Vogtle PEmails

From: Christian Araguas
Sent: Wednesday, November 12, 2008 3:16 PM
To: jtdavis@southernco.com
Cc: agaughtm@southernco.com; crpierce@southernco.com; wasparkm@southernco.com
Subject: Advanced Safety Evaluation Report on the VEGP ESP and LWA Part 3a/3
Attachments: Vogtle ESP Advanced SER Section 2.5.1.pdf

Jim,

Attached are the pdf files for each of the individual chapters in the advanced SER. Please begin your proprietary review. Following your review, the documents will be made public in ADAMS and will be posted on the NRC's public website. Let me know if you have any questions. The signed cover letter should go out today. Please confirm receipt of the attached files. Thanks.

Christian Araguas
Lead Project Manager
AP1000 Projects Branch 1
Division of New Reactor Licensing
Office of New Reactors

Hearing Identifier: Vogtle_Public_EX
Email Number: 123

Mail Envelope Properties (Christian.Araguas@nrc.gov20081112151500)

Subject: Advanced Safety Evaluation Report on the VEGP ESP and LWA Part 3a/3
Sent Date: 11/12/2008 3:15:31 PM
Received Date: 11/12/2008 3:15:00 PM
From: Christian Araguas

Created By: Christian.Araguas@nrc.gov

Recipients:
"agaughtm@southernco.com" <agaughtm@southernco.com>
Tracking Status: None
"crpierce@southernco.com" <crpierce@southernco.com>
Tracking Status: None
"wasparkm@southernco.com" <wasparkm@southernco.com>
Tracking Status: None
"jtdavis@southernco.com" <jtdavis@southernco.com>
Tracking Status: None

Post Office:

Files	**Size**	**Date & Time**
MESSAGE	545	11/12/2008 3:15:00 PM
Vogtle ESP Advanced SER Section 2.5.1.pdf		1071481

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

2.5 Geology, Seismology, and Geotechnical Engineering

In Section 2.5, “Geology, Seismology, and Geotechnical Engineering,” of the VEGP SSAR, the applicant described geologic, seismic, and geotechnical engineering properties of the VEGP ESP site. SSAR Section 2.5.1, “Basic Geologic and Seismic Information,” presents information on geologic and seismic characteristics of the VEGP site and region surrounding the site. SSAR Section 2.5.2, “Vibratory Ground Motion,” describes the vibratory ground motion assessment for the ESP site through a PSHA and develops the SSE ground motion. SSAR Section 2.5.3, “Surface Faulting,” evaluates the potential for surface tectonic and non-tectonic deformation at the ESP site. SSAR Sections 2.5.4, “Stability of Subsurface Materials and Foundations,” 2.5.5, “Stability of Slopes,” and 2.5.6, “Embankments and Dams,” describe foundation and subsurface material stability at the ESP site.

The applicant reviewed reports from previous investigations for the existing VEGP Units 1 and 2 as a starting point for the characterization of the geologic, seismic, and geotechnical engineering properties of the site. The applicant also referred to published geologic literature and seismicity data, new borehole data for the proposed VEGP Units 3 and 4, seismic reflection and refraction surveys, and detailed investigations of the nearby SRS. Results of the investigations and analyses performed by the applicant for each of the SSAR Sections (2.5.1 to 2.5.6) provide information used to determine the SSE, as described in NRC RG 1.165 titled, “Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion.”

The applicant defined the following four terms for areas in which investigations for the VEGP ESP site occurred, as designated by RG 1.165.

Site region: an area within 320 km (200 mi) of the site location.
Site vicinity: an area within 40 km (25 mi) of the site location.
Site area: an area within 8 km (5 mi) of the site location.
Site: an area within 1 km (0.6 mi) of the proposed VEGP Units 3 and 4 locations.

This RG also provides guidance on recommended levels of investigation for each of these areas.

The applicant also used the seismic source and ground motion models published in the EPRI’s (1986) “Seismic Hazard Methodology for the Central and Eastern United States [CEUS as the starting point for its seismic hazard evaluation. The applicant used the procedures recommended in RG 1.165 for performing the probabilistic seismic hazard analysis (PSHA) for the ESP site, and employed the performance-based approach described in RG 1.208, “A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion” for determining the SSE.

The applicant conducted field investigations, examined relevant geologic literature, and concluded that no geologic or seismic hazards have the potential to affect the VEGP ESP site, except for the Charleston seismic zone and a small magnitude local earthquake occurring in the site region. The applicant also concluded that there is only limited potential for non-tectonic surface deformation within the 8 km (5 mi) site area radius, and that this potential could be mitigated by excavation of shallow deposits overlying the foundation bearing unit.

This SER, compiled by the NRC staff, is divided into six main sections, 2.5.1 to 2.5.6, which parallel the six main sections included in the applicant's SSAR. Each of the six SER sections is then divided into four sub-sections: (1) "Technical Information in the Application" that describes the contents of the SSAR, the investigations performed by the applicant, and the results; (2) "Regulatory Basis" that provides a summary of the regulations and NRC regulatory guides used by the applicant to formulate the SSAR; (3) "Technical Evaluation" that describes the staff's evaluation of what the applicant did, including any requests for additional information (RAI's), open items, and any confirmatory analyses performed by the NRC staff; and (4) the final "Conclusions" sub-section for each main section that documents whether or not the applicant provided a thorough characterization for the site and if its results provide an adequate basis for the conclusions made by the applicant.

2.5.1 Basic Geologic and Seismic Information

Section 2.5.1.1 of this SER provides a summary of relevant geologic and seismic information contained in SSAR Section 2.5.1 of the VEGP application. SER Section 2.5.1.2 provides a summary of the regulations and guidance used by the applicant to perform its investigation. SER Section 2.5.1.3 provides a review of the staff's evaluation of SSAR 2.5.1, including any requests for additional information, any open items, and any confirmatory analyses performed by the staff. Finally, SER Section 2.5.1.4 provides an overall summary of the applicant's conclusions, as well as the staff's conclusions, restates any bases covered in the application, and confirms that regulations were met or fulfilled by the applicant.

In SSAR Section 2.5.1, the applicant described geologic and seismic characteristics of the VEGP site region and site area. SSAR Section 2.5.1.1, "Regional Geology," describes the geologic and tectonic setting of the site region (within a 320 km (200 mi) radius), and SSAR Section 2.5.1.2, "Site Geology," describes the structural geology of the site area (within an 8 km (5 mi) radius). In SSAR Section 2.5.1, the applicant also provided an update of geologic, seismic and geophysical data for the VEGP site and then reviewed the updated information, pursuant to RG 1.165, to determine whether any of the data published since the mid-1980's requires an update to the 1986 EPRI seismic source model.

The applicant developed SSAR Section 2.5.1 based on information derived from the review of previously prepared reports for existing VEGP Units 1 and 2, and published geologic literature, new boreholes drilled for potential VEGP Units 3 and 4, and seismic reflection and refraction surveys conducted for the ESP application. The applicant also used recently published literature to supplement and update existing geologic and seismic information.

2.5.1.1 Technical Information in the Application

2.5.1.1.1 Regional Geologic Description

SSAR Section 2.5.1.1, "Regional Geology," discusses the physiography, geomorphology, geologic history, stratigraphy, and geologic setting within a 320 km (200 mi) radius of the VEGP site. The applicant reviewed previous reports prepared for VEGP Units 1 and 2, as well as geophysical data and published geologic literature, in order to compile the regional geologic description. The applicant collected new data in order to assess whether or not the Pen Branch fault is a capable tectonic structure of Quaternary age (1.8 million years ago (mya) to present). The applicant concluded that regional geologic characteristics pose no safety issues that would impact the VEGP site. The applicant applied the information in this section towards developing a basis for evaluation of the geologic and seismic hazards covered in succeeding sections of the SSAR. Based on its review, the applicant presented the following information related to the regional geology for the ESP site.

Physiography, Geomorphology and Geologic History

SSAR Section 2.5.1.1.1 describes the regional physiography and geomorphology of the ESP site. From northwest to southeast, the site region includes parts of the Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain physiographic provinces. Figure 2.5.1-1, reproduced from SSAR Figure 2.5.1-1, illustrates these four provinces. The VEGP ESP site lies within the Coastal Plain province approximately 48 km (30 mi) southeast of the line ("fall line") separating crystalline rocks of the Piedmont province from sediments of the Coastal Plain province. The Coastal Plain province is one of low topographic relief. Depositional landforms and topography strongly modified by fluvial erosion characterize the VEGP ESP site within the Coastal Plain province. Based on published information (Soller and Mills, 1991), the applicant described Carolina Bays (shallow, elliptical landforms which commonly occur in the Coastal Plain province) as surficial, non-tectonic features resulting from erosion by southwesterly-oriented winds (eolian erosion) that have no effect on subsurface sediments. Several investigators have documented that strata are continuous and undeformed beneath both bay and interbay areas.

The applicant described the geologic history of the ESP site in SSAR Section 2.5.1.1.2. Although the ESP site is located in the Coastal Plain, all major lithotectonic (characteristically unified rock assemblage) divisions of the Appalachian mountain belt occur within the site region. The applicant stated that geologic structures and stratigraphic sequences within these lithotectonic divisions represent a complex geologic evolution ending in the modern-day, passive Atlantic continental margin. This complex evolution resulted in the deposition of Cretaceous (144 to 65 mya) and Tertiary (65 to 1.8 mya) age sediments of the Coastal Plain; Quaternary (1.8 mya to present) materials in fluvial terraces along the Savannah River and its tributaries; and colluvial (loose, heterogeneous soil material and rock fragments), alluvial (unconsolidated material deposited during relatively recent geologic time by running water) and eolian sediments, all within the site area.

Stratigraphy and Geologic Setting

In SSAR Section 2.5.1.1.3, the applicant described regional stratigraphy and geologic setting (including stratigraphy, rock type, and geologic history) for the (1) Valley and Ridge; (2) Blue Ridge; (3) Piedmont; (4) Mesozoic rift basins; and (5) Coastal Plain provinces.

1. Folded and thrust-faulted Paleozoic (543 to 248 mya) sedimentary cover rocks overlying crystalline basement represent the Valley and Ridge lithotectonic terrane, located about 290 km (180 mi) west-northwest of the VEGP ESP site. A series of northeast-southwest trending, parallel valleys, and ridges are responsible for the physiographic expression within the Valley and Ridge terrace. Most of the folding and faulting deformation is likely late Paleozoic in age (at least 248 mya).

2. A complexly folded, faulted, penetratively deformed, metamorphosed crystalline basement and cover rock sequence containing intrusive igneous rocks represents the Blue Ridge lithotectonic province, located about 225 km (140 mi) northwest of the ESP site. Multiple deformation events indicated by deformation features in the rocks relate to late Proterozoic to late Paleozoic (248 mya and older) extension and compression.

3. Variably deformed and metamorphosed igneous and sedimentary rocks ranging in age from Proterozoic to Permian (248 mya and older) represent the Piedmont Province, located about 48 km (30 mi) northwest of the ESP site. The applicant stated that Piedmont province rocks generally underlie Coastal Plain province sediments, but that the southeastern extent of the Piedmont province beneath the Coastal Plain is unknown.

4. Mesozoic Rift Basins typically consist of non-marine sandstone, conglomerate, siltstone, shale, carbonates, coal, and basaltic igneous rocks. One of these basins, the Dunbarton Triassic basin, is beneath the Coastal Plain sediments at the VEGP ESP site. Geophysical investigations, including seismic reflection, suggest that the Triassic (206 to 24 mya) section of the Dunbarton basin is at least 2 km (1.2 mi) thick. The primary fault bounding this basin on the northwest side is the Pen Branch fault, which dips to the southeast. The applicant described the Pen Branch fault to be a Paleozoic reverse fault, reactivated as an extensional normal fault during the Mesozoic (248 to 65 mya) and subsequently reactivated as a reverse fault during the Cenozoic (65 mya to present).

5. Erosion-beveled rocks of Paleozoic and Triassic age (543 to 206 mya) and unconsolidated to poorly consolidated Coastal Plain sediments deposited unconformably above the erosional surface represent the Coastal Plain province where the ESP site is located. This seaward-dipping wedge extends from the contact with crystalline rocks of the Piedmont physiographic province (the fall line) to the edge of the continental shelf. Sediment thickness increases from zero at the fall line to about 1200 m (4000 feet) at the Georgia coastline. The sediment thickness is about 335 m (1000 feet) in the center of the VEGP site area and is composed of Upper Cretaceous, Tertiary, and unconsolidated Quaternary deposits.

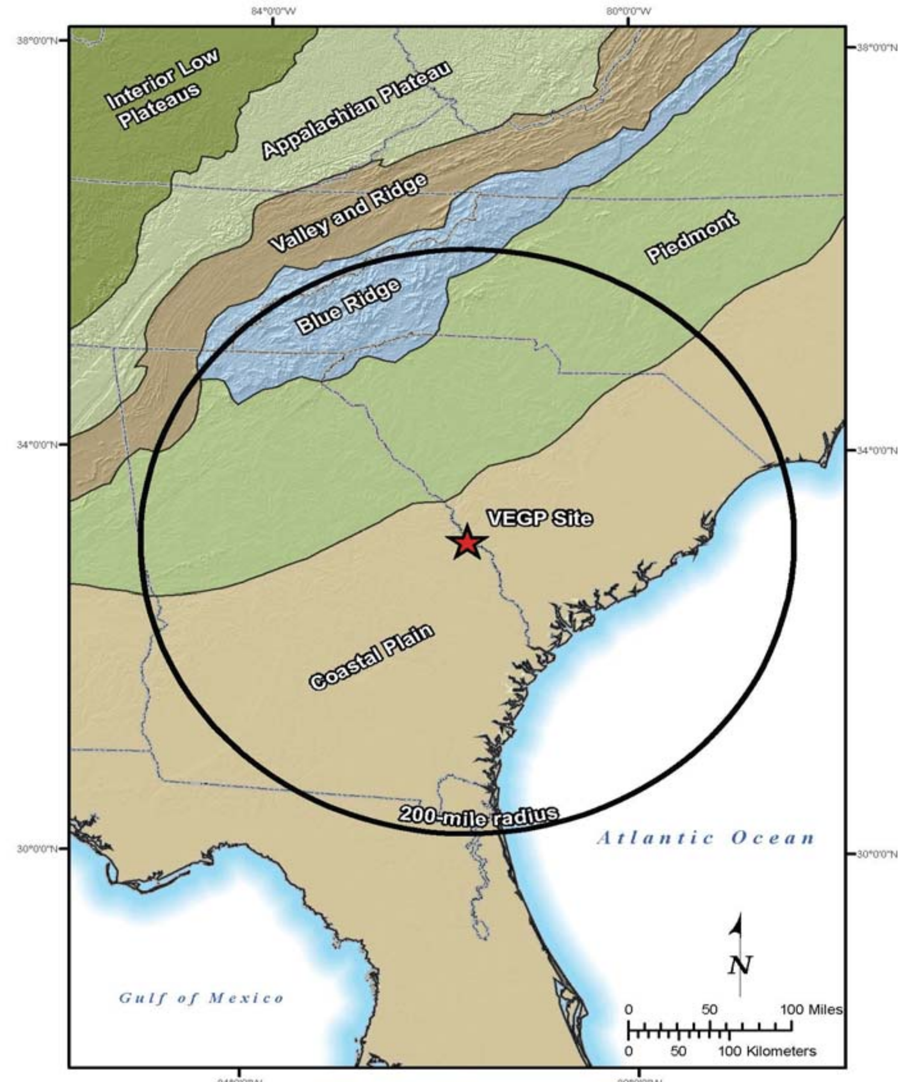

Figure 2.5.1-1 - Physiographic Provinces of the Southeastern United States

Quaternary Period (1.8 mya-present) surfaces and deposits are preserved primarily in the fluvial terraces along the Savannah River and its major tributaries, as well as in colluvium, alluvium, and eolian sediments in upland settings. Nested fluvial terraces, preserved along the east side of the Savannah River, can be used to evaluate Quaternary deformation within the Savannah River area. Major stream terraces develop as a result of sequential erosional and depositional events which may be due to tectonism, isostacy, or climatic variations. In SSAR Section 2.5.1.1.3.5, the applicant described two prominent terraces above the modern flood plain and along the east side of the Savannah River in the ESP site vicinity. The Bush Field terrace (mapped as Quaternary terrace surface "Qtb") is preserved primarily on the northeast side of the Savannah River and its surface ranges from 8 to 13 m (26 to 43 ft) above the river. Ellenton terrace surfaces (mapped as "Qte") range from 17 to 25 m (56 to 82 ft) above the river. The applicant estimated the age of the older Ellenton terrace to be 350 thousand to 1 million years old. The younger Qtb terrace is estimated to be about 90 thousand years old.

2.5.1.1.2 Regional Tectonic Description

The applicant described the tectonic setting, tectonic structures, and seismic source zones in sub-sections 2.5.1.1.4.1 through 2.5.1.1.4.6 of SSAR Section 2.5.1.1.4. The applicant discussed plate tectonic evolution of the Appalachian orogenic belt at the latitude of the ESP site, tectonic stress in the mid-continent region, principal regional tectonic structures, Charleston tectonic features, SRS tectonic features, and seismic sources defined by regional seismicity. SSAR Section 2.5.1.1.5 outlines the applicant's review of regional gravity and magnetic data, and the models used to supplement their interpretations of regional geologic and tectonic features discussed in SSAR Sections 2.5.1.1.3 and 2.5.1.1.4. The applicant concluded that (1) tectonic features in the site region are Paleozoic (> 248 mya), Mesozoic (248 to 65 mya), and Cenozoic (< 65.5 mya) in age but only the Quaternary (< than 1.8 mya) features require additional consideration for this ESP; (2) there is no significant change to the understanding of stress in the CEUS that would require updates to the currently accepted data; (3) of 11 potential Quaternary features evaluated by the applicant, only paleoliquefaction features associated with the Charleston source earthquakes clearly demonstrate the existence of a Quaternary tectonic feature; (4) based on new source geometry and earthquake recurrence information, the Charleston seismic source requires updated parameters; and (5) that there are no unexplained anomalies expressed in the gravity or magnetic data for the VEGP site region and no evidence present in the data for Cenozoic age structures or deformation. Based on published information, the applicant presented the following information related to the regional tectonic setting:

<u>Plate Tectonic Evolution and Stress Field</u>

The applicant discussed plate tectonic evolution of the Appalachian orogenic belt at the latitude of the site region in SSAR Section 2.5.1.1.4.1 and acknowledged the four principal tectonic elements of the Appalachian orogen: the Valley and Ridge province, Blue Ridge province, Piedmont province, and Coastal Plain province. These four tectonic elements correspond to the four physiographic provinces described in SSAR Section 2.5.1.1.1 and shown in Figure 2.5.1-1. The Appalachian orogenic belt, trending northeast-southwest and extending from southern New York State into Alabama, records the opening (between 900 to 543 mya) and closing (543 to 248 mya) of the proto-Atlantic Ocean along the eastern margin of ancestral North America. Compressional deformation due to continental collisions occurred during the Ordovician (490-443 mya), Devonian (417 to 354 mya), and Late Paleozoic (320 to 250 mya). Triassic (248 to 206 mya) basins, including the Dunbarton Basin, which occur in the Appalachian orogenic belt, represent Mesozoic rifting. Stratigraphic units of the coastal plain, the province within which the ESP site lies, record development of a passive continental margin along the east coast of the United States that followed the Mesozoic rifting and the opening of the present-day Atlantic ocean basin. The applicant concluded that, despite uncertainties in regard to origin, mode of emplacement, and boundaries of the different structural and lithologic terranes that exist in the principal tectonic provinces, there is reasonable agreement among existing tectonic models on regional structural features of the southern Appalachian orogenic belt.

