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SCE&G®
A SCANA COMPANY

March 16, 2009
NND-09-0052

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

ATTN: Document Control Desk

Subject: Virgil C. Summer Nuclear Station (VCSNS) Units 2 and 3 Combined License Application (COLA) - Docket Numbers 52-027 and 52-028 Response to NRC Request for Additional Information (RAI) Letter No. 033

Reference: Letter from Ravindra G. Joshi (NRC) to Alfred M. Paglia (SCE&G), Request for Additional Information Letter No. 033 Related to SRP Section 2.5.1 for the Virgil C. Summer Nuclear Station Units 2 and 3 Combined License Application, dated February 12, 2009.

The enclosure to this letter provides the South Carolina Electric & Gas Company (SCE&G) response to the RAI items included in the above referenced letter. The enclosure also identifies any associated changes that will be incorporated in a future revision of the VCSNS Units 2 and 3 COLA.

The responses to NRC RAI Numbers 02.05.01-1-4, 02.05.01-6-11, 02.05.01-13-18, 02.05.01-21-25, 02.05.01-29, 02.05.01-32, 02.05.01-34-39, and 02.05.01-42-49 are still under development and review by SCE&G. The final responses to those RAIs are expected be provided to the NRC by March 31, 2009.

Should you have any questions, please contact Mr. Al Paglia by telephone at (803) 345-4191, or by email at apaglia@scana.com.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on this 16th day of March, 2009.

Sincerely,

Ronald B Clary

Ronald B. Clary
General Manager
New Nuclear Deployment

D083
NRO

JMG/RBC/jg

Enclosure

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NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-5

FSAR Section 2.5.1.1.2.3.1 (pgs. 2.5.1-14 and 2.5.1-15) refers to the "Piedmont gradient" of the regional gravity field, but appears to label this gradient as the "Appalachian gravity gradient" in FSAR Figures 2.5.1-207 and 2.5.1-208.

In order for the staff to completely understand regional gravity gradients being discussed for the site region and their potential relationship to geologic features, please clarify the reference to the Piedmont gradient in the text versus the Appalachian gravity gradient in Figures 2.5.1-207 and 2.5.1-208.

VCSNS RESPONSE:

FSAR Figures 2.5.1-207 and 2.5.1-208 show the location of the Appalachian gravity gradient. This same feature is referred to in the text of FSAR Subsection 2.5.1.1.2.3.1 as the Piedmont gradient. For consistency between FSAR text and FSAR figures, the text of FSAR Subsection 2.5.1.1.2.3.1 will be modified such that the term "Piedmont gradient" is replaced by the term "Appalachian gravity gradient."

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

FSAR Subsection 2.5.1.1.2.3.1, second and third paragraphs, pages 2.5.1-14 and 2.5.1-15, will be updated in a future FSAR revision as follows:

Previous researchers refer to this long-wavelength feature in the gravity field as the "Piedmont gradient" or the "Appalachian gravity gradient" (~~References 269 and 237~~References 269, 237, and 405). For the purposes of the VCSNS FSAR, the term "Appalachian gravity gradient" is adopted for this feature. At the latitude of Virginia, north of the VCSNS site region, Harris et al. (Reference 269) interpret the ~~Piedmont gradient~~Appalachian gravity gradient to reflect the eastward thinning of the North American continental crust and associated positive relief on the Moho with proximity to the Atlantic margin. Gravity models by Iverson and Smithson (Reference 296) along the southern Appalachian COCORP seismic reflection profile, and by Dainty and Frazier (Reference 237) in northeastern Georgia, suggest that the gradient probably arises from both eastward thinning of continental crust and the obduction of the Inner Piedmont and Carolina-Avalon terranes, which have higher average densities than the underlying Precambrian basement of North America.

Superimposed on the long-wavelength Appalachian gravity gradient ~~Piedmont gradient~~ are numerous high and low-gravity anomalies that have wavelengths of about 10 to 20 kilometers, and which are elliptical to irregular in plan view. These anomalies are especially well expressed in the Carolina-Avalon terrane (in accordance with Reference 279) between the Central Piedmont shear zone and the Modoc shear zone (Figure 2.5.1-205). Based on comparison of the gravity maps with geologic maps, many of these anomalies are spatially associated with Paleozoic igneous intrusions and plutons. The basement of the Carolina Zone at this latitude is interpreted to be crust of an oceanic island arc terrane or terranes that were accreted to the Appalachian orogen during the Taconic orogeny (References 292 and 279). The composition of this crust generally is intermediate between felsic and mafic (Reference 350). The intrusions and plutons in the Carolina Zone with associated gravity anomalies fall more toward the extremes in felsic and mafic compositional ranges for igneous rocks, which give rise to density contrasts with the country rock they intrude. In general, gravity highs are associated with mafic intrusions and mafic basement rocks, and gravity lows are associated with granitic plutons. Detailed gravity modeling by Cumbest et al. (Reference 233) in the vicinity of the Dunbarton Basin south-southwest of the VCSNS site supports the general association of 10- to 20-kilometer-high and -low anomalies in the Piedmont gravity field with mafic and felsic intrusions, respectively.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-12

FSAR Section 2.5.1.1.2.4.1 (pg 2.5.1-20) discusses the Gold Hill fault extension. This section states, based on structural correlations with the Deal Creek shear zone and cross-cutting relationships with igneous bodies as defined by West (1998), that the Gold Hill fault extension is between 400-325 my old. The data from West (1998) on which this interpretation is based are not presented in the FSAR. Furthermore, the Deal Creek shear zone is not discussed in the FSAR, and publications (e.g., Hibbard and others, 2007; Allen, 2007) presenting more recent information on the Gold Hill shear zone are not mentioned.

