection 2.5.1.1.4.4.4.6). You indicated that there was little evidence to support the existence of any fault.

"With regard to your RAI response, please address the following issues:

- "Older Coastal Plain units more widely exposed and mapped on the SE side of the fault (up thrown side) than on the NW side.
- "The LiDAR surface map provided in your response is inconclusive because an 8 m elevation difference across the fault would not show in Figure 6 at the scale presented. Furthermore, locating a fault that is 'coming ashore' would require examination all along the coast line at a large scale resolution (close in detail). Pazzaglia's dotted line is an approximation of the location of his interpreted fault. This also applies to examination of the bay bathymetry.
- "You argue that lack of elevation data for the base of the TP beds precludes corroborating Pazzaglia's 8 m offset. Pazzaglia made his correlation based on the elevation differences of more than one distinct unconformity in Coastal Plain units, both exposed and buried (examined in a trench dug into the Coudon Farm terrace, about 3 m deep).
- "Contrary to your assertion that soil profiles do not correlate across the bay, Pazzaglia does not attempt to correlate the soils located at Coudon's Farm terrace with Turkey Point soils. This is not the basis of his fault interpretation.
- "The marine seismic reflection data disclosing paleochannels of the Susquehanna River does not cover the specific area under discussion. However, you pointed out that there are paleochannel segments that are straight. This does not require that the straight eastern Chesapeake Bay coastline must be non-tectonic in origin.
- "The Susquehanna River channel takes a sharp turn to the south at its mouth or the head of the bay. This is also supported by the series of submarine paleochannels.
- "The bathymetric profile across the bay in Figure 4 indicates a smooth profile but the scale of presentation does not permit close examination of the profile. The offshore

location of the fault could be located just off shore from Turkey Point, in the thalweg channel of the Susquehanna River. Newell at al, 2004 interpreted recent river/deltaic deposits along the base of the bay, almost as far south as Annapolis. These deposits could mask a small surface expression of a submarine fault.

- “Sea cliffs on west-facing shorelines of the Elk Neck and Delmarva Peninsulas, along with all streams draining east indicating a tilted block.
- “The argument that there have not been subsequent, independent studies to Pazzaglia's does not in itself rule out a fault interpretation.
- “In response to RAI 48 b, Part 2, the applicant described the distinction between Higgins' and Pazzaglia's geologic mapping. Higgins' map (Figure 5a) is an earlier interpretation (Enclosure 1 of UN#10–129, page 11) that does not necessarily refute Pazzaglia's interpretation. NRC staff note that the differences are mostly a matter of breaking out subunits from formerly undifferentiated upland gravel deposits or reinterpreting an informal unit into a distinct stratigraphic formation. Southeast of the fault, Pazzaglia breaks out additional units, the Bryn Mawr and Perryville Formations, from Higgins' undifferentiated upland gravel unit. Northwest of the fault, Pazzaglia reinterprets Higgins' upland gravel as Pensauken Fm.

“Please provide a discussion about this potential fault that addresses the above issues.”

<u>USGS review:</u>
The COLA should be modified as recommended in the last three paragraphs of the review to make the COLA’s discussion of this topic scientifically convincing.

The thrust of this review is to explain that the response, as presently organized, does not make the most effective use of its two strongest arguments. We recommend that both arguments be summarized at the start of an otherwise unchanged response. Details of our recommendation follow.

The response addresses the ten bulleted items of the RAI more or less satisfactorily. The reason for this assessment is that in general it does not seem feasible to demonstrate the absence of a fault like the one that has been suggested by Pazzaglia to lie underwater between the mouth of the Susquehanna River and Turkey Point. As the RAI points out, if the fault exists underwater, the sediment input of the Susquehanna River may hide even an active fault from all but an expensive and thorough program of marine seismic-reflection profiling. The RAI also notes that if the fault extends onto land, it could do so anywhere in such a large area that only an expensive and thorough program of Quaternary mapping and paleoseismic trenching would be likely to find it even if it was active.

The response describes several attempts to find a fault using different kinds of data. All the attempts have failed. The variety of the methods casts doubt on the presence of significant young faulting, but as the RAI points out, repeated failure to find evidence of young faulting cannot rule it out.

However, the response provides information with which the applicant could develop a stronger and more straightforward argument. Pazzaglia suggested the fault on the basis of an 8-m difference in the elevations of the Turkey Point beds on opposite sides of the bay. As explained in the rest of this review, the response contains information that can remove the significance of the elevation difference in two ways.