In SSAR Section 2.5.1.1.4.2, the applicant discussed the regional tectonic stress acting on the mid-continent region, specifically the CEUS. The 1986 EPRI evaluation of intra-plate stresses determined that the CEUS is characterized by northeast-southwest directed horizontal compressive stress attributed mostly to ridge-push forces associated with the Mid-Atlantic ridge. The applicant concluded that based on investigations conducted since the EPRI study, which support the initial EPRI findings, there is no significant change to the understanding of stress in the CEUS and therefore it is not necessary to reevaluate the seismic potential of tectonic sources in the region based on the regional tectonic stress.

Principal Regional Tectonic Structures

In SSAR Section 2.5.1.1.4.3, the applicant defined and discussed four categories of principal regional tectonic structures occurring within a 320 km (200 mi) radius of the VEGP site based on age of formation or reactivation of the structures. These four categories included tectonic structures of (1) Paleozoic (543 to 248 mya); (2) Mesozoic (248 to 65 mya); (3) Tertiary (65 to 1.8 mya); and (4) Quaternary (1.8 mya to present) age. The applicant also discussed regional geophysical anomalies and lineaments potentially equated with tectonic features.

1. Paleozoic Tectonic Structures. The applicant indicated that rocks and structures within the physiographic provinces included in the site region are associated with thrust sheets that formed by convergent Appalachian orogenic events during the Paleozoic. In the case of the Coastal Plain province where the ESP site is located, these rocks and structures are buried beneath sedimentary cover. The majority of these structural features dip eastward into a basal, shallow dipping fault (decollement) structure. The applicant discussed two primary Paleozoic fault zones, the Augusta and the Modoc, as well as a number of other Paleozoic faults within the ESP site region, including the Hayesville Fault, the Brevard Fault, the Towaliga Fault, the Central Piedmont Suture, and the Eastern Piedmont Fault System. The applicant concluded that none of these structures are capable tectonic sources of concern for the VEGP site and that no new information has been published since 1986 on these Paleozoic faults in the site region that would result in a significant change to the EPRI seismic source model.

2. Mesozoic Tectonic Structures. The applicant recognized the broad zone of fault-bounded depositional basins associated with crustal extension and rifting in early Mesozoic time (Triassic period, 248 to 206 mya). These are relatively common features along the east coast of North America. Figure 2.5.1-2, taken from SSAR Figure 2.5.1-16, shows one of these east-northeast-trending Triassic basins, the Dunbarton Basin, which lies beneath the VEGP site and the SRS. This basin, approximately 50 km (31 mi) long and 10 to 15km (6 to 9 mi) wide, is bounded on its northwest side by the Pen Branch Fault, which experienced normal fault displacement during the Triassic. The Pen Branch fault is interpreted to have been reactivated in the Cenozoic (65 mya to present) as a reverse fault. The applicant stated that no definitive

correlation of seismicity with any Mesozoic normal fault has been conclusively demonstrated.

3. <u>Tertiary Tectonic Structures</u>. The applicant stated that only a few tectonic features were active in the Tertiary Period (65 to 1.8 mya) within the ESP site area. The applicant referred to a series of arches and embayments (topographic highs and lows) that exerted control on Coastal Plain sedimentation from late Cretaceous through Pleistocene time (144 mya to 10,000 ya) as indicative of episodic differential tectonic movement. The applicant concluded that the most prominent arches in the VEGP site region, the Cape Fear Arch on the South Carolina-North Carolina border, and the Yamacraw Arch on the Georgia-South Carolina border show no evidence of being active.

4. <u>Quaternary Tectonic Structures</u>. The applicant discussed 11 potential Quaternary features within a 320 km (200 mi) radius of the VEGP ESP site as shown in Figure 2.5.1-3, reproduced from SSAR Figure 2.5.1-17. Table 2.5.1-1, reproduced from SSAR Table 2.5.1-1, provides definitions and classes used to categorize these same potential features. The 11 potential Quaternary features discussed by the applicant include the Charleston, Georgetown, and Bluffton paleoliquefaction features, the East Coast Fault System (ECFS), the Cooke fault, the Helena Banks fault zone, the Pen Branch fault, the Belair fault, the fall lines of Weems (1998), the Cape Fear arch, and the Eastern Tennessee Seismic Zone (ETSZ). The three paleoliquefaction features are classified by Wheeler (2005) as “Class A”, indicating there is geologic evidence to demonstrate the existence of Quaternary tectonic deformation related to these features. The other eight features are classified as “Class C”, indicating there is insufficient geologic evidence to demonstrate the existence of Quaternary deformation associated with these features. The applicant discussed only the Belair Fault Zone and the fall lines of Weems (1998) in SSAR Section 2.5.1.1.4.3 since the other potential Quaternary features are discussed in detail in other sections of the SSAR.

The applicant documented that the Belair Fault Zone, located about 48 km (30 mi) northwest of the ESP site, occurs as a series of northeast-striking, southeast-dipping oblique-slip faults with no evidence of historic or recent associated seismicity. The applicant concluded that Quaternary slip is allowed, but not clearly demonstrated, by available data.

Weems (1998) identified numerous anomalously steep stream segments in the Blue Ridge and Piedmont physiographic provinces of North Carolina, Virginia, and Tennessee and recognized that these steep “fall zones”, located north and northeast of the ESP site, are aligned from stream to stream along paths that are subparallel to the regional structural grain of the Appalachian orogenic belt. Although Weems (1998) favored a neotectonic (less than 23.8 mya) origin for these fall lines, Wheeler (2005) classified them as Class C features because he did not consider Quaternary tectonic faulting to be demonstrated by the available data.

In addition to the 11 potential Quaternary features listed above, the applicant recognized that a number of regional geophysical anomalies and lineaments occur within 320km (200 mi) of the VEGP site, including the East Coast Magnetic Anomaly (ECMA), the Blake Spur Magnetic Anomaly, the Grenville Front, the New York-Alabama Lineament (NYAL), and the Clingman and Ocoee Lineaments.

The applicant described the ECMA and the Blake Spur Magnetic Anomaly, both of which are located off the east coast of North America and interpreted to be Mesozoic in age. The applicant concluded that neither of these anomalies are associated with a regional fault or other tectonic structure and do not represent a potential seismic source for the VEGP site.

The applicant classified the NYAL as a linear feature 1600 km (1000 mi) in length defined by a series of northeast-southwest-trending magnetic gradients in the Valley and Ridge physiographic province that intersects and truncates other magnetic anomalies. King and Zietz (1978) interpreted this lineament to be a major strike-slip fault in Precambrian basement, while Shumaker (2000) equated it to a right-lateral wrench fault that formed during an initial phase of Precambrian continental rifting.

The Clingman Lineament is 1200 km (750 mi) in length and also trends northeast, showing up as an aeromagnetic linear feature passing through parts of the Blue Ridge and the eastern Valley and Ridge provinces from Alabama to Pennsylvania. The Ocoee Lineament is described as a splay that branches southwest from the Clingman Lineament approximately at latitude 36N. The Clingman-Ocoee Lineaments are subparallel to and located 50-100 km (30-60 mi) east of the NYAL.

The applicant described the “Ocoee block” as a Precambrian basement block located northwest of the ESP site and just outside of the 320 km (200 mi) site radius. The majority of southern Appalachian seismicity is interpreted to occur within the Ocoee block that coincides with the western margin of the ETSZ, as discussed in SSAR Section 2.5.1.1.4.6 “Seismic Sources Defined by Regional Seismicity”. Johnston et al. (1985) interpreted seismicity within the Ocoee block as related to strike-slip displacement on faults striking north-south and east-west. More recently, Wheeler (1996) proposed that earthquakes within the Ocoee block may be related to reactivation of Precambrian normal faults as reverse or strike-slip faults in the “modern” tectonic setting.

The applicant described regional gravity and magnetic data in relation to the VEGP site region in Section 2.5.1.1.5 of the SSAR. Regional maps of North American gravity and magnetic fields were published by the Geological Society of America in 1987 as part of the Decade of North American Geology project. These maps are at a scale that allows identification and assessment of gravity and magnetic anomalies with wavelengths of about 10 km (6 mi) or greater. The applicant concluded there are no unexplained anomalies in the gravity data for the VEGP site region, and no data or gravity modeling results show evidence of Cenozoic tectonic activity or specific structures of Cenozoic age in the site region.

The applicant discussed regional magnetic signatures for the VEGP site region in Section 2.5.1.1.5.2 of the SSAR. The applicant concluded that (1) magnetic data do not have sufficient resolution to identify discrete faults such as the Pen Branch Fault; (2) there are no unexplained anomalies in the magnetic data for the VEGP site region; and (3) no data show evidence for Cenozoic structures in the VEGP site region.

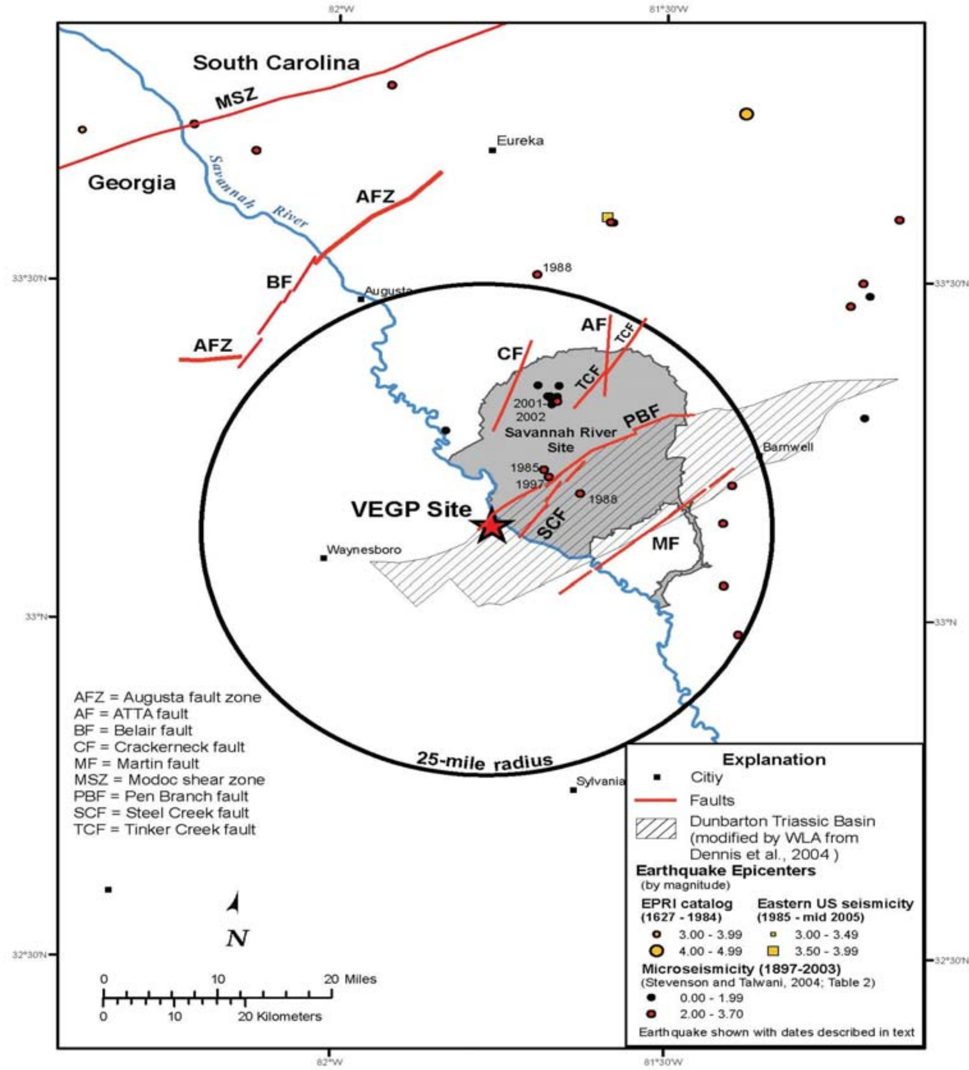

Figure 2.5.1-2 - Site Vicinity Tectonic Features and Seismicity (Reproduced from SSAR Figure 2.5.1-16)

Table 2.5.1-1 - Definitions of Classes Used in the Compilation of Quaternary Faults, Liquefaction Features, and Deformation in the Central and Eastern United States (Reproduced from SSAR Table 2.5.1-1 after Crone and Wheeler, 2000)

Class Category	Definition
Class A	Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether the fault is exposed for mapping or inferred from liquefaction to other deformational features.
Class B	Class B Geologic evidence demonstrates the existence of a fault or suggests Quaternary deformation, but either (1) the fault might not extend deeply enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A.
Class C	Class C Geologic evidence is insufficient to demonstrate (1) the existence of tectonic fault, or (2) Quaternary slip or deformation associated with the feature.
Class D	Class D Geologic evidence demonstrates that the feature is not a tectonic fault or feature. This category includes features such as demonstrated joints or joint zones, landslides, erosional or fluvial scarps, or landforms resembling fault scarps, but of demonstrable non-tectonic origin.

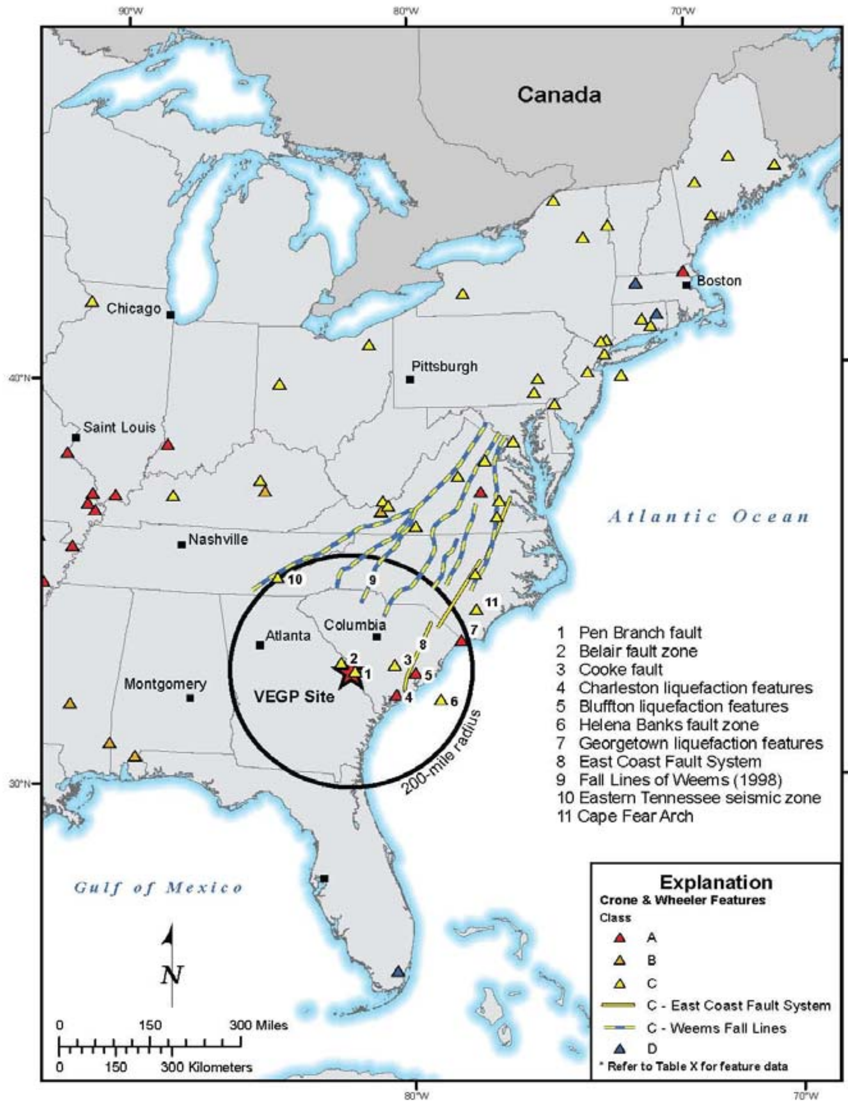

Figure 2.5.1-3 - Potential Quaternary Features Map (Reproduced from SSAR Figure 2.5.1-17)

Savannah River Site Tectonic Features

In SSAR Section 2.5.1.1.4.5, the applicant discussed faults that are interpreted to occur at the SRS on the eastern side of the Savannah River directly across from the VEGP ESP site. Locations of most of these faults are indicated on Figure 2.5.1-2. Most SRS faults are defined in the subsurface by interpretation of seismic reflection profiles, although information from seismic refraction studies and borehole studies is also used. The applicant stated that considerable uncertainty exists in regard to orientation and continuity of some of these faults. The applicant made no conclusion as to the capability of any of the SRS faults except for the Millet fault, which the applicant concluded showed no evidence of being a capable tectonic structure younger than the middle Eocene (40 mya). Four of the SRS faults occur within the VEGP site area: (1) Pen Branch, (2) Steel Creek, (3) Ellenton, and (4) Upper Three Runs faults.

1. The applicant described the northeast-trending Pen Branch fault as extending southwest off the SRS and across the Savannah River to the VEGP site location (Figure 2.5.1-2 from SSAR Figure 2.5.1–16). Since the Pen Branch is interpreted to extend beneath the VEGP site, the applicant discussed this feature in detail in SSAR Section 2.5.1.2.4.

2. The applicant described the northeast-trending Steel Creek fault, shown in Figure 2.5.1-2, as extending southwest into the VEGP site area to a point off the SRS on the west side of the Savannah River. This fault is located about 4 km (2.5 mi) east-southeast of the VEGP site location. Stieve and Stephenson (1995) considered the age of latest movement on this fault to be unresolved, but indicated that Cretaceous (144 to 65 mya) units are cut by the fault.

3. The applicant stated that the Ellenton fault strikes north-northwest, is near vertical, and extends into the VEGP site area with a location about 8 km (5 mi) northwest of the site location. However, data quality for definition of this structure is defined as poor and some researchers do not show this fault trace on their map of SRS faults.