In order for the staff to completely understand geologic setting of the Summer site in relation to regional tectonic structures, please discuss the suggested age constraint for the Gold Hill fault based on relationships with the Deal Creek shear zone, including a summary of the information from West (1998) that make this interpretation possible. Please also provide a discussion of the Deal Creek shear zone and factor in more recent published information for discussion of the Gold Hill shear zone.

VCSNS RESPONSE:

Technically, the age estimates of the Gold Hill-Silver Hill shear zone (GHSZ) do not rely upon the relationship with the Deal Creek shear zone. In fact, the FSAR should refer to cross-cutting relationships with the Cross Anchor fault, not the Deal Creek shear zone, as a source of timing information for the GHSZ. West (1998) (FSAR Reference 2.5.1-403) correlates the GHSZ and the Deal Creek shear zone as extensions of one another because of their similarity in attitude (northeast-striking) and deformation styles (both exhibit mica-defined dextral shear bands). On the basis of this correlation, West (1998) assigned the timing of the GHSZ to the Deal Creek shear zone. However, the timing estimate of the GHSZ is based only upon the interpretations that the GHSZ itself (1) cuts gabbroic plutons northeast of the Whitmire reentrant that are interpreted to be part of approximately (ca.) 400 Ma Concorde plutonic suite (West 1998) (FSAR Reference 2.5.1-403), and (2) the GHSZ is cut by the Cross Anchor fault (West 1998) (FSAR Reference 2.5.1-403). Dennis and Wright (1995) (Reference 1) interpreted an unnamed granite, dated at 326 ± 3 Ma, to cut and post-date the Cross Anchor fault. However, West (1998) (FSAR Reference 2.5.1-403) interpreted the same pluton as syn- to pre-kinematic to deformation on the fault and thus interpreted movement on the fault to be ca. 325 Ma. In either case, the evidence in South Carolina suggests that the Gold Hill fault was active after 400 Ma and before approximately 325 Ma.

More recently, several abstracts and a fieldtrip guidebook (Hibbard et al. 2008) (Reference 2) provide additional data that suggest a more complex tectonic history for the GHSZ in two locations in North Carolina. Close to the South Carolina state line, deformation along the GHSZ is intense and includes dextral and southeast-vergent thrusting (Hibbard et al. 2008) (Reference 2.) Allen et al. (2007) (Reference 3) interpret the Waxhaw granite as late- to syn-kinematic to this dextral-reverse GHSZ deformation, and take the ca. 539 Ma U-Pb zircon, monazite, and xenotime ages for this pluton to indicate earliest Cambrian deformation. Moreover, Allen et al. (2007) (Reference 3) indicate that 400 Ma titanite growth in the Waxhaw granite may be related to the nearby intrusion of undeformed gabbros, perhaps indicating that deformation on the GHSZ had ceased by 400 Ma. To the northeast, in central North Carolina, the GHSZ kinematics include both sinistral and southeast-vergent thrust deformation, which is interpreted as synchronous with a series of Late Ordovician folds (Hibbard et al. 2008) (Reference 2.) However, $^{40}Ar/^{39}Ar$ mica ages of ca. 377, 338 and 335 Ma from the fault zone may indicate later localized reactivation of deformation in the Devonian and/or Mississippian (Hibbard et al. 2007 (Reference 4); Hibbard et al. 2008 (Reference 2)).

In summary, nearest the site in South Carolina, the estimates for kinematics and timing of the GHSZ indicate dextral deformation occurred between 400 Ma and ca. 325 Ma (Dennis and Wright 1995 (Reference 1); West 1998 (FSAR Reference 2.5.1-403)). To the northeast, in southern North Carolina, dextral deformation occurred in the earliest Cambrian and was possibly over by ca. 400 Ma (Allen et al. 2007) (Reference 3). Farther to the north, in central North Carolina, deformation was sinistral in the Late Ordovician, although evidence exists for potential Devonian and/or Mississippian deformation as well (Hibbard et al. 2008) (Reference 2.) Hence, these studies indicate that the tectonic history for this structure is complex (Allen et al. 2008) (Reference 5.) The best evidence for the latest movement on the GHSZ, however, is based on its cross-cutting relationship with the Cross Anchor fault that constrains latest motion to sometime prior to ca. 325 Ma (West 1998) (FSAR Reference 2.5.1-403) (Dennis and Wright 1995) (Reference 1). In summary, all investigators provide data indicating that the Gold Hill-Silver Hill shear zone and the Deal Creek shear zone, by extension, are not capable faults.

References:

1. Dennis, A.J. and Wright, J.E., Mississippian (ca. 326-323 Ma) U-Pb crystallization for two granitoids in Spartanburg and Union counties, South Carolina: Carolina Geological Society Guidebook, p. 43-47, 1995.
2. Hibbard, J., Pollock, J., Allen, J., and Brennan, M., The heart of Carolinia: Stratigraphic and tectonic studies in the Carolina terrane of central North Carolina, Geological Society of America Southeast Section Fieldtrip Guidebook, 54 p., 2008.
3. Allen, J.S., Miller, B., Hibbard, J., and Boland, I., Significance of intrusive rocks along the Charlotte-Carolina terrane boundary: evidence for the timing of deformation in the Gold Hill fault zone near Waxhaw, NC: Geological Society of America Southeast Section Abstracts with Programs, v. 39, p. 12, 2007.