First, the response reports one or more interviews in which Pazzaglia noted that topographic relief of the land surface on which the Turkey Point beds were deposited could be responsible for the 8-m elevation difference (p. 14 and 16 of the response). This suggestion of a nontectonic origin of the 8-m difference comes from the most authoritative source possible: the geologist who proposed the fault in the first place. The suggestion provides an alternative explanation of the only evidence for the existence of the fault.

Second, the Turkey Point beds are contained within the regionally recognized and mapped Pensauken Formation. Figure 3 of the response demonstrates that the base of the Pensauken Formation northeastward from Turkey Point exhibits pre-depositional topographic relief that is abundant enough and large enough to strongly support Pazzaglia's suggested alternative interpretation of the 8-m elevation difference.

Specifically, Figure 3 shows 35 changes between adjacent LiDAR-based elevations of the Pensauken base along a traverse 20 km (12 mi) long. The 20-km traverse length is comparable to the distance between the two Turkey Point exposures whose elevations differ by 8 m. The 35 elevation changes along the traverse are 1–16 m and have a median value of 5 m. One-third of the 35 measurements equal or exceed 8 m. The implication of these values is that the Turkey Point elevations may contain a pre-depositional component that is likely equal to or significantly larger than 8 m.

Thus, it may not be feasible to demonstrate the absence of young faulting. However, the geologist who proposed the fault's existence has pointed out a reasonable alternative explanation for the evidence underlying the original proposal. The applicant has shown that the alternative explanation requires only topographic variability that is widespread in the study area at a pertinent stratigraphic level. Additionally, the topographic variability is larger than needed to explain the 8-m elevation difference of the Turkey Point beds, although the measurements that could support this statement are not reported in the response. Any subsequent attempt to argue that the fault is likely to exist and be active would require extremely strong supporting evidence to counter the evidence in the response, particularly if the measurements and a histogram of them are included.

Figure 3 of the response and a numerical summary of its elevation changes, together with any appropriate other figures and parts of the response text, are central to this reasoning. The speculated faulting has received much attention in professional circles, so addressing its possible occurrence is important. However, Figure 3 is not among those planned to be added to a revised COLA. Figure 3 and supporting parts of the response should be added to the COLA to strengthen the response's case.

Additionally, Figure 2.5–303 is planned to be added to the COLA. If it is added, it must be redrafted. The structure contours and their values are illegible and nearly invisible on the screen and in colored and black and white prints. Without legible contours and values the figure does not contribute to the response's argument.

RAI 219, QUESTION 02.05.01–68

"FSAR Sections 2.5.1.1.4.4.5.4 on the Ramapo Fault system and 2.5.1.1.4.4.5.5 on the Kingston Fault cite Figure 2.5–31 when discussing the Ramapo, Kingston, and New York Bight faults, which indicates these faults as circled numbers. In RAI 02.05.01–24 NRC staff asked the applicant to provide a figure that shows the fault lines and map relations that are described in the text. In response the applicant provided 4 additional maps. You also indicated that there would be no change to the FSAR.

"NRC staff note that the discussions in the original FSAR about these faults cannot be understood without additional illustrations/maps beyond Figure 2.5–31. The map and cross section of the Kingston fault are needed to understand the uncertainty of the interpretation of a fault in the first place. It is difficult to understand the general geologic setting and relative position of these faults to each other as well. Please explain why you do not plan to include a more illustrative map/figure to support the text."

<u>USGS review:</u>
No additional information is needed.

The response provides the requested figures, which will be added to and cited in a revised COLA.

RAI 219, QUESTION 02.05.01–69

"FSAR section 2.5.1.2.6.4 states that "There is no evidence of earthquake-induced liquefaction in the State of Maryland" and cites the Crone and Wheeler papers. In RAI 02.05.01–28 NRC staff pointed out that the Crone and Wheeler database does not support that statement and asked if potential liquefaction features had been investigated as part of the geologic investigation for the site. NRC staff also requested you provide details of any such survey. In RAI 02.05.01–30, NRC staff asked you to provide liquefaction information for the site area along with methods used and a summary of the findings.

"In response, you indicated that the investigation for potential liquefaction features done for this COL application included a literature review, discussions with subject matter experts, an aerial and field reconnaissance, and a review of aerial photography. You stated that based on this work there is no liquefaction within 25 miles of CCNPP and within the state of MD. You planned no revision to the FSAR.

"NRC staff note that the original statement citing Crone and Wheeler as the basis of the conclusion that there is no earthquake induced liquefaction in the state of MD remains in the FSAR and does not actually support that conclusion.

"a. Dr. Martitia Tuttle is a regional expert in paleoliquefaction. Please explain if you reviewed Tuttle publications about potential paleoliquefaction within the state of MD.