4. The applicant stated that research indicates the Upper Three Runs fault is restricted to crystalline basement rocks, and that seismic reflection revealed no evidence for this fault offsetting Coastal Plain sediments. There is some indication that this fault extends southwest from the SRS, across the Savannah River, into the VEGP site area, and is located about 5 mi north of the site location. However, other investigators do not show this fault trace on their map of SRS faults.

Additional faults have been proposed outside the VEGP site area: (1) ATTA, (2) Crackerneck, (3) Martin, (4) Tinker Creek, (5) Lost Lake, and (6) Millet faults.

1. As described by the applicant, the ATTA fault is near vertical, strikes north-northeast, and is located about 25 km (16 mi) northeast of the VEGP site location, as shown in Figure 2.5.1-2. Research indicated a vertical separation of basement rocks by this fault of 25 m (82 ft) based on seismic reflection data, and also that penetration of the ATTA fault above basement is uncertain due to a lack of good seismic reflectors.

2. The applicant described the Crackerneck fault, which is located about 16 km (10 mi) north of the VEGP site location. Shown in Figure 2.5.1-2, this fault strikes northeast and dips steeply southeast. Research indicates that the fault exhibits a maximum vertical separation of basement rocks of about 30 m (98 ft) based on seismic reflection data, with offset decreasing upward to about 7 m (23 ft) at the top of the Upper Eocene Dry Branch formation (approximately 38.8 mya). The Middle Eocene Blue Bluff Marl (about 40 mya in age), the proposed foundation bearing unit for VEGP Units 3 and 4, underlies the Dry Branch.

3. The applicant described the Martin fault, which is located about 14.5 km (9 mi) south-southeast of the VEGP site location (based on aeromagnetic data). Shown in Figure 2.5.1-2, this fault strikes northeast with an undefined dip. Researchers estimated a vertical separation of the basement surface of about 18.5 to 31 m (60 to 100 ft) based on data from two boreholes.

4. The applicant described the Tinker Creek fault, which is located about 19 km (12 mi) north-northeast of the VEGP site location. Shown in Figure 2.5.1-2, this is interpreted to strike northeast and dips southeast. Seismic reflection data suggest a vertical separation of basement rocks by the Tinker Creek fault of 24 m (79 ft) at its northeastern extent, but the southeastern extent of the fault remains unresolved.

5. Cumbest et al (1998) defined the trace of the Lost Lake Fault based on its apparent control of groundwater flow pathways, locating it about 19 km (12 mi) north of the VEGP site location. The applicant reported that seismic and borehole data to constrain location, geometry, sense of slip, and age of latest movement are lacking.

6. The Millet fault is located about 14.5 km (9 mi) south-southeast of the VEGP site location. A study of this proposed fault by Bechtel (1982) was reviewed by the NRC staff, who concluded that there is no evidence for a capable tectonic structure as young as the Middle Eocene (40 mya) Blue Bluff Marl, which was characterized as tectonically undeformed.

Charleston Tectonic Features

In SSAR Section 2.5.1.1.4.4, the applicant discussed Charleston tectonic features, including potential source faults, area seismic zones, and area seismically-induced liquefaction features. These features, some defined since the EPRI (1986) seismic source models were developed, have been identified in or near the meizoseismal area (area of maximum damage) of the August 1886 Charleston earthquake and occur about 136 km (85 mi) east-southeast of the VEGP site.

The 1886 Charleston earthquake is recognized as one of the largest historical earthquakes to occur in the eastern United States. It produced a Modified Mercalli Intensity (MMI) X in the epicentral area near Charleston, and was felt as far away as Chicago, IL. Bakun and Hopper (2004) estimated a maximum magnitude for the 1886 Charleston earthquake ranging between M 6.4 to 7.1, a value similar to the upper-bound maximum magnitude used by EPRI (1986) for its source model. Due to a lack of observable surface deformation, the source of this earthquake has been inferred based on geology, paleoseismic features, and instrumented seismicity. The applicant recognized that, although the 1886 event was almost certainly related to a capable tectonic source, the earthquake has not been tied to any specific tectonic structure. The applicant concluded, in light of new information about source geometry and earthquake recurrence rate, that the EPRI (1986) source models for the 1886 Charleston earthquake warranted an update. The applicant presented the updated seismic source parameters in SSAR Section 2.5.2.2.2.4.

The applicant discussed the following potential causative faults for the 1886 Charleston earthquake event: (1) East Coast Fault System (ECFS), (2) Adams Run fault, (3) Ashley River fault, (4) Charleston fault, (5) Cooke fault, (6) Helena Banks fault zone, (7) Sawmill Branch fault, (8) Summerville fault, and (9) Woodstock fault. Figure 2.5.1-4, taken from SSAR Figure 2.5.1-19, shows these faults.

1. The applicant described the inferred ECFS, the southern section of which is marked by an alignment of river bends and consequently referred to as the "zone of river anomalies" (ZRA), as a northeast-trending fault system extending a total distance of about 600 km (373 mi) from Charleston, SC to southeastern Virginia. Researchers identified geomorphic anomalies (the ZRA) located along (and northwest of) the Woodstock fault and consequently defined the southern segment of the ECFS to extend the strike trend of the Woodstock fault. Data suggests that the fault system may have been active in the past 130,000 to 10,000 years and may remain active at the present time. It is further suggested that the ECFS may have been the source for the 1886 Charleston earthquake. Wheeler (2005) classified the ECFS as a Class C structure based on lack of demonstrable evidence for tectonic faulting or Quaternary slip or deformation associated with the feature.

2. The applicant described the Adams Run fault as being inferred from microseismicity and borehole data, but stated that the data were not consistent with the occurrence of fault displacement. The applicant further indicated no geomorphic evidence for the Adams Run fault and local microseismicity, as shown in Figure 2.5.1-5 from SSAR Figure 2.5.1-20, does not define a discrete structure.

3. The applicant described the Ashley River fault as being defined by a northwest-trending zone of seismicity in the meizoseismal area of the 1886 Charleston earthquake. This fault is interpreted to be a southwest-side-up reverse fault that offsets the northeast-trending Woodstock fault.

4. The applicant described the Charleston fault, also shown in Figure 2.5.1-5, as being defined by data from geologic maps and boreholes. This fault is interpreted as a major high-angle reverse fault which has been active in the Holocene (past 10,000 years). The applicant indicated that this fault has no clear geomorphic expression, nor is it clearly defined by the pattern of microseismicity in the vicinity of the fault.

5. The applicant described the Cooke fault, shown in Figure 2.5.1-5, as being defined by seismic reflection profiles in the meizoseismal area of the 1886 Charleston earthquake and interpreted as either an east-northeast-striking, northwest-dipping structure, or part of the ECFS. Crone and Wheeler (2000) classified the Cooke fault as a Class C feature based on lack of evidence for faulting younger than Eocene (54.8 to 33.7 mya).

6. The Helena Banks fault zone, located about 15 to 30 km (10 to 20 mi) off the coast of South Carolina, is clearly shown in seismic reflection lines. The applicant documented that Crone and Wheeler (2000) described this fault zone as a potential Quaternary tectonic feature, but classified it as a Class C feature since there is insufficient evidence to demonstrate Quaternary activity in the zone. The applicant stated that data suggest that the fault zone could, at a "low probability", be considered a potentially active fault. The applicant also stated that, if the Helena Banks fault zone is active, it could possibly explain distribution of paleoliquefaction features along the South Carolina coast.

7. The applicant described the Sawmill Branch fault, shown in Figure 2.5.1-5, as a northwest-trending structure defined by microseismicity and interpreted to be an extension of the Ashley River fault that offsets the Woodstock fault in a left-lateral sense. The applicant stated that microseismicity in the vicinity of the proposed Sawmill Branch fault does not clearly define a structure distinct from the Ashley River fault (the Ashley River fault was also defined based on seismicity).

8. The applicant described the Summerville fault, shown in Figure 2.5.1-5, which was initially defined by Weems et al. (1997) based on microseismicity. However, the applicant concluded that there is no geomorphic expression, borehole evidence, or microseismicity related to a discrete structure to indicate the existence of the Summerville fault.

9. The applicant described the Woodstock fault, shown in Figure 2.5.1-5, as a postulated north-northeast-trending, dextral strike-slip fault in the meizoseismal area of the 1886 Charleston earthquake defined by a linear zone of seismicity. Researchers subdivided this fault into two segments offset in a left-lateral sense across the Ashley River fault, and later included it as a part of the proposed ZRA in the southern portion of the ECFS.

<u>Charleston Area Seismic Zones</u>

The applicant discussed three zones of increased seismicity identified in the greater Charleston area, including the (1) Middleton Place-Summerville, (2) Bowman, and (3) Adams Run seismic zones. These three zones are shown in Figure 2.5.1-4. Details of the seismicity data catalog are discussed in SSAR Section 2.5.2.1.

1. The applicant described the Middleton Place-Summerville Seismic Zone as an area of elevated microseismicity located about 19 km (12 mi) northwest of Charleston. Between 1980 and 1991, 58 events with magnitudes ranging from body wave magnitude (mb) 0.8 to 3.3 and hypocentral depths ranging from 2 to 11 km (1 to 7 mi) were recorded in this zone, which lies inside the meizoseismal area of the 1886 Charleston earthquake. The elevated microseismicity in the Middleton Place-Summerville seismic zone has been attributed to stress concentrations associated with intersection of the Ashley River and Woodstock faults, and there is speculation that the 1886 Charleston earthquake had its source in this zone. Persistent foreshock activity was reported prior to the 1886 Charleston earthquake in the Middleton-Summerville seismic zone.

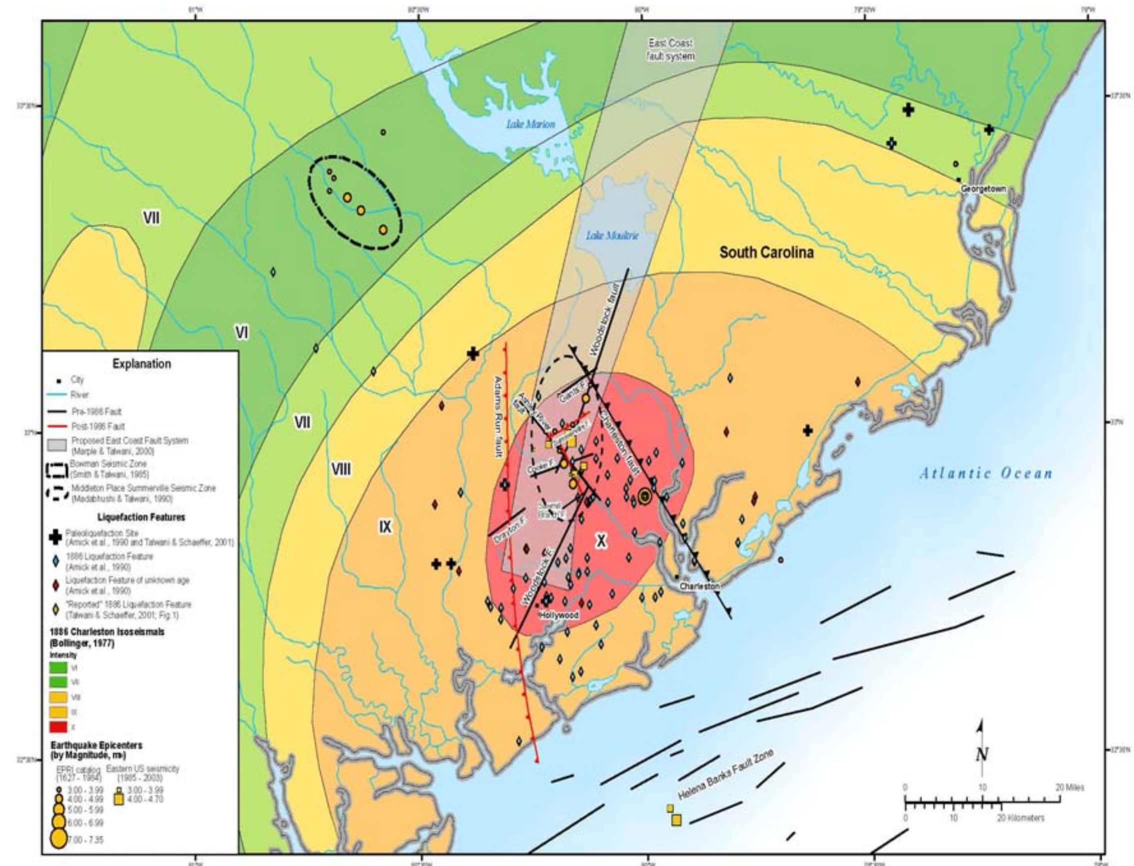

Figure 2.5.1-4 - Local Charleston Tectonic Features (Reproduced from SSAR Figure 2.5.1-19)

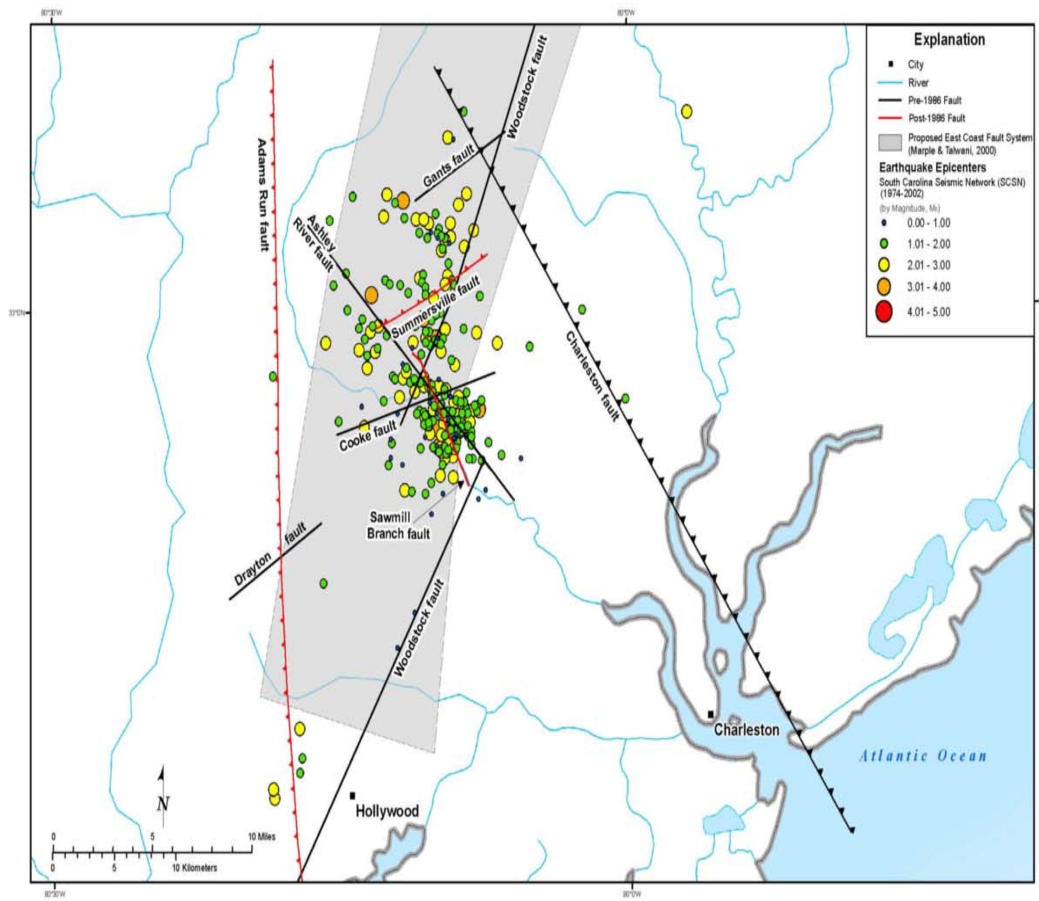

Figure 2.5.1-5 - Local Charleston Seismicity (Reproduced from SSAR Figure 2.5.1-20)

2. The applicant documented that the Bowman seismic zone lies outside the meizoseismal area of the 1886 Charleston earthquake. It is located about 80 km (50 mi) northwest of Charleston and 96 km (60 mi) east-northeast of the VEGP site as shown in Figure 2.5.1-4. The zone was identified based on a series of earthquakes with magnitudes of M3-4 which occurred in that zone between 1971-1974.

3. The applicant described the Adams Run seismic zone, located within the meizoseismal area of the 1886 Charleston earthquake as being defined by four earthquakes with magnitudes less than M2.5. Three of these four earthquakes occurred over a two day period in December 1977. This seismic zone occurs about 120 km (75 mi) east-southeast of the VEGP site and is not shown in Figure 2.5.1-4 as the text indicates.

Charleston Area Seismically-Induced Liquefaction Features

The applicant discussed Charleston area soil liquefaction in SSAR Section 2.5.1.1.4.4, which has proven to be the most broadly observable earthquake-induced phenomenon in the Charleston area. Liquefaction occurs when a mass of saturated, granular material temporarily loses its shear strength and its ability to act as a solid due to an increase in pore water pressures that exceeds overburden pressures. During an earthquake, waves are propagated upward through rock and soil, creating shear stresses that cause sediments with a high volume change capacity (saturated sediments) to compact. As pore water pressures increase, saturated materials are forced to flow in the direction of maximum principal compressive stress, typically upward through zones of weakness in dense overlying sediments. The presence of liquefaction features in the geologic record, and radiometric age dating of these features, aids in formulating an earthquake chronology with estimated magnitudes based on characteristics of the features and their geographic distribution. This extends the earthquake record back in time for defining longer-term earthquake occurrence rates.

The applicant presented data on liquefaction features observed in the South Carolina Coastal Plain and these features are shown in Figure 2.5.1-4. These liquefaction features were produced by the 1886 Charleston earthquake and earlier moderate to large earthquakes in the region. The presence of liquefaction features attributed to the 1886 Charleston earthquake and paleoliquefaction features related to earlier Quaternary earthquake events demonstrates repeated seismicity within the region and, hence, the presence of a capable tectonic source in the vicinity of Charleston. The applicant recognized that liquefaction features interpreted to have been produced by the 1886 Charleston earthquake are most heavily concentrated in the meizoseismal area for that earthquake as well as in some outlying areas. The applicant provided a description of potential Charleston earthquake sources in SSAR Section 2.5.1.1.4.4, but no definitive link has yet been made between a particular fault and the 1886 Charleston event, or any previous earthquake event. The applicant presented refinements of earthquake recurrence estimates for the Charleston area in detail in SSAR Section 2.5.2.2.2.4.

Paleoliquefaction features attributed to pre-1886 earthquakes are abundant along the South Carolina coast. These features were evaluated to estimate earthquake recurrence rates in the Charleston area. Talwani and Schaeffer (2001) proposed two earthquake scenarios: Scenario 1 assumes that some events in the paleoearthquake record were smaller in magnitude (estimated M6+) than events to the northeast of Charleston, while Scenario 2 allows all earthquakes in the record to be large events (estimated M7+) located near Charleston. Based on these two scenarios, Talwani and Schaeffer (2001) estimated recurrence intervals of about 550 years (Scenario 1) and 900-1000 years (Scenario 2).