4. Hibbard, J., Miller, B., Hames, W., Allen, J., and Sandard, I., Carolinia; definition and recent finding in central North Carolina: Geological Society of America, Southeastern Section Abstracts with Programs, v. 39, p. 11-12, 2007.
5. Allen, J.S., Hibbard, J.P., and Boland, I.B., Structure, kinematics, and timing of the Gold Hill Fault Zone in Hancock, South Carolina, and Waxhaw, North Carolina: South Carolina Geology, v. 46, p. 15-29, 2008.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

FSAR Subsection 2.5.1.1.2.4.1, ninth paragraph, page 2.5.1-20, will be updated in a future FSAR revision as follows:

<u>Gold Hill Fault Extension</u>
Horton and Dicken (Reference 289) and Hibbard et al. (Reference 284) map an unnamed fault north of the Beaver Creek shear zone that is considered the southwest extension of the Gold Hill fault (Figures 2.5.1-211 and 2.5.1-212). At its nearest point, this fault is located approximately 20 miles north of the VCSNS site. The southwest extension of the Gold Hill fault is truncated by, and therefore predates, the Cross Anchor fault. Based upon <u>crosscutting relationships</u> ~~structural correlations~~ with the ~~Deal Creek shear zone~~<u>Cross Anchor fault</u> (Figure 2.5.1-211) and ~~crosscutting relationships with~~ intrusive igneous bodies, West (Reference 403) constrains motion on the Gold Hill fault to between approximately 400 and 325 Ma.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-19

FSAR Section 2.5.1.1.2.4.2 (pg 2.5.1-23) discusses regional Mesozoic tectonic structures. This section states that the minimum age of displacement on the Wateree Creek fault is constrained to be Triassic based on cross-cutting dikes which are not offset, and the Summers Branch and Ridgeway faults are both interpreted to be Triassic structures on the basis of their association with the Wateree Creek fault.

In order for the staff to assess the hazard potential for these three faults, please summarize the information on the relationship of the Summers Branch and Ridgeway faults to the Wateree Creek fault that is used to document that all three faults are Triassic in age.

VCSNS RESPONSE:

As described in FSAR Subsection 2.5.1.2.4.2, Secor et al. (1982) (FSAR Reference 2.5.1-364) map the Wateree Creek fault as a steeply west-dipping, greater than 8-mi-long, approximately north-striking, unsilicified fault zone. Based on diabase dikes of probable Triassic to early Jurassic age that cross, but are not cut by, the Wateree Creek fault, Secor et al. (1982) (FSAR Reference 2.5.1-364) constrain the age of faulting to sometime prior to early Jurassic.

Secor et al. (1998) (FSAR Reference 2.5.1-368) map the Ridgeway fault as a greater than 9-mi-long, approximately north-striking fault zone. Constraints on the age of the Ridgeway fault are poorly resolved. According to Secor et al. (1998) (FSAR Reference 2.5.1-368):

> *[The age of the Ridgeway fault] is loosely delimited by the fact that it cuts rocks that were deposited and acquired penetrative deformation fabric in the Late Proterozoic to early Cambrian and apparently does not cut the Upper Cretaceous kaolinitic sand unit.* [p. 9]

Moreover, Secor et al. (1998) (FSAR Reference 2.5.1-364) note similarities between the Wateree Creek and Ridgeway faults, including strike and length. As such, the Ridgeway and Wateree Creek faults likely are similar in age. The youngest unfaulted strain markers on the Wateree Creek fault are diabase dikes of probable Triassic to early Jurassic age that indicate the latest movement was prior to the early Jurassic. The youngest unfaulted strain marker on the Ridgeway fault is Upper Createceous in age, suggesting that both faults may be pre-Upper Cretaceous in age.

Secor et al. (1982) (FSAR Reference 2.5.1-364) map the Summers Branch fault as an 8-mi-long, approximately north-striking, unsilicified fault zone. Evidence for the Summers Branch fault is speculative, however, and no actual outcrops from within the fault zone have been found. Secor et al. (1982) (FSAR Reference 2.5.1-364) do not provide age constraints for the Summers Branch fault, but they interpret it to be an age similar to the Wateree Creek fault described above. More recent mapping by Maher et al. (1991), on which Secor is a co-author, omits the Summers Branch fault altogether. Constraints on the age of the Summers Branch fault, if it exists, are poorly resolved. Based on similarities with the Wateree Creek and Ridgeway faults, including mapped length and orientation, the Summers Branch fault, if it exists, likely is Mesozoic or older in age.

Reference:

Maher, H.D. Jr., Sacks, P.E., and Secor, D.T. Jr., *The Eastern Piedmont in South Carolina*: in *The Geology of the Carolinas*, J.W. Horton Jr. and V.A. Zullo (eds.), Carolina Geological Society 50th Anniversary Volume, University of Tennessee Press, p. 93-108, 1991.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-20

FSAR Section 2.5.1.1.2.4.2 (pg 2.5.1-24) discusses the Longtown fault, stating that Jurassic age diabase dikes cross-cut, and are not offset by, the fault. However, this FSAR section then states that post-Mesozoic slip along the fault cannot be precluded by the available data.

In order for the staff to assess the hazard potential of the Longtown fault, please explain why the crosscutting dikes of Jurassic age do not preclude post-Mesozoic displacement along the fault.