"b. In figure 4 of the response to this question is an oblique aerial photo of a terrace along the Potomac River. There are two circular features in the foreground that appear as sand blow deposits. Please discuss the origin of these circular features.

"c. Please explain why the response to this question is not to be included in a future FSAR revision."

USGS review:
No additional information is needed.

The response provides the requested information: (1) Dr. Tuttle was contacted and stated that she did not know of any paleoliquefaction features in Maryland, (2) the circular features shown in a figure in an earlier response are actually elongated, curved, and most probably fluvial in origin, and (3) the misattribution to Crone and Wheeler (2000) has been removed.

Section 02.05.02: Vibratory Ground Motion

RAI No. 216, Question 02.05.02–15

"The smooth 10^4 and 10^5 UHRS, provided in FSAR Table 2.5–23, are developed using controlling earthquake magnitude and distance values shown in FSAR Table 2.5–21 and the hard rock spectral shapes for CEUS earthquake ground motions recommended in NUREG/CR–6728. Please specify which equation or combination of equations was used from NUREG/CR–6728."

USGS review:
No additional information is needed.

The applicant provided needed information about the equation used. The applicant responded that Equation (4–9) of NUREG/CR–6728 was used to develop smooth 10^{-4} and 10^{-5} high-frequency and low-frequency hard rock UHRS, weighting the single- and double-corner CEUS models equally. The model coefficients are given in Table 4–3 of the NUREG. These spectra are shown in FSAR Figures 2.5–70 and 2.5–71 and were used to develop the amplification factors of FSAR Table 2.5–23. Though no additional information is needed, including this information in the COLA would help clarify how the calculations were performed.

RAI 216, Question 02.05.02–16

"According to FSAR Section 2.5.2.6, the horizontal GMRS (for each spectral frequency), is obtained by scaling the smooth rock 10^{-4} UHRS by the design factor specified in Regulatory Guide 1.208. RG 1.208 states that it is acceptable to use a value equal to 45 percent of the mean

10^{-5} UHRS if AR is greater than 4.2 (i.e. if the hazard curves are not approximated by a power law equation in the range of 1 E-04 to 1 E-05). Please indicate whether you used CAV (cumulative absolute velocity) filtering, which would result in an AR greater than 4.2."

USGS review:
No additional information is needed.

The applicant responded that they did not use a CAV filter and that the COLA will not be revised to indicate this fact.

RAI 216, Question 02.05.02–17

"FSAR Section 2.5.2–6 states that the GMRS was smoothed, particularly around 1.5 Hz. Please provide details regarding how this smoothing was performed."

USGS review:
No additional information needed.

The applicant addressed the question as to how the spectrum was smoothed. The applicant responded by stating that smoothing was done for 0.4 Hz and between 1.25 Hz and 4 Hz by using a running average of the spectral amplitude at each frequency and the spectral amplitudes at each adjacent frequency, using the 38 frequencies at which spectral amplitudes were calculated (that is, the frequencies given in FSAR Table 2.5–22 and 2.5–23). Specifically, the final spectral amplitude for 0.4 Hz was the equally weighted average of spectral amplitudes at 0.3 Hz, 0.4 Hz, and 0.5 Hz, the final spectral amplitude for 1.5 Hz was the equally weighted average of spectral amplitudes at 1.25 Hz, 1.5 Hz, and 2 Hz, and similarly smoothed for the final spectral amplitudes of 1.25 Hz, 2 Hz, 3 Hz, and 4 Hz.

RAI 216, Question 02.05.02–18

"FSAR Section 2.5.2.5.1.2 states that a value of 160 pcf (2592 kg/m^3) is used for the unit weight of the bedrock. However, FSAR Section 2.5.4.7.2 states that the rock unit weight estimated from the available literature is 162 pcf. Although the difference between these values is small, please clarify this inconsistency."

USGS review:
No additional information is needed.

The applicant clarified the discrepancy and updated the COLA. The applicant responded by stating that the value for the unit weight of rock is given as 162 pcf in FSAR Section 2.5.4.7.3.2, "Shear Modulus Degradation Curves for Rock." In the absence of rock core samples for direct measurement of rock density at the CCNPP Unit 3 site, this value was obtained from the literature. Based on results of testing 257 rock specimens from 27 localities across the U.S. and statistical analysis of the data, an average unit weight of 162.3 pcf was reported for all the rock groups. For the purpose of analysis of site-specific amplification factors, an average rock unit weight of 162 pcf was considered reasonable for rocks beneath the CCNPP Unit 3 site, and this value was used. The value of 160 pcf given in FSAR Section 2.5.2.5.1.2, "Base Case Soil/Rock CCNPP Unit 3 and Uncertainties," was an approximation of this estimate.