Seismic Sources Defined by Regional Seismicity

In SSAR Section 2.5.1.1.4.6, the applicant discussed the ETSZ and three other seismogenic and capable tectonic source zones located outside the 320 km (200 mi) radius of the site region (Central Virginia, New Madrid, and Giles County seismic zones (GCSZ)). These seismic zones are shown in SER Figure 2.5.1-6 taken from SSAR Figure 2.5.1-15.

The ETSZ is a northeast-trending area of concentrated seismicity, characteristically generated by small-to-moderate earthquakes, which is located in the Valley and Ridge Physiographic province of eastern Tennessee. The applicant recognized that, although most seismic events in ETSZ have occurred more than 320 km (200 mi) from the VEGP site location and consequently outside the site region, diffuse seismicity on the southeastern margin of the zone is located just within the boundary of the site region. This zone, approximately 300 km (185 mi) long and 50 km (30 mi) wide, has produced no damaging earthquake in historical time. The zone exhibits no geologic evidence of prehistoric earthquakes larger than any historical event that has occurred within the zone. However, the ETSZ has been classified by some as the second most active seismic area in the United States east of the Rocky Mountains (after the New Madrid Seismic Zone (NMSZ)). Others have determined that this zone produced the second highest release of seismic strain energy in the CEUS during the 1980s.

Earthquakes in the ETSZ occur at depths of 5 to 26 km (3 to 16 mi) in Precambrian crystalline basement rocks that underlie exposed thrust sheets made up of Paleozoic rock units, suggesting that seismogenic structures in the zone are not related to surface geologic features of the Appalachian orogen. None of the earthquakes exceeded a moment magnitude of M4.6. Earthquakes within the ETSZ cannot be attributed to known faults and the applicant reported that no capable tectonic sources have been identified within the zone, although seismicity appears to be spatially associated with the prominent magnetic field gradient defined by the NYAL. Most seismicity in the ETSZ lies between the NYAL on the west and the Clingman and Ocoee lineaments on the east, in a "block" labeled as the Ocoee block. The applicant concluded that no new information has been developed since 1986 for the ETSZ to require a significant revision to the EPRI (1986) source model, but provided additional discussion of the ETSZ in relation to potential seismic hazard for the VEGP site location in SSAR Section 2.5.2.2.2.5.

The applicant recognized the potential for distant large earthquakes in the CEUS to contribute to the long-period ground motion hazard at the VEGP site, and consequently discussed the following three additional seismic source zones–(1) Central Virginia, (2) New Madrid, and (3) Giles County–located more than 320 km (200 mi) from the site location.

1. The Central Virginia Seismic Zone (CVSZ), shown in Figure 2.5.1-6, is an area of low-level seismicity located more than 560 km (350 mi) north-northeast of the VEGP site location, extending about 120 km (75 mi) north-south and 144 km (90 mi) east-west between Richmond and Lynchburg, VA. The largest historical earthquake to occur in the CVSZ (December 1875) had a body-wave magnitude of 5.0 and a maximum intensity of VII in its epicentral region. Wheeler and Johnston (1992) indicated that seismicity in the CVSZ ranges in depth from about 4 to 13 km (2 to 8 mi), suggesting that the events extend both above and below the Appalachian detachment zone (discussed in SSAR Section 2.5.1.1.4.1). Two paleoliquefaction sites reflecting prehistoric seismicity have been found within the CVSZ, but no capable tectonic sources have been identified. The

applicant concluded that no new information has been developed since 1986 for the CVSZ to require a significant revision to the EPRI (1986) source model.

2. The NMSZ is an area defined by post-Eocene (younger than 33.7 mya) to Quaternary (1.8 mya to the present) faulting located more than 640 km (400 mi) west of the VEGP site location, extending from eastern Missouri to southwestern Tennessee (Figure 2.5.1-6 from SSAR Figure 2.5.1-15). The zone, approximately 220 km (125 mi) long and 40 km (25 mi) wide, is interpreted to be made up of three fault segments: a southern northeast-trending strike-slip fault, a middle northwest-trending reverse fault, and a northern northeast-trending strike-slip fault. Three large-magnitude historical earthquakes occurred in this zone between December 1811 and February 1812 with magnitudes ranging from M7.1 to M7.5. Since the EPRI (1986) study, estimates of maximum magnitude have generally been in the range of those used in the 1986 EPRI models. However, recent summaries of paleoseismic data suggest a mean recurrence time of 500 years, an order of magnitude less than seismicity-based recurrence estimates used in EPRI (1986).

   The applicant concluded that this estimate of recurrence time represents a significant update of source parameters for the NMSZ used by EPRI (1986).

3. The GCSZ is located in Giles County, VA, more than 250 mi from the VEGP site location, as shown in Figure 2.5.1-6. Bollinger and Wheeler (1988) reported that earthquakes in this zone occur in Precambrian crystalline basement beneath the overlying Appalachian thrust sheets at depths from 5 to 25 km (3 to 16 mi). The data on depth of earthquakes in the GCSZ imply that seismogenic structures in the zone are unrelated to surface geology of the Appalachian orogen. Shallow Late Pliocene to Early Quaternary faults near Pembroke, VA, which lie within the area defined as the GCSZ, are classified as Class B features because it is not determined if they are of tectonic origin or related to solution collapse. The applicant concluded that no new information has been developed since 1986 for the GCSZ to require a significant revision to the EPRI (1986) source model.

2.5.1.1.3 Site Area Geologic Description

Sub-sections 2.5.1.2.1 to 2.5.1.2.3 of SSAR Section 2.5.1.2 describe the geology of the site area, including physiography and geomorphology, geologic history, and stratigraphy). The applicant concluded that the physiography, geomorphology, geologic history, and stratigraphy of the site area pose no safety concerns for the ESP site. The applicant presented the following information related to site area geology.

Physiography, Geomorphology and Geologic History

In SSAR Section 2.5.1.2.1, the applicant described physiography and geomorphology of the ESP site area. The site area lies within the Upper Coastal Plain, about 48 km (30 mi) southeast of the fall line that separates the Piedmont and Coastal Plain physiographic provinces, as shown in Figure 2.5.1-1. The Savannah River, located on the east side of the ESP site, is the primary drainage system in the site area and acts as the state line boundary between Georgia and South Carolina. The Savannah River is incised into surrounding topography to form steep bluffs and a topographic relief of nearly 45 m (150 ft) from river level to the VEGP site. The surface topography, characterized by gently rolling hills, ranges from about 60 to 90 m (200 to 300 ft) above mean sea level (msl) across the site area.

The applicant reported that two types of surface depressions occur in the Coastal Plain that are both non-tectonic in origin. The first type of surface depression is referred to as "Carolina Bays", and results from eolian, surficial processes. The second type of non-tectonic surface depression most likely results from the dissolution of calcareous stratigraphic units at depth. The applicant stated that these surface depressions in the site area were noted and extensively studied during the initial site investigations for VEGP Units 1 and 2.

The applicant described the geologic history of the ESP site area in SSAR Section 2.5.1.2.2. The Upper Coastal Plain is a relatively flat-lying section of unconsolidated marine and fluvial sediments overlying a basement complex of Paleozoic (greater than 248 mya) metamorphic and igneous rocks, and Triassic (248 to 206 mya) basin sedimentary rocks. Paleozoic and Triassic rocks were beveled by erosion prior to deposition of Coastal Plain sediments. The applicant reported that this erosional surface dips southeast beneath the sediments at approximately 9.5 m/km (50 ft/mi). The Coastal Plain section consists of stratified sands, clays, limestone, and gravel deposits that dip gently seaward, with the oldest sediments in the site area being Upper Cretaceous (greater than 65 mya) units and the youngest sediments being Quaternary (1.8 mya to Present) alluvium in stream and river valleys.

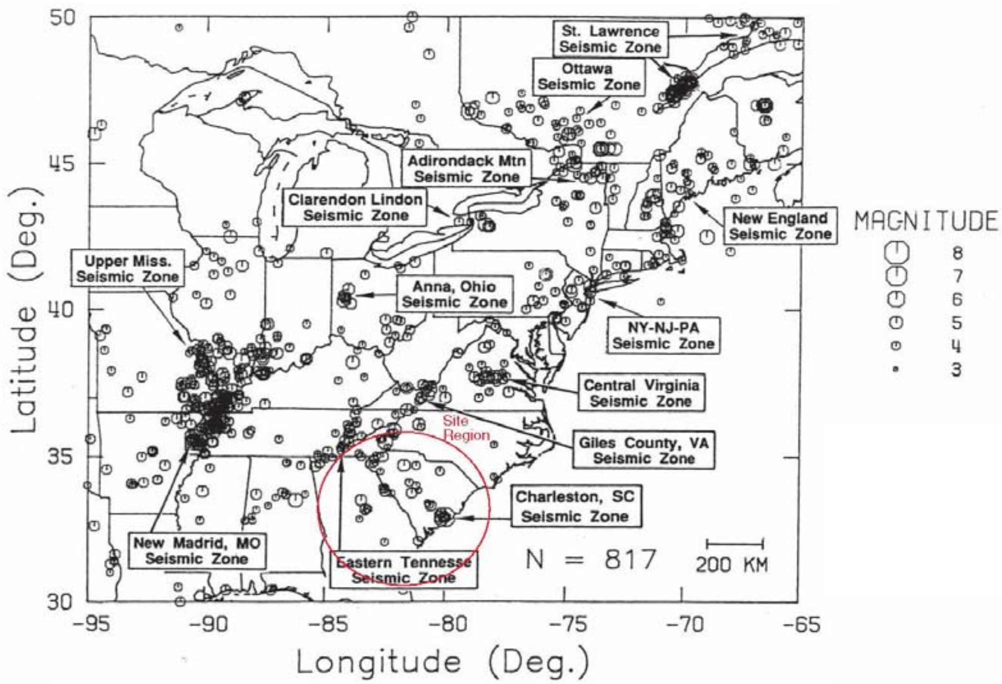

Figure 2.5.1-6 - Seismic Source Zones and Seismicity in the Central and Eastern U.S (Reproduced from SSAR Figure 2.5.1-15)

Stratigraphy

The applicant described the stratigraphy of the ESP site area in SSAR Section 2.5.1.2.3, including basement rock and coastal plain stratigraphy within the site area. The applicant based the stratigraphic descriptions on information from regional geologic maps, site area studies performed for VEGP, borehole data, and surface geophysical surveys. Figure 2.5.1-7, reproduced from SSAR Figure 2.5.1-38, shows a detailed, site-specific stratigraphic column, including sedimentary and depth-to-basement data, based on borehole B-1003, drilled within the VEGP site area.

The applicant described basement rock in the site area in SSAR Section 2.5.1.2.3.1. Basement lithologies consist of Paleozoic (543 to 248 mya) crystalline rock underlying Coastal Plain sediments in the northwestern portion of the site area, and sedimentary rock of the Dunbarton Triassic Basin beneath Coastal Plain sediments in the southeastern part. Based on logs from borehole B-1003 and inferences from seismic reflection and refraction surveys performed as part of the ESP investigation program, the applicant indicated that Triassic basement at the site occurs at a depth of 318 m (1,049 feet), or 250 m (826 ft) below mean sea level. The applicant stated that rocks of the Dunbarton Basin consist of mudstones, sandstones, and conglomerates with varying degrees of lithification based on borehole B-1003.

The applicant described site area Coastal Plain stratigraphy in SSAR Section 2.5.1.2.3.2, including the Cretaceous (144 to 65 mya), Tertiary (65 to 2 mya), and Quaternary (1.8 mya to present) stratigraphy. Weakly consolidated to unconsolidated Coastal Plain sediments that dip and thicken to the southeast unconformably (i.e., not succeeding the underlying rocks in immediate order of age and not fitting together with them as part of a continuous sequence) overlie Paleozoic (543 to 248 mya) and Triassic (248 to 206 mya) basement rocks in the site area. These units range in age from Upper Cretaceous (100 to 65 mya) to Miocene (23.8 to 5.3 mya) and are about 318 m (1,049 ft) thick in the site area.

The upper Cretaceous (100 to 65 mya) stratigraphic units logged in borehole B-1003, which unconformably overlie basement rocks, include the Cape Fear, Pio Nono, Upper Gaillard/Black Creek, and Steel Creek Formations. The applicant stated that these Upper Cretaceous units are primarily a mix of stratified sands, silts, clays, and gravels deposited in a fluvial deltaic environment.

AGE				UNIT	DEPTH (FT)	ELEVATION (FT MSL)
Cenozoic	TerTiary	Eocene	Upper	Barnwell Group	Ground surface	+223
				• Tobacco Road Sand		
				• Dry Branch Formation		
				• Clinchfield Formation		
				o Utley Limestone Member	48	+175
			Middle	Claiborne Group		
				• Lisbon Formation	86	+137
				o Blue Bluff Member / McBean Member		
				• Still Branch Sand	149	+74
				• Congaree Formation	216	+7
			Lower			
		Paleocene	Upper	• Snapp Formation	331	-108
				• Black Mingo Formation	438	-215
			Lower			
Mesozoic	Cretaceous	Upper			477	-254
				• Steel Creek Formation		
				• Gaillard Formation/ Black Creek Formation	587	-364
				• Pio Nono Formation / Unnamed Sand	798	-575
				• Cape Fear Formation	858	-635
	Triassic				1049	-826
				Triassic (Dunbarton) basin	Boring terminated at 1338	

Figure 2.5.1-7 - Site Stratigraphic Column Based on Boring B-1003 (Reproduced from SSAR Figure 2.5.1-38)

Tertiary (65 to 2 mya) sediments ranging in age from Paleocene (65 to 54.8 mya) to Miocene (23.8-5.3 mya), unconformably overlie the Upper Cretaceous (100 to 65 mya) section in the site area and include the following formations: Black Mingo, Snapp, Congaree, Still Branch Sand, Lisbon, Clinchfield, Dry Branch, Tobacco Road, and Hawthorne of the Barnwell Group, and the Pinehurst. The applicant stated that the Tobacco Road and Hawthorne Formations of the Barnwell Group and the Pinehurst Formation were not identified in any site borings but do occur in the site area. The applicant indicated that fluvial deposits at the base of the Tertiary give way to marginal marine, shallow shelf, mixed inner-tidal deposits, and to high-energy fluvial deposits.

The applicant reported that the Tertiary age (65 to 2 mya) Lisbon Formation includes the extensively mapped, shallow-shelf Blue Bluff Marl, which is the foundation-bearing stratigraphic unit for VEGP Units 1 and 2. This unit is the dominant facies in the VEGP site area and contains shell fragments suspended in a fine-grained micrite (carbonate-rich mud) matrix with occasional shell-rich zones and a carbonate unit referred to as the McBean Limestone.

The applicant reported that Quaternary age (1.8 mya to present) sediments occur as alluvium in stream and river valleys, forming terraces above the modern (Holocene age) flood plain of the Savannah River in the ESP site area. The applicant stated that these terraces are Pleistocene in age.

2.5.1.1.4 Site Area Structural Geology

In SSAR Section 2.5.1.2.4, the applicant reviewed published information to identify four faults and one monoclinal fold within a 5-mile radius of the VEGP ESP site. The four identified faults, each of which originates in basement rock underlying the Coastal Plain sediments, include the Pen Branch, Ellenton, Steel Creek and Upper Three Runs faults. The applicant interpreted the Upper Three Runs and Steel Creek faults as being incapable structures based on the fact that they are restricted to basement rock units and show no evidence that they have offset overlying Coastal Plain sediments. The Ellenton fault is no longer projected on updated fault maps and is considered by the applicant to be an incapable tectonic structure, if it does exist. The Pen Branch fault was examined in detail by the applicant and is discussed in detail below. The northeast-southwest trending monoclinal fold, located in the Blue Bluff Marl, was interpreted by the applicant to be spatially associated with the Pen Branch fault and potentially indicative of reverse fault movement on the Pen Branch.

In addition to reviewing published data, the applicant presented new information from seismic reflection and refraction surveys as well as from an evaluation of Quaternary age fluvial terraces overlying the Pen Branch Fault. The applicant collected this information for the ESP application specifically to determine whether the Pen Branch Fault is a capable tectonic feature. The applicant concluded that the structural geology of the site area poses no safety issues for the ESP site and that the Pen Branch Fault exhibits no Quaternary displacement and does not require further analysis for seismic hazard or surface faulting at the site.

Faults, Folds, Lineaments, Deformation Zones

The Pen Branch fault was first discovered in the subsurface of the SRS. Based on borehole and seismic reflection data, it is interpreted to exceed 40 km (25 mi) in length; to comprise several subparallel, northeast striking, southeast dipping segments; and to project southwestward beneath the VEGP ESP site. Although the Pen Branch fault is interpreted to be a non-capable structure from previous investigations by Bechtel (1989), Snipes et al. (1989), Geomatrix (1993), and Cumbest et al. (1998), the applicant conducted a detailed investigation of the fault based on its proximity to the VEGP site, and presented the findings from that investigation in SSAR Section 2.5.1.2.4.1.

The applicant conducted a review of previous investigations of the Pen Branch fault as a basis for conducting its own investigation. The applicant collected and processed seismic reflection and refraction data at the VEGP site to better characterize the fault parameters. Finally, the applicant undertook a focused geomorphic study to survey and interpret remnants of a Quaternary (1.8 mya to present) river terrace (the Ellenton Terrace), including mapping, collection of elevation data, and construction of a longitudinal profile of the terrace.

The applicant reviewed 17 years of previous investigations of the Pen Branch fault and provided a brief historical interpretation in SSAR Section 2.5.1.2.4.1. The Pen Branch fault is interpreted to be the western boundary fault of the Dunbarton Triassic Basin that juxtaposes Paleozoic (543 to 248 mya) crystalline rock against Triassic (248 to 206 mya) sedimentary rock. Seismic reflection data identifies a maximum vertical separation of the contact between basement rocks and Coastal plain sediments of about 28 m (92 ft), with offset decreasing upward into the Coastal Plain stratigraphic section. There is no evidence for post-Eocene (54.8 to 33.7 mya) displacement in previous subsurface investigations of the Pen Branch fault, which prompted Crone and Wheeler (2000) to assign the Pen Branch fault as a Class C feature.