VCSNS RESPONSE:

There is a typographical error in FSAR Subsection 2.5.1.1.2.4.2. Specifically, the assertion that post-Mesozoic slip along the Longtown fault "cannot be precluded by available data" [FSAR p. 2.5.1-24] should have used the word "can" instead of "cannot." Mapping by Barker and Secor (FSAR Reference 2.5.1-208) shows diabase dikes of Triassic or Jurassic age that cross, but are not offset by, the Longtown fault (FSAR Figure 2.5.1-213). As such, these data indicate a Mesozoic or older age for the Longtown fault. The text of FSAR Subsection 2.5.1.1.2.4.2 will be modified to clearly indicate a Mesozoic or older age for the Longtown fault.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

FSAR Subsection 2.5.1.1.2.4.2, fifth paragraph, pages 2.5.1-23 and 2.5.1-24, will be updated in a future FSAR revision as follows:

<u>Longtown Fault</u>
The Longtown fault strikes west-northwest in the Ridgeway-Camden area (Figure 2.5.1-213), about 25 miles from the VCSNS site. As mapped by Secor et al. (Reference 368), the Longtown fault terminates eastward against the Camden fault. The Longtown fault is associated with fracturing and brecciation of the crystalline rocks, and fragments of silicified breccia are found along its trace (Reference 368). Total slip on the Longtown fault is unresolved, although Secor et al. (Reference 368) suggest total displacement on the order of hundreds to thousands of meters is likely in order to explain the apparent disruption of crystalline rocks across the fault. Map relationships suggest that the Longtown fault vertically separates the Late Cretaceous basal unconformity (Reference

368). However, it is possible that the irregularity in the basal unconformity represents buried topography and not tectonic deformation (Reference 208). Mapping by Barker and Secor (Reference 208) shows diabase dikes of Triassic or Jurassic age that cross, but are not offset by, the Longtown fault (Figure 2.5.1-213). ~~.~~ As such, these data indicate a Mesozoic or older age for the Longtown fault. ~~Available data suggest that the most recent slip on the Longtown fault may have occurred during the Mesozoic. There is no evidence for post-Mesozoic slip on the Longtown fault, but this cannot be precluded by available data.~~

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-26

FSAR Figure 2.5.1-215 illustrates locations of 14 proposed Quaternary features which occur in the site region. However, with the exception of the Falls Lines of Weems (1998), strike trends of these features are not shown in the figure to enable an assessment of linear trends of the features.

In order for the staff to assess the hazard potential for the 14 proposed Quaternary features, please indicate strike trends and fault lengths for these features in Figure 2.5.1-215.

VCSNS RESPONSE:

Crone and Wheeler (2000) (FSAR Reference 2.5.1-232) and Wheeler (2005) (FSAR Reference 2.5.1-406) identified fourteen proposed Quaternary features within the site region, as shown in FSAR Figure 2.5.1-215. Due to the scale of Figure 2.5.1-215 and to preserve legibility, the table below describes orientation and length information, where applicable, for these fourteen features.

Feature Name	**Orientation**	**Length**	**Reference(s)** (1)	**Class** (2)
1. Fall Lines of Weems	NE	450 mi	Weems (1998) FSAR Reference 2.5.1-398	C
2. Belair fault	NE	15+ mi	Dennis et al. (2004) FSAR Reference 2.5.1-246	C
3. Pen Branch fault	NE	20+ mi	Snipes et al. (1993) FSAR Reference 2.5.1-374	C
4. Cooke fault	ENE	6 mi	Behrendt et al. (1981) FSAR Reference 2.5.1-210; Hamilton et al. (1983) FSAR Reference 2.5.1-268	C
5. East Coast Fault Zone	NE [N35°E]	375 mi [125 mi]	Marple and Talwani (2000) FSAR	C [C]

[southern segment]			Reference 2.5.1-325	
6. Eastern Tennessee Seismic Zone	NE	185 mi	Powell et al. (1994) FSAR Reference 2.5.1-345	C
7. Stanleytown-Villa Heights faults	NNE	600 ft each	Conley and Toewe (1968) Reference 1	C
8. Pembroke fault	ENE	330+ ft	Law et al. (2000) FSAR Reference 2.5.1-313	B
9. Bluffton liquefaction features	n/a (3)	n/a (3)	Talwani and Schaeffer (2001) FSAR Reference 2.5.1-386	A
10. Helena Banks fault	ENE	75 mi	Behrendt and Yuan (1987) FSAR Reference 2.5.1-209; Behrendt at al. (1983) FSAR Reference 2.5.1-211	C
11. Charleston liquefaction features	(3)	(3)	Talwani and Schaeffer (2001) FSAR Reference 2.5.1-386	A
12. Georgetown liquefaction features	(3)	(3)	Talwani and Schaeffer (2001) FSAR Reference 2.5.1-386	A
13. Cape Fear Arch	NW	100+ mi	Crone and Wheeler (2000) FSAR Reference 2.5.1-323	C
14. Hares Crossroads fault	(4)	(4)	Prowell (1983) FSAR Reference 2.5.1-346	C

Notes:
(1) Source reference for feature orientation and/or length.
(2) Feature class from Crone and Wheeler (2000) (FSAR Reference 2.5.1-232) and Wheeler (2005) (FSAR Reference 2.5.1-406.)
(3) Orientation and length data for individual liquefaction and paleoliquefaction features are not applicable. Taken together, however, the distribution of Bluffton, Charleston, and Georgetown features indicates a NE orientation, parallel to the South Carolina coast.
(4) The proposed Hares Crossroads fault was recognized in a single, two-dimensional roadcut exposure. As such, orientation and length information are not available.

Reference:

1. Conley, J.F. and Toewe, E.C., Geology of the Martinsville West quadrangle, Virginia: Virginia Division of Mineral Resources Report of Investigations 16, 1:24,000-scale, 1968.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-27

FSAR Section 2.5.1.1.2.4.4 (pgs 2.5.1-27 and 2.5.1-28) discusses the Belair Fault and indicates that this structure may be a tear fault or lateral ramp in the hanging wall of the Augusta fault zone. If the Belair fault is associated with the Augusta fault zone in this manner, then movement on the Belair may be related to movement on the larger, regional-scale Augusta fault. The FSAR indicates that information exists (Prowell and O'Connor, 1978) which constrains the age of last movement on the Belair Fault to sometime between post-late Eocene and pre-26,000 years ago, rendering this fault to be a structure in the site region interpreted to show possible evidence of Quaternary movement.