The applicant will update the COLA as follows: The eighth paragraph of FSAR Section 2.5.2.5.1.2, will be updated as follows in a future COLA revision: “Unit weights for the soils beneath the site are in the range of about 115 to 120 pcf (pounds per cubic foot) (1,842 kg/m^3 to 1,922 kg/m^3). The bedrock unit weight was assigned a value of 162 pcf (2,595 kg/m^3) (Deere, 1966).”

FSAR Section 2.5.2.8 will be updated to add the following reference in a future COLA revision: “Deere, 1966. Engineering classification and index properties of intact rock, University of Illinois, Prepared for Air Force Weapons Laboratory, Technical Report Number AFWL–TR–65–116, D. Deere and R. Miller, December 1966.”

RAI 216, Question 02.05.02–19

“FSAR Section 2.5.2.5.1.2 states that site-specific RCTS-based shear modulus degradation and damping ratio curves were used for the final site amplification factor analysis for soils above a depth of 400 ft. However, FSAR Section 2.5.4.7.3.1 states that in the absence of actual data for the upper 400 ft of site soils, generic EPRI curves were adopted from EPRI TR–102293 (EPRI, 1993). Please clarify this discrepancy.”

<u>USGS review:</u>
No additional information is needed.

The applicant clarified the discrepancy and will update the COLA. The applicant responded by stating the following. UniStar Nuclear Energy substantially rewrote FSAR Sections 2.5.4 and 2.5.5 in October 2009. This update was submitted to the NRC in letter UN#09–4273. Updated FSAR Section 2.5.4.2.5.9 indicates that the shear modulus degradation and damping ratio curves used for the final site amplification analysis are generic curves fitted to site-specific laboratory testing data. The strain-dependent properties for the CCNPP Unit 3 project are developed by fitting generic curves to the site-specific data reported from Resonant Column Torsional Shear (RCTS) tests. EPRI curve selection for the upper 400 ft (122 m) of the site soils was based on available soil characterization data from the site investigation. A detailed description of the RCTS curve fitting process is provided in the report "Reconciliation of EPRI and RCTS Results, Calvert Cliffs Nuclear Power Plant Unit 3" and is included as COLA Part 11J.

The third paragraph of FSAR Section 2.5.2.5.1.2 will be updated as follows in a future COLA revision: “Initially, generic EPRI curves from EPRI TR–102293 (EPRI, 1993) were adopted to describe the strain dependencies of shear modulus and damping for all subsurface soils. The EPRI ‘sand’ curves cover a depth range of as much as 1,000 ft (305 m). Since soils at the CCNPP Unit 3 site extend beyond 1,000 ft (305 m), similar curves were extrapolated from the EPRI curves, extending beyond 1000 ft (305 m), to obtain data for deeper soils. EPRI curves for the upper 400 ft (122 m) of the site soils were based on available results from the site investigation as described in Section 2.5.4.2.5.9. Below 400 ft (122 m), a site-specific geologic profile was used as a basis for the soil profiles, including engineering judgment to arrive at the selected EPRI curves. The damping curves for soils were truncated at 15 percent for the initial site response analysis."

RAI 216, Question 02.05.02–20

"FSAR Section 2.5.2.5.1.5 states that Random Vibration Technology (RVT) was used to calculate the site response. Please provide the model input parameters and modeling assumptions, so that the staff can verify the method and input and output parameters."

<u>USGS review:</u>
No additional information is needed.

The applicant provided the requested information and files. The applicant responded that the site response calculations for the site were performed using the Random Vibration Theory (RVT) approach. In many respects, the inputs and assumptions are the same for an RVT analysis and for a time-history-based analysis (that is, an analysis with the program SHAKE). Both the RVT and time-history (SHAKE) procedures assume a horizontally layered half-space representation of the site and assume an equivalent-linear representation of dynamic response to vertically propagating shear waves. Starting from the same inputs in the form of response spectra, both procedures will lead to similar estimates of site response. The main advantage of the RVT approach is that it does not require the spectral matching of multiple time histories to a given rock response spectrum. Instead, the RVT approach uses a probabilistic representation of the ensemble of all input motions corresponding to that given response spectrum and then calculates the response spectrum of the ensemble of dynamic responses.

Site-response calculations were performed for three levels of bedrock motion corresponding to mean annual frequencies of 1 E-4, 1 E-5, and 1 E-6 and for high-frequency (HF) and low-frequency (LF) motions. Only the 1 E-4 and 1 E-5 HF and LF motions are used for Section 2.5.2. That is, four input motions were used for the development of the GMRS. For each of these input motions, site response was calculated for 60 site columns that were calculated as part of the site randomization step. Thus 240 analyses of site response were made for GMRS development.