In January and February 2006, the applicant collected seismic reflection and refraction data along four lines designed to image the Pen Branch fault and assess depth and character of basement rocks beneath the Coastal Plain sediments in the VEGP site area. Based on results of this survey, included in SSAR Section 2.5.1.2.4.2, the applicant concluded that the Pen Branch fault does indeed strike northeast, dips southeast, and lies beneath the site. Just as reported for the Pen Branch fault at the SRS, the strike of the fault beneath the VEGP is somewhat variable. Seismic sections indicate that the fault strikes about N34°E beneath the VEGP (southwest of the Savannah River), changing to about N45°E, then continuing southwest along the strike, and dipping 45°SE. Figure 2.5.1-8, reproduced from SSAR Figure 2.5.1-34, illustrates this interpreted change in strike from the SRS and across the VEGP site. The applicant also interpreted that, based on the new data, there is evidence that the Pen Branch fault intersects a monoclinal fold occurring in the Middle Eocene (54.8 to 33.7) Blue Bluff Marl. The Blue Bluff unit shows reverse fault displacement due to movement on the Pen Branch fault. Therefore the applicant concluded that Eocene age slip occurred on the Pen Branch fault.

In SSAR Section 2.5.1.2.4.3, the applicant described an evaluation of the Ellenton Terrace (Qte), a Quaternary age Savannah River terrace, located about 6 km (4 mi) east-northeast of the VEGP site, which overlies the Pen Branch Fault on the SRS and is estimated to be between 350 thousand and 1 mya old. Savannah River fluvial terraces represent the only significant Quaternary deposits and surfaces that straddle the trace of the Pen Branch fault. The applicant conducted this evaluation of the Qte to improve the resolution of the terrace surface elevation and to independently assess the presence or absence of any Quaternary tectonic deformation associated with the Pen Branch fault. This investigation included a review of previously published literature, aerial photographic analysis and geomorphic mapping, and field reconnaissance. The applicant surveyed about 2600 new elevation data points on the terrace surface and constructed a longitudinal profile approximately normal to the local strike of the Pen Branch Fault and parallel to the long axis of the terrace.

The applicant stated that results of a longitudinal profile of the Ellenton terrace surface in the study area provide evidence of no discernable tectonic deformation that can be attributed to the underlying Pen Branch fault within the resolution of the terrace elevation data, estimated to be about 1 m (3 ft). Based on this lack of evidentiary deformation in the Ellenton Qte, the absence of any post-Eocene (older than 33.7 mya) fault displacements interpreted in the seismic reflection and refraction study, and results of previous studies related to the Pen Branch fault, the applicant concluded that the Pen Branch fault is not a capable tectonic structure and that this conclusion is further supported by the previous results in Bechtel (1989), Snipes et al. (1989), Geomatrix (1993), and Cumbest et al. (1998 and 2000).

2.5.1.1.5 Site Area Earthquakes and Seismicity

Historical and Instrumentally Recorded Seismicity

The applicant summarized seismicity data in the VEGP ESP site vicinity (within a 40-km (25-mi) radius of the site) in SSAR Sections 2.5.3.1.4 and 2.5.3.3. The EPRI catalog of historical seismicity demonstrates that no known earthquake greater than mb 3 occurred within the site vicinity prior to 1984, while the SRS seismic recording network documents no recent microseismic activity (mb less than 3) within an 8 km (5 mi) radius of the VEGP site since 1976. The applicant stated that the nearest microseismic event to the VEGP ESP site was located on the SRS, about 11 km (7 m) northeast of the VEGP site. Figure 2.5.1-2, taken from SSAR Figure 2.5.1-16, shows diffuse microseismic activity recorded by the SRS seismic recording network since 1976, within a 40 km (25 mi) radius of the VEGP site.

Correlation of Earthquakes with Tectonic Features

The applicant described three small earthquakes that occurred between 1985 and 1997 with magnitudes ranging between 2.0 and 2.6 and depths ranging from 2.5 to 6 km (1.5 to 3.5 mi). In addition to these events, the applicant described a magnitude 3.2 event located north of the SRS in Aiken, SC, and a series of several small events (magnitudes ≤ 2.6) that occurred in 2001-2002 within the SRS boundaries. The applicant reviewed the locations of these events with respect to mapped faults in the ESP site vicinity–as well as previous studies of these events by Stevenson and Talwani (2004), Talwani et al. (1985), and Crone and Wheeler (2000)–and concluded that there is no spatial correlation of seismicity with known or postulated faults or geomorphic features.

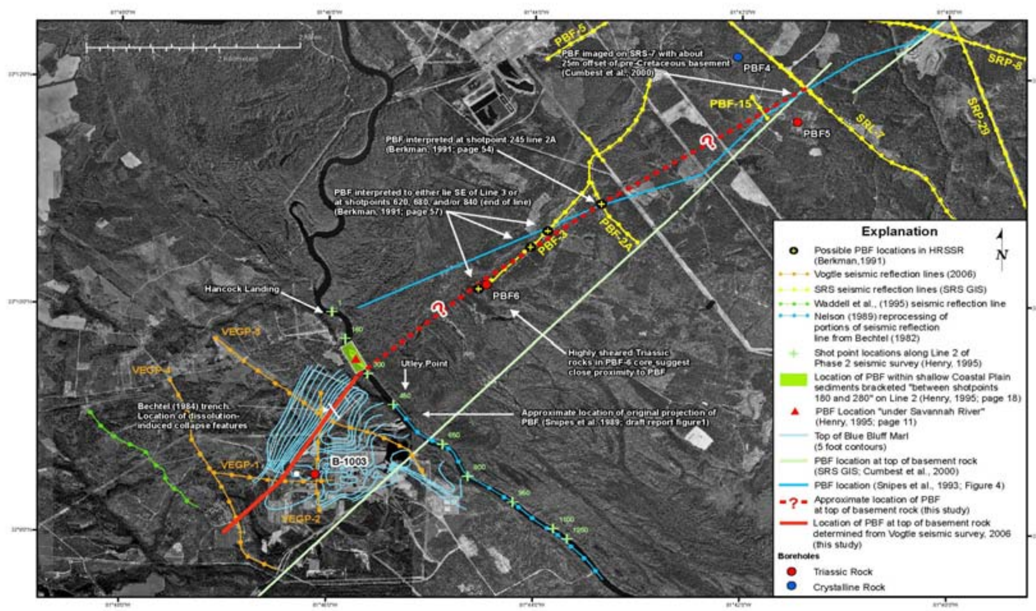

Figure 2.5.1-8 - Location of the Pen Branch Fault (Reproduced from SSAR Figure 2.5.1-34)

2.5.1.1.6 Site Area Non-Tectonic Deformation Features

In SSAR Section 2.5.3.8, the applicant addressed the potential for the following non-tectonic deformation features at the VEGP ESP site: (1) dissolution collapse features and (2) clastic dikes.

In SSAR Section 2.5.3.8.2, the applicant discussed the potential for non-tectonic surface deformation at the ESP site, including interpretation of dissolution collapse features and "clastic dikes". Regarding dissolution collapse features discussed in SSAR Section 2.5.3.8.2.1, the applicant indicated that small-scale structures (including warped bedding, fractures, joints, minor fault offsets, and injected sand dikes) identified in the walls of a trench at the VEGP site were local features related to dissolution of the Utley Limestone (Clinchfield Formation) and subsequent collapse of overlying Tertiary sediments. The age of these features was interpreted to be younger than Eocene-Miocene host sediments and older than the overlying late-Pleistocene Pinehurst Formation. The applicant stated that no late Pleistocene or Holocene dissolution features were identified at the site. The applicant indicated that mitigation of collapse due to dissolution of the Utley Limestone, which overlies the Blue Bluff Marl at the site, could be accomplished by planned excavation and removal of the Utley to establish the foundation grade of the plant atop the Blue Bluff Marl.

In SSAR Section 2.5.3.8.2.2, the applicant addressed clastic dikes, described as relatively planar, narrow (centimeters to decimeters in width), clay-filled features that flare upwards and are decimeters to meters in length. Bechtel (1984) distinguished two types of clastic dikes in the walls of the trench on the VEGP site where dissolution collapse features were found. The first type of clastic dikes was interpreted to be "sand dikes" that resulted from injection of poorly consolidated fine sand into overlying sediments. The second type was "clastic dikes" produced by weathering and soil-formation processes that were enhanced along fractures that formed during dissolution collapse. Bechtel (1984) concluded the dikes were primarily a weathering phenomena controlled by depth of weathering and paleosol development in Coastal Plain sediments and subsequent erosion of the land surface. Clastic dike features identified by Bartholomew et al. (2002) within the site area were observed during the ESP field reconnaissance. The applicant interpreted these features to be non-tectonic in origin, although Bartholomew et al. (2002) suggested they may be evidence for paleoearthquakes associated with late Eocene to late Miocene faulting, possibly along the Pen Branch Fault.

2.5.1.1.7 Human-Induced Effects on Site Area Geologic Conditions

SSAR Section 2.5.1.2.6.5 states that no mining operation, other than borrow of surficial soils, and no excessive extraction or injection of groundwater, or impoundment of water has taken place within the site area that would impact the geologic conditions at the VEGP site.

2.5.1.1.8 Site Area Engineering Geology Evaluation

The applicant described the engineering geology evaluation of the ESP site in SSAR Section 2.5.1.2.6, including engineering soil properties and behavior of foundation materials; zones of alteration, weathering, and structural weakness; deformational zones; prior earthquake effects; and effects of human activities. In SSAR Section 2.5.1.2.6.1 for engineering soil properties and behavior of foundation materials, the applicant indicated that engineering soil properties were discussed in SSAR Section 2.5.4 and acknowledged that variability of properties in the foundation-bearing layer will be evaluated and mapped as the excavation is completed. The applicant discussed zones of alteration, weathering, and structural weakness in SSAR Section 2.5.1.2.6.2 and indicated that any desiccation, weathered zones, joints, or fractures will be mapped and evaluated as the excavation proceeds. In SSAR Section 2.5.1.2.6.4 on prior earthquake effects, the applicant stated that extensive studies of outcrops, alluvial terraces, and flood plain deposits have not shown evidence for post-Miocene (older than 5.3 mya) earthquake activity. In SSAR Section 2.5.1.2.6.5 on effects of human activities, the applicant stated that no effects resulting from human activity (e.g., mining operations, extraction or injection of groundwater, or impoundment of surface water) have occurred in the site area that affected geologic conditions at the site.

2.5.1.2 Regulatory Evaluation

The acceptance criteria for identifying basic geologic and seismic information are based on meeting the relevant requirements of 10 CFR Part 52.17 and 10 CFR Part 100.23. The staff considered the following regulatory requirements in reviewing the applicant's discussion of basic geologic and seismic information:

1. 10 CFR 52.17(a)(1)(vi), which requires that an ESP application contain a description of the geologic and seismic characteristics of the proposed site.

2. 10 CFR 100.23(c), which requires an ESP applicant to investigate geologic, seismic, and engineering characteristics of a site and its environs in sufficient scope and detail to permit an adequate evaluation of the proposed site; to provide sufficient information to support evaluations performed to determine the SSE Ground Motion; and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site.

3. 10 CFR 100.23(d), which requires that geologic and seismic siting factors considered for design include a determination of the SSE Ground Motion for the site; the potential for surface tectonic and non-tectonic deformation; the design bases for seismically-induced floods and water waves; and other design conditions including soil and rock stability, liquefaction potential, and natural and artificial slope stability. Siting factors and potential causes of failure to be evaluated include physical properties of materials underlying the site, ground disruption, and effects of vibratory ground motion that may affect design and operation of the proposed power plant.

The basic geologic and seismic information assembled by the applicant in compliance with the above regulatory requirements should also be sufficient to allow a determination at the COL stage of whether the proposed facility complies with the following requirements in Appendix A to 10 CFR Part 50:

1. GDC 2, which requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

To the extent applicable in the regulatory requirements cited above, and in accordance with RS-002, the staff applied NRC-endorsed methodologies and approaches (specified in Section 2.5.1 of NUREG-0800) for evaluation of information characterizing the geology and seismology of the proposed site as recommended in RG 1.70, Revision 3 and RG 1.165.

2.5.1.3 Technical Evaluation

This SER section presents the staff's evaluation of the geologic and seismic information submitted by the applicant in SSAR Section 2.5.1. The technical information presented in SSAR Section 2.5.1 resulted from the applicant's surface and subsurface geologic, seismic, and geotechnical investigations, which were undertaken at increasing levels of detail moving closer to the site. Through its review, the staff determined whether the applicant had complied with the applicable regulations and conducted these investigations at the appropriate levels of detail within the four circumscribed areas designated in RG 1.165, which are defined based on various distances from the site (i.e., circular areas drawn with radii of 320 km (200 mi), 40 km (25 mi), 8 km (5 m), and 1 km (0.6 mi) from the site).

SSAR Section 2.5.1 contains geologic and seismic information collected by the applicant in support of the vibratory ground motion analysis and site SSE spectrum provided in SSAR Section 2.5.2. RG 1.165 indicates that applicants may develop the SSE ground motion for a new nuclear power plant using either the EPRI or Lawrence Livermore National Laboratory (LLNL) seismic source models for the CEUS. However, RG 1.165 recommends that applicants update the geologic, seismic, and geophysical database and evaluate any new data to determine whether revisions to the EPRI or LLNL seismic source models are necessary. Consequently, the staff focused its review on geologic and seismic data published since the late 1980s to assess whether these data indicate a need for changes to the EPRI or LLNL seismic source models.

To thoroughly evaluate the geologic and seismic information presented by the applicant, the staff obtained the assistance of the USGS. The staff and its USGS advisors visited the ESP site to confirm interpretations, assumptions, and conclusions presented by the applicant related to potential geologic and seismic hazards.

2.5.1.3.1 Regional Geologic Description

In SSAR Sections 2.5.1.1.1, 2.5.1.1.2, and 2.5.1.1.3, the applicant reviewed and summarized published information related to the physiography and geomorphology (Section 2.5.1.1.1), geologic history (Section 2.5.1.1.2), and stratigraphy and geologic setting (Section 2.5.1.1.3) of the site region. Based on information presented in SSAR Sections 2.5.1.1.1, 2.5.1.1.2, and 2.5.1.1.3, the applicant concluded that the physiography, geomorphology, geologic history, stratigraphy, and geologic setting of the site region posed no safety issues for the ESP site. Consequently, the applicant considered the site suitable in regard to these specific regional features and their characteristics. The staff's evaluation of SSAR Sections 2.5.1.1.1, 2.5.1.1.2, and 2.5.1.1.3 is presented below.

Physiography, Geomorphology, and Geologic History

The staff focused its review of SSAR Sections 2.5.1.1.1 and 2.5.1.1.2 on the applicant's descriptions of the physiography, geomorphology, and geologic history within the site region, with an emphasis on the Quaternary Period (1.8 mya to the present). In SSAR Section 2.5.1.1.1, the applicant described each physiographic province within the site region, with emphasis on the Coastal Plain physiographic province since the ESP site is located in that province. In SSAR Section 2.5.1.1.2, the applicant described geologic history of the site region, including each episode of continental rifting and collision as well as the deposition of Coastal Plain sedimentary units found at the ESP site.

Based on its review of SSAR Sections 2.5.1.1.1 and 2.5.1.1.2, the staff concludes that the applicant presented a thorough and accurate description of the physiography, geomorphology, and geologic history of the site region in support of the ESP application as required by 10 CFR 52.17(a)(1)(vi), and 10 CFR 100.23(c), and 10 CFR 100.23(d). These two SSAR sections present well-documented geologic information, which the applicant derived from published sources. The applicant provided an extensive list of references for these sources, which the staff examined in order to ensure the accuracy of the information presented by the applicant in the SSAR.

Stratigraphy and Geologic Setting

The staff focused its review of SSAR Section 2.5.1.1.3 on the applicant's descriptions of the stratigraphy and geologic setting within the site region. The staff's review concentrated on surfaces and deposits of Quaternary age that are preserved primarily in subhorizontal fluvial terraces occurring along the Savannah River and its major tributaries. Development of fluvial terraces can be related to sequential erosion and deposition in response to faulting, climatic, isostatic (i.e., regional changes in crustal loading leading to upwarping or downwarping of portions of the earth's crust), or eustatic (i.e., global sea level changes) effects or a combination of these mechanisms. Because fluvial terrace deposits initially form as relatively level to gently inclined surfaces, the possibility exists for analyzing variations in elevations of the terrace surfaces to evaluate the potential for Quaternary deformation (i.e., tilting, warping, or offset due to fault displacement) in the site area as long as nontectonic processes, such as surficial erosion or dissolution at depth, have not strongly modified its morphology. In particular, the applicant identified a series of four abandoned fluvial terraces (Qty, Qtb, Qte, and Qto from youngest to oldest) that occur in the site area at elevations above the present-day flood plain of the Savannah River and overlie the Pen Branch fault, a structure that the applicant determined does underlie the ESP site. The applicant used these terraces to assess the presence or absence of Quaternary tectonic deformation on the Pen Branch fault.

Regarding the Pen Branch fault, the applicant analyzed seismic reflection data collected for the ESP application to determine that the fault underlies the ESP site. The fault has also been imaged beneath the SRS on the eastern side of the Savannah River, although it shows no surface expression either at the SRS or the ESP site. Although evidence from stratigraphic data discussed by the applicant in the SSAR suggests that the last motion on the Pen Branch fault was pre-Eocene (greater than 33.7 mya) in age, the applicant understood the need to analyze this fault in more detail because of its location relative to the ESP site.

In RAI 2.5.1-1, the staff asked the applicant to indicate whether the fluvial terraces (Qty, Qtb, Qte, and Qto) are regional in extent or are local features uplifted by slip along the Pen Branch fault. In response, the applicant stated that the four abandoned terraces of the Savannah River extend well beyond the vicinity of the Pen Branch fault and are regional in extent. The four terraces extend for at least 33 km (20 mi) upstream and 29 km (18 mi) downstream (i.e., straight-line distances) from the VEGP ESP site. In addition, the applicant stated that the development of a sequence of laterally extensive fluvial terraces is characteristic of other major Piedmont-draining river systems as well as the Savannah River. In conclusion, the applicant stated, "The fact that the major fluvial terrace surfaces are correlative between major Piedmont-draining river systems suggests that these terraces form in parallel response to regional climatic and/or eustatic conditions, and are not the result of local tectonic perturbations."

Based on an evaluation of the applicant's response, the staff concludes that, since the terraces are regional in extent, it is highly unlikely that they developed due to tectonic displacement along the Pen Branch fault. The trace of the fault is nearly perpendicular to the long axis of the terrace surfaces (see SSAR Figure 2.5.1-43), so the terraces are favorably oriented to register Quaternary deformation along the Pen Branch fault. Alternatively, the staff believes a more likely origin for the terraces involves regional changes in sea level relative to the continental land mass. These regional changes resulted from either climatic, isostatic, or eustatic effects or some combination of these nontectonic mechanisms. Climatic, isostatic, and eustatic perturbations alter sea level relative to the land mass on a regional scale, either by raising the sea level itself (climatic and eustatic changes) or isostatically uplifting blocks of continental crust due to regional crustal unloading (isostatic changes). The mechanism of tectonic perturbations is separate and distinct from these regional changes in sea level and would involve tectonic uplift (e.g., fault displacement) to raise a fault block and produce abandoned fluvial terraces atop that block. The staff's conclusion that the fluvial terraces developed as a result of nontectonic processes rather than by tectonic uplift is based on the staff's evaluation of the applicant's response to RAI 2.5.1-1, and subsequent RAI responses pertaining to the same subject (i.e., RAI 2.5.1-2 and RAI 2.5.1-3).