In order for the staff to assess the hazard potential for the Belair fault, please discuss how the inference of possible Quaternary movement on this fault, coupled with its potential relationship to the regionalscale Augusta fault zone, could affect seismic hazard at the Summer site.

VCSNS RESPONSE:

As indicated in FSAR Subsection 2.5.1.1.2.4.4, mapping and structural analysis by Bramlett et al. (1982) (FSAR Reference 2.5.1-219) indicate that the Belair fault likely formed as lateral ramp or tear associated with the Augusta fault when these faults initiated during the Paleozoic Alleghanian orogeny. The timing and sense-of-slip for the most-recent movements on the Belair and Augusta faults, however, demonstrate that these two structures have not reactivated as a single tectonic element in Cenozoic or younger time. Prowell et al. (1975) (FSAR Reference 2.5.1-349) and Prowell and O'Connor (1978) (FSAR Reference 2.5.1-348) document Cenozoic, brittle, reverse slip on the Belair fault. The available data can be interpreted as indicating, but do not provide compelling evidence for, Quaternary slip on the Belair fault (Crone and Wheeler 2000) (FSAR Reference 2.5.1-232). In contrast, the latest movement on the Augusta fault exhibits a normal sense-of-slip and is constrained to late in the Alleghanian by geologic relations and $^{40}Ar/^{39}Ar$ cooling ages (Maher 1987 [FSAR Reference 2.5.1-320]; Maher et al. 1994 [FSAR Reference 2.5.1-321]).

Augusta fault movement spanned ductile to brittle conditions associated with late Alleghanian extension of the southern Appalachians (Maher et al. 1994) (FSAR Reference 2.5.1-321). The brittle overprinting on the Augusta fault is consistent with the ductile normal sense of slip. In contrast, the Belair fault exhibits a reverse sense-of-slip during its Cenozoic reactivation. Therefore, different slip histories and opposite senses of dip-slip for the Belair and Augusta faults demonstrate that these two faults have not been reactivated as a single structure during the Cenozoic Era.

The Belair fault has demonstrated Cenozoic slip, similar to other faults in the Coastal Plain, including the Pen Branch fault. As described in the Vogtle ESP Final Safety Evaluation Report (FSER) (Reference 1, ADAMS Accession ML090130404), detailed geomorphic studies of the Pen Branch fault along the margin of the Dunbarton basin have confirmed that this structure is not a capable tectonic source. None of the faults in the Coastal Plain that exhibit Cenozoic reactivation represent capable tectonic sources. Therefore, the hazard in this region is best modeled as areal seismic sources.

Reference:

1. Vogtle ESP Final Safety Evaluation Report - Chapter 2.0, Section 2.5 Geology, Seismology, and Geotechnical Engineering, dated February 4, 2009, (ADAMS Accession ML090130404).

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-28

FSAR Section 2.5.1.1.2.4.4 (pg 2.5.1-28) discusses the Pen Branch fault and concludes that it is not a capable tectonic structure. The FSAR refers to studies performed for the Vogtle ESP application, but does not summarize the evidence taken from these studies used to conclude that the Pen Branch fault is not a capable structure.

In order for the staff to assess the hazard potential for the Pen Branch fault, please summarize the information presented in the cited original source which was used to conclude that the Pen Branch fault is not a capable tectonic structure.

VCSNS RESPONSE:

As described in the Vogtle ESP Final Safety Evaluation Report (FSER) (Reference 1, ADAMS Accession ML090130404), NRC staff concur with the "conclusion that the Pen Branch fault is not a capable tectonic structure (as defined by RG 1.165)." [p.2-213] This conclusion is based largely on studies performed for the Vogtle ESP application, including:

- Geomorphic analysis of a Quaternary fluvial terrace surface overlying the Pen Branch fault at the Savannah River Site (SRS) in South Carolina,
- Seismic reflection surveys of the Pen Branch fault at the Vogtle site in Georgia, and
- Review of published literature.

These studies are described in detail in the Vogtle ESP FSER (Reference 1) and are described briefly below.

The Vogtle ESP FSER (Reference 1) describes the evaluation of topographic data collected along a Savannah River fluvial terrace surface at the SRS. The 350 ka to 1 Ma Ellenton terrace of the Savannah River forms a laterally continuous alluvial surface by which to assess the presence or absence of Quaternary tectonic deformation associated with the underlying Pen Branch fault. As part of work performed for the Vogtle ESP application, 2,600 new elevation data points were surveyed on the terrace surface. Elevations of the best-preserved remnants of the terrace surface range from 153 to 156 ft and the overall uncertainty in the elevation of the best-preserved remnants of the Ellenton terrace surface was estimated to be about 3 ft (Reference 1.) Longitudinal profiles approximately normal to the local strike of the Pen Branch fault and

parallel to the long axis of the terrace were constructed from these data. The results of this study demonstrate a lack of tectonic deformation in the 350 ka to 1 Ma Ellenton fluvial terrace surface within a resolution of about 3 ft (Reference 1.)
Seismic reflection data collected and processed for the Vogtle ESP application imaged the Pen Branch fault in the subsurface beneath the Vogtle site (Reference 1.) Work performed for the Vogtle ESP application used these data to refine the location of the Pen Branch fault at the Vogtle site and across the Savannah River at the SRS. The increased accuracy in the location of the Pen Branch fault was of critical importance to the Ellenton terrace study by allowing for a detailed analysis of an approximately 3-mile-long, fault normal terrace remnant. Moreover, the seismic reflection data suggest the Pen Branch fault at the Vogtle site terminates upward into a monoclinal fold within the Middle Eocene Blue Bluff Marl. These data demonstrate the absence of deformation of post-Eocene units (Reference 1.)