The rock motion input to the RVT calculation is characterized by the rock spectrum, the strong-motion duration associated with that rock spectrum, and the equivalent-strain ratio to use in the equivalent-linear calculations. This input is required for both the time-history and RVT approaches. The duration is calculated from the controlling earthquake magnitude calculated from hazard deaggregation, using standard seismological relations between magnitude, seismic moment, corner frequency, and duration, and using stress-drop and crustal Vs values typical of the eastern United States. The effective strain ratio is calculated using the expression (M-1)/10. Values of effective strain smaller than 0.5 or greater than 0.65 were brought into the 0.5–0.65 range, which is the range recommended by Kramer.

The four files labeled CALVERTROCK_INPUT*.INP, (where the asterisk stands for 1 E-4_HF/LF or 1 E-5_HF/LF) document the rock spectra (spectral accelerations in g, given for 38 frequencies ranging from 0.10 Hz to 100 Hz), strong motion durations (sec), and effective strain ratios (dimensionless).

The 60 files labeled from CalvertrandomizationGMRS_0001.optl_2 to CalvertrandomizationGMRS_0060.optl_2, contain stiffness curves (decimal values of G/Gmax) and damping curves (in percent) as a function of strain (percent), following the format of Option 1 of SHAKE91, and the soil type (with reference to the Option 1 input), thickness (in feet), initial estimate of damping (decimal), total unit weight (kips per cubic foot), and initial shear wave velocity (Vs in feet/second) for each of the 166 layers within each randomized soil column following the format of Option 2 of SHAKE91.

FSAR Figures 2.5–78 through 2.5–85 were developed using these site soil columns and input parameters.

The 64 data files discussed above are contained in Enclosure 2.

The applicant will not change the COLA.

RAI 216, Question 02.05.02–21

"FSAR Section 2.5.2.5.1.5 states that two profiles were evaluated for site response: 1) the entire soil column, including 41 ft (12.5 m) of fill above the foundation of the nuclear island, and 2) a soil column that did not contain any soil above the base of the nuclear island foundation for the calculation of the GMRS. FSAR Section 2.5.2.5.1.5 further states that for the profile including fill, the shear-wave velocity for the fill material was assumed to be those of the subsurface strata I and IIa and the shear modulus degradation and damping curves were assumed to be those of subsurface strata I material. Please justify the use of these material properties for the fill."

<u>USGS review:</u>

No additional information is needed.

Since the NRC staff wrote this RAI, the applicant had performed additional RCTS measurements on the backfill material. They addressed the RAI and updated the COLA. The applicant responded as follows.

The text referenced in Question 02.05.02–21 is found in FSAR Section 2.5.2.5.1.2, and refers to a characterization of the site subsurface material properties originally developed for the project. This initial characterization was used both to develop the site-specific Ground Motion Response Spectra (GMRS) and to develop surface Foundation Input Response Spectra (FIRS) suitable for Emergency Power Generating Buildings (EPGB) and Essential Service Water Buildings (ESWB) located in the Nuclear Island (NI) area, considering a soil column consisting of assumed backfill properties for the top 40 ft. The basis for the assumed properties was that the backfill would be a granular material like the terrace sand of the CCNPP Unit 3 site with representative shear wave velocities.

Following submittal of COLA Revision 6, additional characterizations of the subsurface and backfill have been made and additional analysis of the site-specific amplification factors for ground motions affecting the EPGB, ESWB, and other Category I structures have been performed. The results of this additional characterization of the subsurface were provided to the NRC in the rewrite of FSAR Section 2.5.47. The site-specific FIRS at all elevations of interest resulting from the amplification by the subsurface material have been analyzed and are currently incorporated into a revision of COLA FSAR Section 3.7.18.

The applicant revised the COLA. The last paragraph of FSAR Section 2.5.2.5.1.2 will be updated as follows in a future COLA revision: "Subsequent dynamic laboratory RCTS test results were used to obtain site-specific data on shear modulus and damping characteristics of in place soils in the upper 400 ft (122 m) and of the backfill material as detailed in Section 2.5.4. The site-specific RCTS-based shear modulus degradation and damping ratio curves were used for all final site-amplification factor analysis. A subsurface soil profile extending only to the base of the nuclear island foundation, and including no backfill, was used for the calculation of the GMRS. For development of FIRS in Section 3.7.1, the soil profile appropriate for any given structure was developed from the material properties described and discussed in Section 2.5.4."