To evaluate the potential for Quaternary displacement on the Pen Branch fault, the applicant implemented a detailed investigation of fluvial terrace Qte (the Ellenton terrace) at a location approximately 6 km (4 mi) east-northeast of the ESP site. The purpose of the applicant's study was to "improve the resolution of the terrace surface elevation and independently assess the presence or absence of Quaternary tectonic deformation on the Pen Branch fault." A previous study of the fluvial terraces by Geomatrix (1993) concluded that the Pen Branch fault is not a capable tectonic source and that there is no observable deformation, within a resolution of 2-3 km (7-10 ft), of the overlying Ellenton terrace (Qte). The applicant's investigation improved on the previous investigation by surveying approximately 2600 elevation data points along the Qte terrace surface in the vicinity of the Pen Branch fault. The applicant estimated its uncertainty to be about 1 m (3 ft) and concluded that its profile of the Qte fluvial terrace surface demonstrates the absence of discernible tectonic deformation on the underlying Pen Branch fault within a 1-m (3-ft) limit of resolution for the elevation data.

In RAI 2.5.1-2, the staff asked the applicant to address whether the range in elevation of the Qtb (8 to 13 m (26 to 43 ft)) and Qte (18 to 25 m (56 to 82 ft)) terrace surfaces above the Savannah River surface can be attributed to tilting of these terrace surfaces due to Quaternary slip on the Pen Branch fault. The staff also asked the applicant to discuss the implications of the deformation detection limit of about 1 m (3 ft) for the terrace surfaces. This limit resulted from the applicant's field study. This clarification is particularly important for terrace Qte (the Ellenton terrace), which the applicant analyzed in detail to conclude that the terraces do not exhibit deformation due to Quaternary displacement along the Pen Branch fault. The applicant selected terrace surface Qte for the analysis because of its lateral extent and because it could potentially record tectonic deformation along the Pen Branch fault for up to 1 mya based on its interpreted age of 350,000 to 1 million years. The younger terraces, Qty and Qtb, covered shorter time periods, and the older terrace, Qto, exhibited too much dissection for this type of analysis. To define the best-preserved remnants of terrace surface Qte for analysis, the applicant performed geomorphic mapping and field reconnaissance studies and then surveyed approximately 2600 elevation data points on these terrace surface remnants. The applicant estimated that the overall uncertainty in elevation values of the best-preserved remnants of terrace Qte was about 1 m (3 ft) due to the presence of depressions related to dissolution collapse at depth and local deposition of alluvium and colluvium.

In response to RAI 2.5.1-2, the applicant addressed whether the terrace elevation ranges suggested tilting or warping of terrace Qte by tectonic deformation along the Pen Branch fault and the implications of the 1 m (3 ft) limit of detection for deformation. The applicant concluded that variations in elevation of the Qte terrace surface are due largely to the eroded and dissected character of terrace Qte and not from warping or tilting of the terrace by Quaternary displacement on the Pen Branch fault. The applicant cited supporting evidence that these terrace surfaces clearly exhibit a range of surface elevations resulting directly from erosion and dissection which cannot be obviously equated with displacement along the Pen Branch fault. The applicant also concluded that the deformation detection limit of 1 m (3 ft) is an improvement over that attained in previous studies and consequently acceptable for assessing the possibility of Quaternary deformation of the terrace surface due to displacement along the Pen Branch fault. The applicant stated the following:

> Work performed for the VEGP application uses the 350 ka to 1 Ma Ellenton (Qte) terrace surface as a Quaternary strain marker to assess the presence or absence of evidence for tectonic deformation across the underlying Pen Branch fault. A longitudinal profile of the Qte terrace surface in the study area provides evidence demonstrating the absence of tectonic deformation within a resolution of about 1 m (3 ft). This provides a much smaller deformation detection limit than previous studies, thereby providing greater confidence in the evidence demonstrating the lack of Quaternary deformation on the Pen Branch fault.

To completely evaluate the applicant's field study of the Qte fluvial terrace, as well as the applicant's response to RAI 2.5.1-2, the staff and its consultants visited the ESP site and examined the terrace surface. In particular, the staff focused on the adequacy of the applicant's investigations of the Qte terrace and its suitability as a strain marker to assess the presence or absence of tectonic deformation across the underlying Pen Branch fault. Based on the site visit and an examination of aerial photographs and geologic maps, the staff concludes the following:

1. The Qte fluvial terrace shows no obvious surface warping, tilting, or offset.

2. The 1 m (3 ft) detection limit is equivalent to or less than the topographic variations observed for the terrace surface.

3. The variations in elevation of the Qte terrace surface are likely the result of the eroded and dissected character of the Qte surface rather than tectonic tilting and warping due to Quaternary displacement along the Pen Branch fault.

4. The deformation detection limit of 1 m (3 ft), which the applicant achieved during the ESP-related terrace investigations, is a great improvement over previous studies and is a reasonable limit based on measured variability detected in elevation of this terrace surface due to erosion and dissection of the terrace.

SER Figure 2.5.1-9 is a photograph of the Qte fluvial terrace taken during the site visit by the NRC staff and its USGS consultants. This photograph illustrates the relatively flat terrace surface extending a considerable distance toward the horizon, and reinforces the interpretation of the applicant that this terrace surface is not offset by displacement along the Pen Branch fault.

In RAI 2.5.1-3, the staff asked the applicant to discuss the use of the youngest terrace, Qty (4,000 to 90,000 years in age), as an indicator for more recent (i.e., Holocene (10,000 years to the present in age)) potential displacement or uplift along the underlying Pen Branch fault. In response to RAI 2.5.1-3, the applicant stated the following:

> The discontinuous Qty terrace surface of late Pleistocene to possibly Holocene age does not provide constraints for evaluating the potential for Quaternary displacement on the Pen Branch fault. The significantly older and more laterally continuous remnants of the 350 ka to 1 Ma (Geomatrix, 1993) Ellenton terrace (Qte) provide a more robust datum to evaluate potential tectonic deformation on the Pen Branch fault.

The applicant concluded that the discontinuous nature of terrace Qty does not provide adequate constraint for evaluating the potential for Quaternary displacement on the Pen Branch fault. The applicant cited supporting technical evidence derived from field observations and mapping that the terrace is too discontinuous to permit construction of a longitudinal profile for properly assessing tilting and warping of the terrace surface. The applicant also concluded that terrace Qty is not developed only near the Pen Branch fault and cited evidence derived from its field observations and mapping that the Qty terrace extends outside the site area.

After review of the applicant’s response to RAI 2.5.1-3, as well as geologic field maps of the area, the staff concurs with the applicant’s conclusions that terrace Qty is too discontinuous to be a suitable strain marker for deformation of the terrace surface or the underlying strata. Furthermore, the terrace extends beyond the location of the Pen Branch fault. The staff also agrees with the applicant that terrace Qte provides a much more robust indicator for potential Quaternary displacement of the underlying Pen Branch fault than terrace Qty.

Based on review of SSAR Section 2.5.1.1.3, the staff concludes that the applicant presented a thorough and accurate description of the regional stratigraphy and geologic setting in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c) and 10 CFR 100.23(d). In addition, based on observations made during the site visit and review of the applicant’s responses to RAI 2.5.1-1 through RAI 2.5.1-3, the staff concludes that the applicant’s detailed examination of fluvial terrace surface Qte demonstrates the absence of significant Quaternary displacement on the underlying Pen Branch fault. As a result, the staff concurs with the applicant’s conclusion that the Pen Branch Fault is not a capable tectonic structure (as defined by RG 1.165).

2.5.1.3.2 Regional Tectonic Description

In SSAR Sections 2.5.1.1.4 and 2.5.1.1.5, the applicant reviewed and summarized published information related to the tectonic setting (Section 2.5.1.1.4) and gravity and magnetic data (Section 2.5.1.1.5) of the site region. Based on information presented in SSAR Sections 2.5.1.1.4 and 2.5.1.1.5, the applicant concluded the following:

1. Tectonic features in the site region include structures that are Paleozoic (greater than 248 mya), Mesozoic (248 to 65 mya), Tertiary (65 to 1.8 mya), and Quaternary (1.8 mya to present) in age. Only structures of Quaternary age warrant further consideration for the ESP site with regard to the potential for surface fault displacement and seismic hazards.

2. Of the 11 regional geologic features assessed with regard to their potential for Quaternary activity, only the paleoliquefaction features associated with the 1886

Charleston earthquake clearly demonstrate the existence of a Quaternary tectonic feature.

3. Based on more recent information derived from other investigators on source geometry and earthquake recurrence rates for the Charleston seismic source, the 1986 EPRI Charleston seismic source models need to be updated.

4. All regional seismic source zones, other than the Charleston seismic source zone, have less influence on the ESP site due to their distance from the site. The Charleston seismic source model dominates the ground motion hazard for the ESP site.

5. Within the site region, there is no spatial correlation of earthquake epicenters with known or postulated faults. In general, earthquakes occurring in the South Carolina and Georgia portions of the Coastal Plain and Piedmont provinces are not concentrated or aligned with any mapped faults.

The staff's evaluation of SSAR Sections 2.5.1.1.4 (including SSAR Sections 2.5.1.1.4.1 through 2.5.1.1.4.6) and 2.5.1.1.5 (including SSAR Sections 2.5.1.1.5.1 and 2.5.1.1.5.2) is presented below.

Plate Tectonic Evolution and Stress Field

The staff focused its review of SSAR Sections 2.5.1.1.4.1 and 2.5.1.1.4.2 on the applicant's descriptions of plate tectonic evolution and tectonic stresses within the site region, with an emphasis on the Quaternary Period (1.8 mya to present). In SSAR Section 2.5.1.1.4.1, the applicant described plate tectonic evolution of the Appalachian orogenic belt at the latitude of the site region. The applicant stated that stratigraphic units of the Coastal Plain, the province within which the ESP site lies, record development of a passive continental margin along the east coast of the United States that followed Mesozoic extensional rifting and the opening of the present-day Atlantic Ocean basin. In SSAR Section 2.5.1.1.4.2, the applicant described a detailed study of the orientations and magnitudes of the principal tectonic stresses performed by Moos and Zoback (1992) for the SRS. The applicant stated that the regional stress analyses performed for the CEUS, including the study performed by Moos and Zoback (1992), which characterized a northeast-southwest orientation for the maximum principal compressive stress, did not suggest a need to alter the seismic source models developed by EPRI (1986).
Based on its review of SSAR Sections 2.5.1.1.4.1 and 2.5.1.1.4.2, the staff concludes that the applicant presented a thorough and accurate description of plate tectonic evolutionary history and tectonic stress for the site region in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.23(c), and 10 CFR 100.23(d). These two SSAR sections present well-documented geologic information, which the applicant derived from published sources. The applicant provided an extensive list of references for these sources, which the staff used to confirm the accuracy of the information in the SSAR.

Principal Regional Tectonic Structures

The staff focused its review of SSAR Section 2.5.1.1.4.3 on the applicant's descriptions of tectonic structures (principally faults), with emphasis on the Quaternary Period. In SSAR Section 2.5.1.1.4.3, the applicant described the principal regional tectonic structures based on the age of formation or reactivation of the structures, including those of Paleozoic (greater than 248 mya), Mesozoic (248 to 65 mya), Tertiary (65 to 1.8 mya), and Quaternary (1.8 mya to the present) age. The staff's evaluation of SSAR Section 2.5.1.1.4.3 is presented below.

Figure 2.5.1-9 - Photograph of the relatively horizontal remnant of fluvial terrace Qte (the Ellenton terrace, dated at 1 Ma to 350 ka years old) which occurs on the eastern side of the Savannah River on SRS property and crosses the trace of the Pen Branch fault. This terrace surface exhibits no tilting, warping, or offset due to Quaternary (1.8 mya to the present) displacement along the Pen Branch fault.

Paleozoic Tectonic Structures. The applicant described the Paleozoic tectonic structures that are located in the site region—the Augusta fault zone, Modoc fault zone, Central Piedmont Suture, Eastern Piedmont Fault System, and the Brevard, Hayesville, and Towaliga faults. The applicant concluded that (1) there is no seismicity that can be associated with any of these Paleozoic features; (2) none of the structures are capable tectonic sources; and (3) there is no new information associated with these Paleozoic structures that would necessitate an update of the EPRI (1986) seismic source models.

In SSAR Section 2.5.1.1.4.3, the applicant described two distinct deformation fabrics that are contained in both the Augusta and Modoc fault zones. These deformation fabrics suggest that more than one phase of tectonic deformation may have occurred in these zones. Specifically, the applicant stated that a brittle deformation fabric overprinted (i.e., postdated) formation of a ductile deformation fabric in the Augusta and Modoc fault zones. In RAI 2.5.1-5, the staff asked the applicant to clarify whether the brittle fabric may have formed during a post-Alleghanian deformation event (e.g., during the Quaternary). This clarification is important to document that these two structures are old tectonic features exhibiting no evidence for reactivation during Quaternary time.

In response to RAI 2.5.1-5, the applicant addressed the timing of the development of these two deformation fabrics. The applicant concluded that the brittle deformation fabrics associated with the Augusta and Modoc fault zones, which postdate the ductile mylonitic deformation fabrics in the zones, are either late Alleghanian (greater than 248 mya, at the end of the Paleozoic) or early Mesozoic in age and do not represent Quaternary reactivation in the modern-day stress regime. The applicant cited several supporting lines of evidence for this conclusion:

1. Both the brittle and ductile fabrics exhibit similar movement directions (i.e., similar kinematic histories) during deformation.

2. The observed normal components of brittle movement are not compatible with the modern-day stress field.

3. The observed mineralization of some brittle fabrics exposed at the surface (e.g., silicification of breccias and growth of zeolite minerals and epidote) cannot form under modern-day geologic and hydrothermal conditions.

Based on its review of the applicant's response to RAI 2.5.1-5, the staff concludes that the brittle deformation fabrics do not represent Quaternary deformation, or deformation in the modern-day stress field, along the Augusta or Modoc fault zones. In particular, the staff concurs with the applicant's assertion that the normal components of the brittle movement are incompatible with the modern-day stress regime (i.e., currently a northeast to east-northeast-trending orientation of maximum principal compressive stress) indicating that these fabrics could have developed only as the result of an earlier stress field. The movement history for the brittle deformation fabrics is compatible with the stress field associated with Alleghanian orogeny at the end of the Paleozoic (greater than 248 mya), such that the brittle fabrics of both the Augusta and Modoc fault zones are considerably older than Quaternary. As the applicant stated, Maher et al. (1994) suggest Alleghanian extensional movement along the Augusta fault zone about 274 mya, and Dallmeyer et al (1986) suggest extensional movement of the Modoc fault zone from 310 to 290 mya. Based on this information, the staff also concludes that it is not necessary for the applicant to reassess the seismic hazard potential of these regional structures for the ESP site.

In RAI 2.5.1-6, the staff asked the applicant to include the Central Piedmont Suture and the Eastern Piedmont Fault System on a corrected SSAR Figure 2.5.1-14. In response to this RAI, the applicant confirmed that this correction would be made in the next revision of the ESP application. The staff confirmed that this change was made in revision 2 to the SSAR.

Mesozoic Tectonic Structures. The applicant discussed Mesozoic tectonic structures in SSAR Section 2.5.1.1.4.3, noting that the Dunbarton Triassic basin, an east-northeast-trending Mesozoic (i.e., Triassic (248 to 206 mya)) extensional rift basin, is located beneath both the ESP site and the SRS. The extensional Dunbarton Triassic basin is bounded on its northwest side by the Pen Branch fault, a structure determined by the applicant to underlie the ESP site and to exhibit rejuvenation as an oblique-slip reverse fault during the Cenozoic (65 mya to present) after earlier normal fault displacement during the Mesozoic (248 to 65 mya). The applicant presented a detailed assessment of the potential for Quaternary (1.8 mya to present) displacement along the Pen Branch fault in SSAR Section 2.5.1.2.4. The staff's evaluation of SSAR Section 2.5.1.2.4 is presented in SER Section 2.5.1.3.4.

With regard to regional Mesozoic extensional tectonic terranes, the applicant recognized that areas of extended crust (e.g., such as the eastern part of the Piedmont and beneath the Coastal Plain province in the southeastern United States) may host large earthquakes that are associated spatially with buried faults initially developed in response to extensional rifting. The Pen Branch fault, which forms the northwest boundary of the Dunbarton Triassic basin, is such a fault. The applicant indicated that these buried faults which bound the Triassic basins may be either listric (i.e., a fault with a dip angle that decreases with depth) or a high-angle fault.
In RAI 2.5.1-9, the staff asked the applicant to discuss whether there is any evidence that these buried normal faults are listric or are high-angle faults that could extend through the crust to depths where larger magnitude earthquakes commonly nucleate. In response, the applicant stated the following:

> Data constraining the down-dip geometry of faults that bound Mesozoic basins are equivocal. Seismic reflection data, borehole studies, gravity and magnetic signatures, and geologic mapping have all been used to characterize these faults, but different studies have depicted these faults as both listric and high-angle features. The effects of these two possible geometries on hazard at the site are highly uncertain, but both geometries can produce moderate-to-large magnitude earthquakes on seismogenic structures. Because of the uncertainty regarding their geometry, the EPRI ESTs used area sources instead of individual fault sources to represent these basin-bounding faults in the PSHA.

Due to the uncertainty in the location and subsurface geometry of these faults that bound Mesozoic basins, the staff concurs with the applicant's use of area source zones. Rather than characterizing the seismic potential of each identified or postulated fault, seismic hazard studies for the CEUS generally define broad area seismic source zones. Both the EPRI and LLNL seismic source models use this approach, which is endorsed by RG 1.165. Therefore, the staff concludes that the applicant's response to RAI 2.5.1-9 is adequate and that the applicant has conservatively modeled the seismic sources in the region surrounding the ESP site by using area sources rather than individual fault sources.

Tertiary Tectonic Structures. The applicant described Tertiary tectonic structures in SSAR Section 2.5.1.1.4.3. Within 200 miles of the ESP site only a few tectonic features were active during the Tertiary Period (65 to 1.8 mya). The two most prominent Tertiary structures are the Cape Fear Arch on the South Carolina-North Carolina border and the Yamacraw Arch on the Georgia-South Carolina border. Based on Crone and Wheeler (2000), the applicant concluded that these features do not exhibit any evidence for Quaternary faulting.