Approximately two decades of extensive studies at the SRS have failed to demonstrate post-Eocene deformation associated with the Pen Branch fault (Reference 1.) These studies include seismic reflection and refraction, drilling programs, and geomorphic analyses.

Taken together, the results of the Ellenton terrace study, seismic reflection and refraction surveys, and the literature review performed in support of the Vogtle ESP application indicate no evidence for post-Eocene slip on the Pen Branch fault. As such, the Pen Branch fault is not a capable tectonic structure.

Reference:

1. Vogtle ESP Final Safety Evaluation Report - Chapter 2.0, Section 2.5 Geology, Seismology, and Geotechnical Engineering, ADAMS Accession ML090130404, dated February 4, 2009.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-30

FSAR Section 2.5.1.1.2.4.4 (pgs 2.5.1-29 and 2.5.1-30) discusses the postulated Pembroke faults which are classified as Class B structures (i.e., possible Quaternary faulting) by Crone and Wheeler (2000). However, no information is provided on fault geometry or fault length, and the FSAR states that it is unclear whether they are of tectonic origin or are the result of dissolution collapse.

In order for the staff to assess the hazard potential for these faults, please summarize information on fault geometry and fault length and present lines of evidence related to whether these features are tectonic or non-tectonic in origin as derived from primary data sources, rather than relying only on the compiled information presented by Crone and Wheeler (2000).

VCSNS RESPONSE:

The Pembroke faults are located in alluvial terrace deposits of the New River near Pembroke, Virginia, approximately 200 mi north of the VCSNS site and approximately 180 ft above local river level (Dennison and Stewart 1998) (Reference 2.) New River terrace strata near Pembroke, Virginia are folded in a broad, roughly 100-m-wide, east-northeast-trending anticline with limb dips up to 30° (Law et al. 1992) (Reference 4.) Numerous northeast- to east-northeast-striking extensional and reverse faults, collectively known as the Pembroke faults, are found within these terrace deposits. Most of these faults display individual dip separations of a few decimeters, although the five largest extensional faults have dip separations of 1 m to greater than 7 m (Law et al. 1992) (Reference 4.) Law et al. (1997) (Reference 5) describe maximum total oblique displacement of roughly 11 m for the largest of the extensional faults.

The Pembroke faults are exposed in a two-dimensional road cut, thus fault lengths are unresolved. In the vicinity of the roadcut exposure, there are no scarps or other geomorphic expressions of the Pembroke faults (Dennison and Stewart 1998) (Reference 2.) Based on geophysical surveys, the minimum length of the Pembroke faults is estimated at 100 m (Robinson et al. 1994; Williams and Callis 1996; Callis and Williams 1997; Law et al. 1997; Peavy and Sayer 1998) (References 8; 9; 1; 5; 7.) Moreover, the small slip estimates suggest that these faults likely are a few meters to a few hundred meters long (Crone and Wheeler 2000) (FSAR 2.5.1-232.)

Law et al. (1997) (Reference 5) estimate the age of the faulted deposits at latest Pliocene to early Quaternary. Based on cosmogenic $^{26}AL/^{10}Be$ dating, Granger and

Kirchner (1995) (Reference 3) estimate the burial ages of these sediments between 1.5±0.2 and 2.0±0.2 Ma. These terrace deposits overlie faulted and folded Ordovician carbonate rocks that are susceptible to dissolution. Peavy and Sayer (1998) (Reference 7) observe numerous sinkholes in these terrace deposits and attribute the sinkholes to dissolution of the underlying Ordovician carbonates. During exploratory drilling, Law et al. (1998) (Reference 6) encountered a 10-ft-high subsurface cavity in sandy clays at a depth of 65 ft below ground surface. Law et al. (1998) (Reference 6) suggest that this cavity is the result of dissolution collapse of underlying limestone bedrock and the upward migration of collapse structures through the overlying sediments.

The Pembroke faults are in the general vicinity of the Giles County seismic zone, but it is unclear whether these faults are related to earthquakes or are the result of dissolution collapse. To date, it has not been determined definitively whether tectonic deformation or limestone dissolution and collapse of the overlying sediments best describes the origin of the Pembroke faults (e.g., Williams and Callis 1996; Law et al. 1997; Crone and Wheeler 2000) (References 6; 5; FSAR Reference 2.5.1-232). Some investigators initially concluded that the Pembroke faults formed in response to tectonic rather than surficial processes (Law et al. 1992) (Reference 4). More recently, however, these same researchers and the weight of the evidence described above support karst dissolution as a preferred explanation for formation of the Pembroke faults (Law et al. 1997, 1998) (References 5 and 6).

References:

1. Callis, J.G. and Williams, R.T., "Geophysical images and geologic models for Quaternary faults near Pembroke, Virginia, using seismic reflection and ground penetrating radar," Seismological Research Letters, v. 68, p. 815, 1997.
2. Dennison, J.M. and Stewart, K.G. (eds), Geologic Field Guide to Extensional Structures Along the Allegheny Front in Virginia and West Virginia near the Giles County Seismic Zone, March 28-29 Fieldtrip Guidebook, Geological Society of America Southeastern Section, 102 p., 1998.
3. Granger, D.E. and Kirchner, J.W., "Downcutting rate of the New River, Virginia, from $^{26}Al/^{10}Be$ in buried river gravels," Eos- Transactions of the American Geophysical Union, v. 76, no. 46 supplement, p. F689, 1995.
4. Law, R.D., Pope, M.C., Wirgart, R.H., Bollinger, G.A., and Whitmarsh, R.S., "Geologically recent near-surface folding and faulting in the Valley and Ridge province – new exposures of extensional faults in alluvial sediments, Giles County, SW Virginia," Seismological Research Letters, v. 63, p. 609-610, 1992.
5. Law, R.D., Robinson, E.S., Cyrnak, J.S., Sayer, S., Williams, R.T., Callis, J., and Pope, M., "Geologically-recent faulting and folding of alluvial sediments near Pearisburg, Giles, County, Virginia- tectonic faulting or karst subsidence in origin?" Eos- Transactions of the American Geophysical Union, v. 78, no. 17 supplement, p. S316, 1997.
6. Law, R.D., Robinson, E.S., Sayer, S., Cyrnak, J.S., Williams, R.T., Callis, J., and Pope, M., "Geologically-recent faulting and folding of alluvial sediments near