Quaternary Tectonic Structures. The applicant discussed potential Quaternary tectonic structures in the region surrounding the ESP site in SSAR Section 2.5.1.1.4.3. To evaluate each of these potential Quaternary features, the applicant used the database of Quaternary tectonic features developed by Crone and Wheeler (2000) and Wheeler (2005) for the CEUS. These two studies present a compilation and description of the faults, paleoliquefaction features, seismic zones, and geomorphic features that may have been active or capable during the Quaternary period. Crone and Wheeler categorize each feature as fitting into one of four "fault classes" (Classes A, B, C, D) based on geologic evidence for Quaternary deformation. This categorization is determined from the authors' survey of the published literature rather than from direct field examination of the features. These four fault classes are defined by Crone and Wheeler (2000) and Wheeler (2005) as follows:

1. Class A—Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether mapped or inferred from liquefaction or other features.

2. Class B—Geologic evidence demonstrates the existence of Quaternary deformation, but either the fault may not cut deeply enough to be a potential earthquake source or available geologic evidence is too strong to assign the feature to Class C but not strong enough to assign it to Class A.

3. Class C—Geologic evidence is insufficient to demonstrate the existence of tectonic faulting or Quaternary deformation associated with the feature.

4. Class D—Geologic evidence demonstrates that the feature is not a tectonic fault.

Using Crone and Wheeler (2000) and Wheeler (2005), the applicant identified the following potential Quaternary tectonic features in the region surrounding the ESP site:

- Charleston, Georgetown, and Bluffton paleoliquefaction features (Class A)
- ECFS (Class C)
- Cooke fault (Class C)
- Helena Banks fault zone (Class C)
- Pen Branch fault (Class C)
- Belair fault zone (Class C)
- Fall Lines of Weems (Class C)
- Cape Fear Arch (Class C)
- ETSZ (Class C)

The applicant discussed Charleston features (including the ECFS, the Cooke fault, the Helena Banks fault zone, and the Charleston, Georgetown, and Bluffton paleoliquefaction features) in detail in SSAR Section 2.5.1.1.4.4. The applicant presented its detailed analysis of the Pen Branch fault in SSAR Section 2.5.1.2.4 and discussed the ETSZ in SSAR Section 2.5.1.1.4.6. The applicant evaluated the remaining features (i.e., the Belair fault zone, the Fall Lines of Weems, and the Cape Fear Arch) in SSAR Section 2.5.1.1.4.3. The staff's evaluation of those three remaining features is presented below.

Belair Fault Zone

As mapped, the Belair fault zone is located about 20 km (12 mi) north-northwest of the ESP site and is at least 25 km (15 mi) in length. The applicant indicated that undeformed strata overlying the disrupted stratigraphic units constrain the last episode of displacement along this fault zone between post-Late Eocene and pre-26,000 years ago, allowing for Cenozoic (i.e., 65 mya to present), including Quaternary, displacement along the fault zone. The applicant also stated that the Belair fault zone is probably a tear fault or lateral ramp in the hanging wall of the Augusta fault zone. If this association between the Augusta and Belair fault zones exists, then movement on the Belair zone may be related to displacement on the longer, regional-scale Augusta fault zone. In RAI 2.5.1-10, the staff asked the applicant to explain how the inference of Cenozoic displacement on the Belair fault zone and a possible association with the regional Augusta fault zone might affect seismic hazard for the ESP site. This clarification is important to document whether the Belair fault zone is structurally linked with the Augusta fault zone and whether it has experienced displacement during the Quaternary.

In its response to RAI 2.5.1-10, the applicant addressed the possibility of a connection between the Belair and Augusta fault zones. The applicant stated that timing and sense-of-slip for the most recent movements on the Belair and Augusta faults demonstrate that these two structures did not respond as a single tectonic element in Cenozoic or younger time. Prowell et al. (1975) and Prowell and O'Connor (1978) document brittle failure due to reverse slip on the Belair fault in the Cenozoic (65 mya to present). In contrast, the applicant stated that the latest movement on the Augusta fault, as demonstrated by brittle overprinting of ductile fabrics, exhibits a normal sense-of-slip which is constrained to late Alleghanian time (greater than 248 mya) based on Maher (1987) and Maher et al. (1994). The applicant acknowledged that Crone and Wheeler (2000) classified the Belair fault zone as Class C, suggesting Quaternary slip on the Belair fault is allowed but not demonstrated by geologic data. The applicant concluded, based on the evidence supporting different slip histories and opposite senses of dip-slip for the Belair and Augusta faults, that reactivation of these two faults as a single structure during the Cenozoic is not indicated.

Based on its review of the applicant's response to RAI 2.5.1-10, the staff concludes that the Belair and Augusta fault zones are not currently linked tectonic features. In particular, the staff concurs that there is strong field evidence for different slip histories and opposite senses of dip-slip for the Belair and Augusta faults and no indication that the structures were reactivated as a single structure during the Cenozoic.

<u>Fall Lines of Weems (1998)</u>

The applicant discussed a series of anomalously steep stream segments derived by Weems (1998) from a study of longitudinal profiles of streams flowing across the Blue Ridge and Piedmont physiographic provinces in North Carolina, Virginia, and Tennessee. Weems (1998) noted that these steep stream segments occurred as seven "fall zones" that were generally subparallel to the northeast-southeast regional "grain" of the Blue Ridge and Piedmont provinces as reflected by physiography, lithologic belts, and regional tectonic features. Weems (1998) suggested three hypotheses to explain this phenomenon, including climatic factors, rock characteristics, and neotectonic effects (i.e., tectonic deformation that is post-Miocene, or greater than 5.3 mya, in age). The applicant stated that the Fall Lines of Weems are classified as Class C features by Wheeler (2005) since they do not demonstrate Quaternary age deformation. Consequently, the applicant concluded that these features do not represent Quaternary faulting in the site region.

Cape Fear Arch

The Cape Fear Arch is a topographic high located on the South Carolina-North Carolina border which is bounded by the Salisbury embayment topographic low to the northeast and the Georgia embayment low to the southeast. The applicant stated that the Cape Fear Arch, a feature previously discussed under the section on tertiary tectonic structures, was classified as Class C by Crone and Wheeler (2000) based on a lack of evidence for Quaternary faulting. The applicant concluded that this feature does not exhibit evidence of Quaternary faulting in light of the Crone and Wheeler (2000) classification and that there is no existing evidence to indicate this feature is a tectonically active structure.

Based on its review of SSAR Section 2.5.1.1.4.3 related to a discussion of faults, the staff concludes that the applicant presented a thorough and accurate description of regional Paleozoic, Mesozoic, Tertiary, and Quaternary tectonic deformation features in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). In addition, based on its review of the applicant's responses to RAI 2.5.1-5, RAI 2.5.1-6 and RAI 2.5.1-9, the staff concludes that regional Paleozoic (greater than 248 mya), Mesozoic (248–65 mya), and Tertiary (65–1.8 mya) features are older structures that do not exhibit Quaternary deformation, and no further assessment of seismic hazard potential in relation to any of these regional structures is necessary for the ESP site.

In regard to Quaternary structures discussed by the applicant in SSAR Section 2.5.1.1.4.3, the staff concurs with the applicant that there is strong field evidence for different slip histories and opposite senses of dip-slip for the Belair and Augusta faults, as the applicant qualified in the response to RAI 2.5.1-10. The staff further concurs with the applicant that these structures did not reactivate as a single, linked structure during Cenozoic time (65 mya to present, which includes the Quaternary). In addition, concerning Quaternary history for the seven Fall Lines of Weems (1998), the citation by the applicant of Wheeler (2005) as the primary basis for assessing the potential for Quaternary activity, in relation to the fall lines, is deemed insufficient by the staff. From previous analysis of these features in connection with the SER for North Anna (see NUREG-1835, "Safety Evaluation Report for an Early Site Permit (ESP) at the North Anna ESP Site," issued September 2005), the staff concludes that differential erosion resulting from variable hardness in rock units is a more plausible origin for the fall lines than Quaternary tectonism. The staff further notes that interpretation of the fall lines as Quaternary tectonic features comes solely from Weems, and no other investigators have suggested this origin. Concerning Quaternary activity for the Cape Fear Arch, the staff concurs with the applicant that there is no existing evidence to indicate that this feature is a tectonic structure exhibiting Quaternary deformation.

Furthermore, the staff concurs with the applicant that potential seismic effects of tectonic structures are fully incorporated into PSHA, because area sources, rather than individual fault sources, are used to capture tectonic features in PSHA. Therefore, the staff believes that specific regional structures need not be defined for PSHA and concludes that the applicant thoroughly evaluated the seismic potential for each of the faults in the site region to determine whether the EPRI PSHA source models require updating.

Principal Regional Tectonic Structures—Charleston

The staff focused its review of SSAR Section 2.5.1.1.4.4 on potential Charleston-area source faults, seismic zones, and liquefaction features, with emphasis on the Quaternary Period. In SSAR Section 2.5.1.1.4.4, the applicant described Charleston tectonic features, including potential source faults, seismic zones, and seismically induced liquefaction features. Analysis of Charleston tectonic features is very important in regard to a potential seismic hazard at the ESP site because the earthquake that occurred in 1886 in the Charleston area is one of the largest historical earthquakes ever to occur within the eastern United States and its source is certain to occur within the ESP site region. After a review of more recent geologic investigations in the Charleston area (some of which described liquefaction features related to the 1886 Charleston earthquake and earlier events likely generated from the same seismic source), the applicant concluded that significant new information related to source geometry and earthquake recurrence rate for the Charleston seismic source warrants an update of the EPRI (1986) source models used in the PSHA. The applicant presented and discussed these updated seismic source parameters for the 1886 Charleston earthquake in SSAR Section 2.5.2.2.2.4 The staff's evaluation of SSAR Section 2.5.1.1.4.4 is presented below.

<u>Potential Source Faults for Charleston</u>. The applicant recognized that no known tectonic source exists for the 1886 Charleston earthquake. Consequently, location of a "Charleston tectonic source" is based on historical reports of damage and occurrence of seismically induced liquefaction features to define an area rather than a specific source fault. The applicant discussed nine potential tectonic source faults for the 1886 Charleston earthquake—the ECFS, Adams Run fault, Ashley River fault, Charleston fault, Cooke fault, Helena Banks fault zone, Sawmill Branch fault, Summerville fault, and Woodstock fault. The applicant concluded that no specific linkage between any of these features and the 1886 Charleston earthquake could be proposed based on geomorphic, geologic, borehole, or seismic evidence. The applicant's discussion of potential tectonic source features for the 1886 Charleston earthquake did not include two faults shown on SSAR Figures 2.5.1-19 and 2.5.1-20 to occur in the meizoseismal area (i.e., the area of maximum damage to structures resulting from the earthquake) of the Charleston earthquake, namely the Gants and Drayton faults. The staff asked, in RAI 2.5.1-13, the applicant to acquire additional descriptive information on these two faults to enable a thorough review of all faults postulated to occur in the meizoseismal area of the 1886 Charleston earthquake.

In response to RAI 2.5.1-13, the applicant provided descriptive information for the Gants and Drayton faults. For the Drayton fault, the applicant concluded that Cenozoic (65 mya to present), and consequently Quaternary (1.8 mya to present), displacement is precluded based on interpretations of seismic reflection data (Hamilton et al., 1983) which suggest that the fault terminates at a depth of about 750 m (2500 ft) below the ground surface in a Jurassic (206 to 144 mya) basalt layer. For the Gants fault, the applicant concluded that seismic reflection data suggested that the fault may disrupt Cenozoic strata, but with decreasing displacement during Cenozoic time. The conclusions drawn by the applicant for both the Gants and Drayton faults are, therefore, supported by the evidence derived from seismic reflection data, as neither fault exhibits any surface expression.

Based on its review of the applicant's response to RAI 2.5.1-13, the staff concludes that the response provides an adequate description of the Gants and Drayton faults. The staff also concludes that neither of these two faults exhibit any obvious linkage to the 1886 Charleston earthquake in space or time. Because the applicant could not correlate this earthquake with any of the nine potential source faults discussed in SSAR Section 2.5.1.1.4.4, including the Gants and Drayton faults, and uncertainty remains in selecting a specific tectonic source, the staff considers it important that the applicant incorporate the new information on source geometry and earthquake recurrence rate for the 1886 Charleston earthquake into the seismic source models for Charleston. The applicant incorporated these new data into the analyses discussed in SSAR Section 2.5.2.2.2.4 (seismic potential for a Charleston source fault is captured in PSHA by use of a source area rather than a specific tectonic structure for the Charleston area).

Potential Seismic Source Zones for Charleston. Regarding seismic source zones for the 1886 Charleston earthquake, the applicant discussed three zones of increasing seismicity identified in the Charleston area. The zones include the Middleton Place-Summerville, Bowman, and Adams Run seismic zones. The characteristics of these zones are discussed in SSAR Section 2.5.1.1.4.4 and SER Section 2.5.1.1.2. The applicant reached no specific conclusions regarding these three seismic zones in SSAR Section 2.5.1.1.4.4. Details related to specific data in the seismicity catalog for these three zones are discussed in SSAR Section 2.5.2.1. The staff found the descriptions of the seismic source zones, based on published literature (provided by the applicant in SSAR Section 2.5.1.1.4.4) to be acceptable.

Charleston Area Liquefaction Features. Regarding seismically induced liquefaction features in the Charleston area, the applicant stated that such features produced by the 1886 Charleston earthquake are most heavily concentrated in the meizoseismal area for that earthquake. The applicant also reported the locations of prehistoric liquefaction features related to significant seismic events that pre-dated the 1886 Charleston earthquake, but likewise interpreted to most likely have been generated by the same tectonic source. The applicant indicated that, based on consideration of these prehistoric liquefaction data, Talwani and Schaeffer (2001) suggested a mean recurrence interval of 550 years for a Charleston-type earthquake. This interval is roughly an order of magnitude less than the seismicity-based estimates used by EPRI (1986) to characterize recurrence interval for earthquakes generated by the Charleston seismic source. Based on the identification of earthquakes pre-dating the 1886 Charleston seismic event from the prehistoric liquefaction features, the applicant refined earthquake recurrence rate estimates for a Charleston-area earthquake in SSAR Section 2.5.2.2.2.4. The applicant made no specific conclusions regarding seismically induced liquefaction features in SSAR Section 2.5.1.1.4.4.

With regard to liquefaction features in the Charleston area, the staff found that the descriptions of these features provided by the applicant in SSAR Section 2.5.1.1.4.4 needed clarification. To better correlate liquefaction features with proposed tectonic sources, in RAI 2.5.1-11, the staff asked the applicant to include new figures that clearly distinguished liquefaction features related to the 1886 Charleston earthquake from the prehistoric liquefaction events shown in SSAR Figure 2.5.1-19. In RAI 2.5.1-12, the staff asked the applicant to include an additional pertinent reference by Bollinger (1977). The applicant provided the new figures and the reference in its responses to RAI 2.5.1-11 and RAI 2.5.1-12.

The staff concludes that the applicant presented a thorough and accurate geologic description of Charleston tectonic features (including potential source faults, seismic source zones, and liquefaction features) in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). In addition, based on its review of the information presented by the applicant on Charleston tectonic features in SSAR Section 2.5.1.1.4.4, and the applicant’s responses to RAI 2.5.1-11, RAI 2.5.1-12, and RAI 2.5.1-13, the staff concurs with the applicant that no specific linkage between any of the nine faults discussed and the 1886 Charleston earthquake can be proposed based on geomorphic, geologic, borehole, or seismic evidence. The staff also concludes that it is important for the applicant to incorporate new information on source geometry and earthquake recurrence rate for the Charleston seismic source into PSHA source models for the ESP site. Furthermore, with regard to seismically induced liquefaction features, the staff concurs with the applicant that liquefaction features produced by the 1886 Charleston earthquake are most heavily concentrated in the meizoseismal area. The applicant refined earthquake recurrence rate estimates for a

Charleston-area earthquake in SSAR Section 2.5.2.2.2.4. The staff considers it important for the applicant to define a seismic source zone for a Charleston-area earthquake by considering all faults and liquefaction features that it deemed feasible to include for establishing reasonable geologic boundaries for the seismic source zone.

Principal Regional Tectonic Structures—Savannah River Site

The staff focused its review of SSAR Section 2.5.1.1.4.5 on the applicant's descriptions of SRS faults, with emphasis on the Quaternary Period. In SSAR Section 2.5.1.1.4.5, the applicant discussed SRS tectonic features, including the Pen Branch, Steel Creek, Ellenton, Upper Three Runs, ATTA, Crackerneck, Martin, Tinker Creek, Lost Lake, and Millet faults. The applicant indicated that four of these faults (i.e., the Pen Branch, Steel Creek, Ellenton, and Upper Three Runs faults) are interpreted to occur within the site area. Because the Pen Branch fault underlies the ESP site, the applicant discussed this fault in great detail in SSAR Section 2.5.1.2.4 on site area structural geology. The staff's evaluation of SSAR Section 2.5.1.1.4.5 is presented below.

Descriptions of faulting at the SRS provided in the SSAR are based on published literature from technical specialists who are very knowledgeable about tectonic features at the SRS. These descriptions are as accurate as possible, based on the consideration that most of these faults are defined in the subsurface primarily from interpretation of seismic reflection profiles (i.e., none of the faults exhibit surface expression at the SRS). The staff asked, in RAI 2.5.1-14, the applicant to obtain clarification of why the density of faults at the SRS on the eastern side of the Savannah River is so much greater than for the ESP site on the western side of the river and the implication this has for the seismic hazard at the ESP site. In RAI 2.5.1-15, the staff asked for a summary of pertinent data derived from the SRS leading to the applicant's conclusion that the Pen Branch fault is not a capable tectonic structure. In RAI 2.5.1-15, the staff also asked the applicant to compare data and analyses for the SRS with data and analyses employed by the applicant to conclude that the Pen Branch fault is not a capable structure at the ESP site. Since detailed studies of faulting at the SRS have been conducted for an extended period of time, and the ESP site is adjacent to the SRS although on the opposite side of the Savannah River, information collected from and analyses performed for the SRS are very pertinent for assessing the potential for capable faults at the ESP site.

In response to RAI 2.5.1-14, the applicant stated that the SRS was the focus of several decades of subsurface exploration and research. The applicant emphasized that the availability of high-resolution seismic reflection profiles that completely traverse the ESP site from north to south (normal-to-regional structural grain) and image the complete Coastal Plain stratigraphic section from the top of the basement to shallow levels, collected as part of the VEGP ESP project, makes the existence of any unrecognized faults at the ESP site unlikely. The applicant also stated that, although the faults shown on the SRS are greater in number, considering the difference in the size of the area of investigation between the SRS and the ESP site, fault densities are comparable. The applicant indicated that resolution and signal-to-noise ratio of the seismic profile that traverses the ESP site (i.e., proposed VEGP Unit 4) are significantly better than almost all of the seismic reflection data available for SRS. Based on these lines of evidence, the applicant concluded that the absence of previously unrecognized faults in the ESP seismic reflection data indicate that faulting at the ESP site and in the site area has been adequately characterized. The applicant thus concluded that no unknown faults exist that would affect the seismic hazard at the site.