Pearisburg, Giles, County, Virginia- tectonic faulting or karst subsidence in origin?" in J.M. Dennison and K.G. Stewart (eds), Geologic Field Guide to Extensional Structures Along the Allegheny Front in Virginia and West Virginia near the Giles County Seismic Zone, Geological Society of America Southeast Section, Fieldtrip Guidebook, p. 95-101, 1998.

7. Peavey, S.T. and Sayer, S., "Analysis of a possible neotectonic feature in SW Virginia using potential field attributes (PFA)," Geological Society of America Abstracts with Programs, v. 30, no. 1, p. 66, 1998.
8. Robinson, E.S., Sayer, S., Phinny, E.J., and Law, R.D., "A geophysical survey of faulted alluvial 'terrace' deposits near Pembroke, Virginia," Geological Society of America Abstracts with Programs, v. 26, no. 4, p. 59-60, 1994.
9. Williams, R.T. and Callis, J.G., "Collocated seismic reflection and radar profiles over Quaternary normal faults in southwestern Virginia," Eos- Transactions of the American Geophysical Union, v. 77, no. 46 supplement, p. F497-F498, 1996.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-31

FSAR Section 2.5.1.1.2.4.5 (pg 2.5.1-31) indicates that the New York-Alabama Lineament (NYAL) is shown on both Figures 2.5.1-211 and 2-5-1-212. However, the NYAL is not shown on Figure 2.5.1-212 as this FSAR section implies.

In order for the staff to assess the accuracy of the regional geologic characterization provided in the FSAR in relation to geophysical anomalies and lineaments, please include the NYAL in Figure 2.5.1- 212 if it is to be cited as showing it, or refer to the correct figure(s) in which it is shown.

VCSNS RESPONSE:

The New York-Alabama Lineament (NYAL) is labeled clearly on FSAR Figure 2.5.1-211, but is located beyond the region shown on FSAR Figure 2.5.1-212. The text of FSAR Subsection 2.5.1.1.2.4.5 will be modified to indicate that the NYAL is shown on Figure 2.5.1-211 and not Figure 2.5.1-212.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

FSAR Subsection 2.5.1.1.2.4.5, seventh paragraph, page 2.5.1-31, will be updated in a future FSAR revision as follows:

The New York-Alabama, Clingman, and Ocoee Lineaments
King and Zietz (Reference 308) ~~identify~~ identified a 1,000-mile (1,600-kilometer)-long lineament in ~~aero~~magnetic maps of the eastern United States that they referred to as the "New York-Alabama lineament" (~~Figures 2.5.1-211 and 2.5.1-212~~Figure 2.5.1-211). The New York-Alabama lineament primarily is defined by a series of northeast-southwest-~~-~~trending linear magnetic gradients in the Valley and Ridge province of the Appalachian fold belt that systematically intersect and truncate other magnetic anomalies. The New York-Alabama lineament also is present as a complementary but less well-defined lineament on regional gravity maps (Reference 308).

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-33

FSAR Section 2.5.1.1.2.4.5 (pg 2.5.1-33) discusses the Grenville Front, but does not state the age of this regional feature.

In order for the staff to assess the adequacy of the regional geologic characterization provided in the FSAR, please qualify the age of the Grenville Front.

VCSNS RESPONSE:

The Grenville orogeny was a major plutonic, metamorphic, and deformational event that affected a broad area along the southeastern border of Laurentia during the Proterozoic, roughly 1,000 Ma (e.g., Whitmeyer and Karlstrom 2007.) The Grenville front marks the northwestern limit of tectonic reworking of rocks of the older provinces during the Grenville orogeny. As such, the Grenville front separates relatively undeformed rocks of the granite-rhyolite province on the northwest from more highly deformed rocks of the Grenville province on the southeast and, at its youngest, is Late Proterozoic in age.

Reference:

Whitmeyer, S.J. and Karlstrom, K.E., Tectonic model for the Proterozoic growth of North America, *Geosphere*, Volume 3, Number 4, p. 220-259, 2007.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-40

FSAR Section 2.5.1.1.3.2.3 (pg 2.5.1-42) states that the January 23, 1812, earthquake in the New Madrid seismic zone was associated with strike-slip displacement along the East Prairie fault located in the northern portion of that seismic zone. Existence of the East Prairie fault is not documented by references.

In order for the staff to completely understand the geologic setting of the Summer site in relation to well defined zones of seismicity within the site region, please provide references to document the location of the east Prairie fault within the New Madrid seismic zone.

VCSNS RESPONSE:

Positive correlation of the January 23, 1812, earthquake in the New Madrid seismic zone with a particular fault, including the East Prairie fault, cannot be definitively stated based on available data. Hough et al. (2000) (FSAR Reference 2.5.1-293) and Bakun and Hopper (2004) (FSAR Reference 2.5.1-206), however, indicate that this earthquake likely occurred in the northern portion of the New Madrid seismic zone. The text of FSAR Subsection 2.5.1.1.3.2.3 will be revised to indicate that the January 23, 1812 earthquake likely occurred somewhere in the northern portion of the New Madrid seismic zone.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

FSAR Subsection 2.5.1.1.3.2.3, sixth paragraph, page 2.5.1-42, will be updated in a future FSAR revision as follows:

The January 23, 1812 earthquake is associated with ~~strike-slip fault displacement on the East Prairie fault along~~ the northern portion of the New Madrid seismic zone (References 293 and 206). Johnston (Reference 297) estimates a magnitude of **M** 7.8±0.33 for the January 23, 1812, event. Hough et al. (Reference 293), however, reevaluate the isoseismal data for the region and conclude that the January 23 event had a magnitude of **M** 7.1. More recently, Bakun and Hopper (Reference 206) estimate a similar magnitude of **M** 7.1.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 033 Dated February 12, 2009

SRP Section: 2.5.1 – Basic Geologic and Seismic Information

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS2)

NRC RAI Number: 02.05.01-41

FSAR Section 2.5.1.1.3.2.3 (pgs 2.5.1-42 and 2.5.1.-43) discusses the Central Virginia seismic zone (CVSZ), including two paleoliquefaction sites identified within the seismic zone. This section states further that, while the paleoliquefaction features reflect pre-historic seismicity within the CVSZ, they "do not indicate the presence of a capable tectonic source". This statement results in confusion because the distinction between the seismic zone (which does contain paleoseismic features indicating pre-historic faulting and resultant seismicity) and a fault acting as the specific tectonic source within the zone (to which the paleoseismic features can be related) is not clearly made.

In order for the staff to assess the information presented in the FSAR on the CVSZ, please make a clearer distinction between the seismic zone and a fault acting as the specific tectonic source within the zone.

VCSNS RESPONSE:

As described in FSAR Subsection 2.5.1.1.3.2.3, the Central Virginia Seismic Zone is an area of persistent, low-level seismicity in the Piedmont province, approximately 250 miles from the VCSNS site. In addition to the historical record of earthquakes in this zone, evidence for prehistoric ground shaking is recorded at two paleoliquefaction sites within the zone (FSAR References 2.5.1-232 and 2.5.1-238). This seismicity, however, is not uniquely attributable to any specific fault source or fault sources. As such, the seismic hazard in the Central Virginia Seismic Zone is modeled as areal seismic source zones (FSAR References 2.5.1-250, 2.5.1-215, and 2.5.1-222), as opposed to a discrete fault source.

Some wording in FSAR Subsection 2.5.1.1.3.2.3 is potentially misleading and will be modified for clarity. Revised FSAR Subsection 2.5.1.1.3.2.3 clearly will state that, whereas both prehistoric and historical earthquakes are associated with the Central Virginia Seismic Zone, this seismicity is not positively associated with any clearly defined fault or faults.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

FSAR Subsection 2.5.1.1.3.2.3, ninth through twelfth paragraphs, page 2.5.1-43, will be updated in a future FSAR revision as follows:

Central Virginia Seismic Zone

The Central Virginia Seismic Zone is an area of persistent, low-level seismicity in the Piedmont province, located more than 250 miles from the VCSNS site (Figure 2.5.1-216). The zone extends about 75 miles in a north-south direction and about 90 miles in an east-west direction from Richmond to Lynchburg, Virginia (Reference 216). The largest historical earthquake to occur in the Central Virginia Seismic Zone was the body-wave magnitude (mb) 5.0 Goochland County event on December 23, 1875 (Reference 216). The maximum intensity estimated for this event was MMI VII in the epicentral region. In addition to the historical record of earthquakes in this zone, evidence for prehistoric ground shaking is recorded at two paleoliquefaction sites within the zone (References 232 and 238).

Seismicity in the Central Virginia Seismic Zone ranges in depth from about 2 to 8 miles (4 to 13 kilometers) (Reference 408). Coruh et al. (Reference 231) suggest that seismicity in the central and western parts of the zone may be associated with west dipping reflectors that form the roof of a detached antiform, while seismicity in the eastern part of the zone near Richmond may be related to a near-vertical diabase dike swarm of Mesozoic age. However, given the depth distribution of 2 to 8 miles (4 to 13 kilometers) (Reference 408) and broad spatial distribution, it is difficult to uniquely attribute the seismicity to any known geologic structure, and it appears that the seismicity extends both above and below the Appalachian detachment.

The historical and prehistoric seismicity within the Central Virginia Seismic Zone is not positively associated with any clearly defined fault or faults. As such, the seismic hazard in this zone is modeled as areal seismic source zones. ~~No capable tectonic sources are identified within the Central Virginia Seismic Zone, but two paleoliquefaction sites are identified within the seismic zone (References 232 and 338). The paleoliquefaction sites reflect prehistoric occurrences of seismicity within the Central Virginia Seismic Zone and do not indicate the presence of a capable tectonic source.~~

The 1986 EPRI source model includes various source geometries and parameters to capture the seismicity of the Central Virginia Seismic Zone (Reference 250). Subsequent hazard studies use Mmax values that are within the range of maximum magnitudes used by the six EPRI models. Collectively, upperbound maximum values of Mmax used by the EPRI ESTs range from mb 6.6 to 7.2 (discussed in Subsection 2.5.2). More recently, Bollinger (Reference 215) estimates an Mmax of mb 6.4 for the Central Virginia seismic source. Chapman and Krimgold (Reference 222) use an Mmax of mb 7.25 for the central Virginia seismic source and most other sources in their seismic hazard analysis of Virginia. This more recent estimate of Mmax is similar to the Mmax values used in EPRI (Reference 250). Similarly, the distribution and rate of seismicity in the central Virginia seismic source have not changed since the 1986 EPRI study (discussed in Subsection 2.5.2). Thus, there is no change to the source geometry or rate of seismicity. Therefore, the conclusion is that no new information has been developed since 1986 that would require a significant revision to the EPRI seismic source model.

ASSOCIATED ATTACHMENTS:

None