In response to RAI 2.5.1-15, the applicant summarized the evidence substantiating that the Pen Branch fault is not a capable tectonic feature as follows:

1. Faulting deforms sediments no younger than Eocene in age. The data for this conclusion are based on 18 closely-spaced SRS drill holes that allowed construction of a subsurface geologic map of a formation above the fault. Additional support for this conclusion is based on geologic mapping and data from 20 auger holes in the Long Branch, South Carolina 7.5 minute quadrangle (Nystrom et al. 1994). The auger holes are located adjacent to the SRS but along strike of the Pen Branch fault and showed no evidence for faulting.

2. Savannah River Quaternary fluvial terraces are not deformed across the fault trace, within a resolution limit of 2 to 3 m (7 to 10 ft), based on longitudinal profiles along two Savannah River terraces (Geomatrix 1993).

3. Based on data from Moos and Zoback (1992), regional principal stress orientations determined from boreholes show that the maximum horizontal stress is parallel to the regional orientation of the Pen Branch fault, making strike-slip faulting unlikely and reverse faulting essentially impossible.

4. The VEGP terrace study documented that no fault-related deformation of the 350 ka to 1 Ma Ellenton (Qte) terrace above the projected surface trace of the Pen Branch Fault occurs within a resolution of 1 m (3 ft). The resolution of this study makes it the most definitive evidence for non-capability of the Pen Branch Fault both at the SRS and the ESP site.

The conclusion stated by the applicant that the absence of previously unrecognized faults in the ESP seismic reflection data indicates that faulting at the ESP site and in the site area has been adequately characterized, as well as its conclusion that there are no unknown faults that would affect the seismic hazard at the site, is supported by the evidence from high-resolution seismic profile data. The conclusion stated by the applicant that faulting does not deform strata younger than Eocene (54.8 to 33.7 mya) is supported by the evidence from 18 drill holes at the SRS. The conclusion stated by the applicant that the analysis of the Ellenton terrace, which overlies the Pen Branch fault, revealed no fault-related deformation within a resolution limit of 1 meter (3 feet) is supported by data collected for the ESP application.

Based on its review of the applicant’s responses to RAI 2.5.1-14 and RAI 2.5.1-15, the staff concludes that the applicant adequately addressed the topics of concern raised in RAI 2.5.1-14 and RAI 2.5.1-15. The staff summarizes and discusses the evidence presented by the applicant indicating that the Pen Branch fault is not a capable tectonic structure in SER Section 2.5.1.3.4.

The staff concludes that the applicant presented a thorough and accurate description of SRS tectonic features in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). In addition, based on its review of the information presented by the applicant on SRS tectonic features in SSAR Section 2.5.1.1.4.5 and the applicant’s responses to RAI 2.5.1-14 and RAI 2.5.1-15, the staff concurs with the applicant that the absence of previously unrecognized faults in the ESP seismic reflection data indicate that faulting at the ESP site and in the site area has been adequately characterized. The staff also concurs with the applicant that unknown faults that would affect the seismic hazard at the site are not likely to exist, but the staff will examine all excavations for the ESP site applying regulatory guidance in RG 1.132, “Site Investigations for Foundations of Nuclear Power Plants”, to ensure that this point is true. The staff further concurs with the applicant's conclusion that faulting does not deform strata younger than Eocene (54.8 to 33.7 mya) because this conclusion is supported by evidence from 18 drill holes at the SRS. Finally, the staff concurs with the applicant's conclusion that the analysis of the Ellenton terrace, which overlies the Pen Branch fault, revealed no fault-related deformation within a resolution limit of 1 m (3 ft) because this conclusion is supported by data collected for the ESP application.

Principal Regional Tectonic Structures—Anomalies and Lineaments

The staff focused its review of SSAR Sections 2.5.1.1.4.3 and 2.5.1.1.5 on the applicant's descriptions of regional geophysical anomalies and lineations and regional gravity and magnetic data, with emphasis on the Quaternary Period. The applicant discussed these anomalies and lineaments in SSAR Section 2.5.1.1.4.3 (the East Coast Magnetic and Blake Spur anomalies and the New York-Alabama, Clingman, and Ocoee lineaments). These two SSAR sections present well-documented geologic information, which the applicant derived from published sources. The applicant provided an extensive list of references for these sources, which the staff examined to ensure the accuracy of the information in the SSAR. The staff's evaluation of SSAR Sections 2.5.1.1.4.3 and 2.5.1.1.5 is presented below.

The applicant concluded that the geophysical anomalies and lineaments discussed in SSAR Section 2.5.1.1.4.3 did not pose concerns for the ESP site in regard to seismic hazard. In SSAR Section 2.5.1.1.5, the applicant summarized regional gravity and magnetic data and concluded that no large, unexplained anomalies exist in either data set, and no evidence exists for Cenozoic (i.e., including Quaternary age) tectonic activity or features based on that data. Information that the applicant presented for these two topics is well documented in published literature.

The staff asked, in RAI 2.5.1-7, the applicant to acquire information on the Grenville Front, listed among the features occurring within the site region but not discussed in SSAR Section 2.5.1.1.4.3, to enable assessment of whether this feature should be considered as a potential seismic source for the ESP site. The staff asked, in RAI 2.5.1-8, the applicant to (1) locate the Clingman and Ocoee lineaments and the Ocoee block on the map shown in SSAR Figure 2.5.1-12; (2) indicate the age of the "modern" tectonic setting referred to by Wheeler (1996) for earthquakes within the region of the Ocoee block to aid assessment of whether faults in this region are potentially capable structures requiring consideration for the ESP site; and (3) indicate whether the New York-Alabama, Clingman, and Ocoee lineaments could be potential seismic sources for the site.

In response to RAI 2.5.1-7, the applicant indicated that the Grenville Front was incorrectly listed as a feature occurring within 320 km (200 mi) of the ESP site (i.e., within the site region) and agreed to include the feature on SSAR Figure 2.5.1-12 to eliminate any confusion about its location. The applicant described the Grenville Front in SSAR Section 2.5.1.1.4.1 as a feature developed in Precambrian time during the Grenville Orogeny (i.e., 1100 mya) and concluded in the response that it does not represent a potential seismic source based on the firm evidence that it developed in Precambrian time.

In the response to RAI 2.5.1-8, the applicant agreed to include the Clingman and Ocoee lineaments and the Ocoee block in SSAR Figure 2.5.1-12. The applicant also indicated that the "modern" tectonic setting refers to the setting for the east coast of the United States as a passive continental margin, with regional tectonic stress for the CEUS characterized by northeast-southwest horizontal compression. The applicant stated that this regional stress orientation is subparallel to the lineaments, suggesting that they are not in the most favorable orientation for failure in this regional stress field. The applicant concluded that, while the New York-Alabama, Clingman, and Ocoee lineaments bound a block (i.e., the Ocoee block) that appears responsible for earthquakes in the ETSZ, most focal mechanism nodal planes derived from fault plane solutions in the ETSZ are not parallel to the northeast-trending lineaments, suggesting that features with this orientation are not favorably oriented for accommodating fault displacement. The applicant cited evidence related to orientation of nodal planes defined in the Ocoee block, derived from Johnston et al. (1985) as stated in SSAR Section 2.5.1.1.4.3, indicating north-south and east-west faults for the Ocoee block rather than structures parallel to the northeast-southwest strike trend of the lineaments. The applicant further stated that the lineaments were known to the technical teams in the 1986 EPRI study, and no new information has been published since 1986 on the lineaments that would require a significant change in the EPRI seismic source model.

Based on its review of the applicant's responses to RAI 2.5.1-7 and RAI 2.5.1-8, the staff concludes that neither the Grenville Front nor the New York-Alabama, Clingman, and Ocoee lineaments are likely to be viable seismic sources.

The staff concludes that the applicant presented a thorough and accurate description of regional geophysical anomalies and lineations and regional gravity and magnetic data in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). Furthermore, based on its review of the information presented by the applicant on regional geophysical anomalies and lineations and regional gravity and magnetic data in SSAR Sections 2.5.1.1.4.3 and 2.5.1.1.5 and the applicant's responses to RAI 2.5.1-7 and RAI 2.5.1-8, the staff concurs with the applicant that no regional anomalies or lineaments and no regional gravity or magnetic data indicated features requiring consideration for seismic hazard analysis at the ESP site. The staff further concurs with the applicant that none of the anomalies or lineaments described by the applicant in SSAR Sections 2.5.1.1.4.3 and 2.5.1.1.5 are likely to be seismic sources requiring seismic hazard consideration at the ESP site.

Seismic Source Zones

The staff focused its review of SSAR Section 2.5.1.1.4.6 on the applicant's descriptions of the seismically defined source zones, including selected seismogenic and capable tectonic sources beyond the site region, with emphasis on the Quaternary Period (1.8 mya to present). In SSAR Section 2.5.1.1.4.6, the applicant described seismic sources (defined based on regional seismicity) comprising the ETSZ within the site region and the Central Virginia, New Madrid, and GCSZs outside of the site region. This SSAR section presents well-documented geologic information which the applicant derived from published sources. The applicant provided an extensive list of references for these sources, and the staff directly examined relevant references to ensure the accuracy of the information derived from published sources and presented in the SSAR. The staff's evaluation of SSAR Section 2.5.1.1.4.6 is presented below.

In regard to seismic sources within, and selected sources outside, the site region, the applicant concluded that only the NMSZ required an update of source parameters, in particular, of the recurrence rate. This conclusion was rendered necessary by new information that the applicant reported in the SSAR, as derived from the published literature. The applicant concluded further that information for none of the other three zones (i.e., the East Tennessee, Central Virginia, and Giles County zones) required a significant revision to the 1986 EPRI source model in light of data that were also derived from the published literature. This information included interpretations from Wheeler (2005) that the East Tennessee and GCSZs are Class C features based on a lack of geologic evidence for large earthquakes associated with the zones.

The staff concludes that the applicant presented a thorough and accurate description of seismic source zones defined by seismicity within the site region, including selected sources outside the site region, in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). Based on its review of the information presented by the applicant on seismic source zones in SSAR Section 2.5.1.1.4.6, the staff also concludes that all regional seismic source zones discussed by the applicant have less influence on the ESP site due to their distance from the site than the updated Charleston seismic source model discussed in SSAR Section 2.5.2.2.2.4. The staff concurs with the applicant that the Charleston seismic source model dominates ground motion hazard for the site. The applicant incorporated new information on source geometry and earthquake recurrence rate for this source into an updated seismic source model in SSAR Section 2.5.2.2.2.4.

Based on its review of SSAR Section 2.5.1.1.4 and the applicant's responses to RAIs as set forth above, the staff concludes that the applicant identified and properly characterized all regional tectonic features. The staff also concludes that SSAR Section 2.5.1.1.4 provides an accurate and thorough description of regional tectonic features, with an emphasis on potential Quaternary deformation, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d).

2.5.1.3.3 Site Area Geologic Description

In SSAR Sections 2.5.1.2.1, 2.5.1.2.2, and 2.5.1.2.3, the applicant reviewed and summarized published information related to physiography and geomorphology (Section 2.5.1.2.1), geologic history (Section 2.5.1.2.2), and stratigraphy (Section 2.5.1.2.3) of the site area. Based on information presented in SSAR Sections 2.5.1.2.1, 2.5.1.2.2, and 2.5.1.2.3, the applicant concluded that physiography, geomorphology, geologic history, and stratigraphy of the site area pose no safety issues for the ESP site. Consequently, the applicant considered the site suitable in regard to these area-specific features and their characteristics. The staff's evaluation of SSAR Sections 2.5.1.2.1, 2.5.1.2.2, and 2.5.1.2.3 is presented below.

Physiography, Geomorphology, and Geologic History

The staff focused its review of SSAR Sections 2.5.1.2.1 and 2.5.1.2.2 on the applicant's descriptions of physiography, geomorphology, and geologic history of the site area, with emphasis on the Quaternary Period. In SSAR Section 2.5.1.2.1, the applicant described the geomorphology of the Coastal Plain physiographic province within which the ESP site lies. In SSAR Section 2.5.1.2.2, the applicant described geologic history of the site area, emphasizing the Coastal Plain. These two SSAR sections present well-documented geologic information, which the applicant derived from published sources. The applicant provided an extensive list of references for these sources, which the staff examined to ensure the accuracy of the information presented by the applicant in the SSAR.

In the description of site area physiography and geomorphology presented in SSAR Section 2.5.1.2.1, the applicant indicated that the Savannah River is relatively straight and incised in the site area in the vicinity of the projected surface trace of the Pen Branch fault. Tectonic uplift, among other factors, can lower the base level to which a stream will naturally erode, resulting in active erosion by down-cutting and incision of the stream channel. The staff asked, in RAI 2.5.1-4, the applicant to address why the Savannah River is relatively straight and incised at a position that appears to correspond with the location of the Pen Branch fault. This clarification is important to enable an assessment of whether reverse or reverse-oblique slip along the Pen Branch fault occurred to uplift the hanging wall fault block; lower the base level to which the Savannah River would erode; and thus create an incised river channel.

In response to RAI 2.5.1-4, the applicant concluded that the straight, incised segment of the Savannah River is not the result of Quaternary displacement along the Pen Branch fault. The applicant cited three lines of evidence interpreted to preclude Quaternary displacement along the Pen Branch fault as being the mechanism that produced this straight, incised segment of the Savannah River channel:

1. The geomorphic surface of the 350 ka to 1 Ma Ellenton fluvial terrace along the Savannah River is undeformed to within a resolution of 1 m (3 ft). The applicant stated that this observation is the best evidence precluding late Quaternary activity of the Pen Branch fault and establishing that the Pen Branch is not a capable fault. The applicant considered it highly unlikely that changes in the modern river channel morphology at the location of the Pen Branch fault would be the result of Quaternary fault activity if the Ellenton terrace surface is preserved across the fault with no evidence of deformation.

2. Several other examples of linear or incised portions of rivers are present in the Coastal Plain within 80 km (50 mi) of the ESP site that are not associated with any mapped fault. The applicant stated that the occurrence of other linear portions of river channels demonstrates that the morphology of the Savannah River adjacent to the VEGP site is not unique, but relatively common in the region. The applicant indicated that these other linear reaches of river channels are not spatially associated with known mapped faults, strongly suggesting a nontectonic origin for this type of feature.

3. Localized remnant surfaces on the modern flood plain that formed as the result of paleochannel migration indicate that, although the river at present appears relatively straight, it has meandered across the flood plain in recent time. Therefore, the applicant stated that the apparent “straight” segment of the Savannah River channel near the ESP site appears to be an ephemeral feature that changes or evolves through geologic time in response to changes in sediment load, discharge, and eustatic base-level change.

Based on its review of the applicant’s response to RAI 2.5.1-4, the staff concludes that the straight, incised channel of the Savannah River which occurs in the site area in the vicinity of the Pen Branch fault does not require a mechanism related to Quaternary displacement along the Pen Branch fault to produce this morphology along the river channel.

Based on its review of SSAR Sections 2.5.1.2.1 and 2.5.1.2.2 and the applicant’s response to RAI 2.5.1-4, the staff concludes that the applicant presented a thorough and accurate description of the physiography, geomorphology, and geologic history of the site area in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d).

Stratigraphy

The staff focused its review of SSAR Section 2.5.1.2.3 on the applicant’s description of stratigraphic units in the site area, with emphasis on sedimentary units of the Coastal Plain within which the ESP site lies. In SSAR Section 2.5.1.2.3, the applicant described Coastal Plain stratigraphy in the site area in detail and also discussed basement rocks (i.e., both Paleozoic crystalline rocks and sedimentary rocks of the Dunbarton Triassic basin) which underlie Coastal Plain sedimentary units in the site area. The applicant used information derived from borehole B-1003 drilled at the ESP site to describe stratigraphic units of the Coastal Plain that occur at the site. The staff also examined core from this specific borehole during a visit to the ESP site, and this examination of subsurface stratigraphy by the staff added credence to the accuracy of the applicant's description of site stratigraphy. The applicant's discussion of previous data on the site-specific stratigraphic units cited well-documented geologic information derived from published sources. The applicant provided an extensive list of references for these sources, which the staff examined to ensure the accuracy of the information presented in the SSAR.

Based on its review of SSAR Section 2.5.1.2.3, the staff concludes that the applicant presented a thorough and accurate description of stratigraphic relationships for the site area in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). SER Section 2.5.4 provides further discussion of the engineering properties of soil and rock materials that underlie the ESP site and the staff's complete evaluation of the applicant's description of these materials.

2.5.1.3.4 Site Area Structural Geology

In SSAR Section 2.5.1.2.4, the applicant reviewed and summarized published information related to the structural geology of the site area, including the Pen Branch, Ellenton, Steel Creek, and Upper Three Runs faults. Of these four faults, the applicant determined that the Pen Branch fault underlies the ESP site and required further investigation to determine whether it is a capable tectonic feature exhibiting Quaternary displacement. Therefore, in addition to summarizing published results from previous studies of the Pen Branch fault, the applicant presented important new information from seismic reflection and refraction surveys and evaluation of Quaternary-age fluvial terraces overlying the Pen Branch fault. The applicant collected this information for the ESP application specifically to determine whether the Pen Branch fault is a capable tectonic feature. The applicant stated that the Upper Three Runs and Steel Creek faults are restricted entirely to basement rocks and do not offset Coastal Plain deposits, and the Ellenton fault no longer appears on recent maps of the SRS where it was first interpreted to occur based on seismic reflection data.

Based on information presented in SSAR Section 2.5.1.2.4, the applicant concluded that the structural geology of the site area poses no safety issues for the ESP site. With due consideration for the results of previous studies of the Pen Branch fault and the new information collected for the ESP application, the applicant concluded that the Pen Branch fault does not exhibit Quaternary displacement and is not a capable tectonic feature requiring analysis for seismic hazard or surface-faulting issues at the site. The applicant also concluded that the Ellenton, Steel Creek, and Upper Three Runs faults are not capable tectonic features. Consequently, the applicant considered the site suitable in regard to area-specific geologic structures (i.e., faults) and their characteristics, including the Pen Branch fault. The staff's evaluation of SSAR Section 2.5.1.2.4 specifically in regard to the Pen Branch fault, including SSAR Sections 2.5.1.2.4.1, 2.5.1.2.4.2, and 2.5.1.2.4.3 is presented below.

<u>Pen Branch Fault</u>

The staff focused its review of SSAR Section 2.5.1.2.4 on the applicant's descriptions of the Pen Branch fault (SSAR Section 2.5.1.2.4.1), including new information collected for the ESP application derived from site subsurface investigation of the Pen Branch fault (SSAR Section 2.5.1.2.4.2) and evaluation of Quaternary river terrace Qte (Ellenton terrace) which overlies the

Pen Branch fault (SSAR Section 2.5.1.2.4.3). The staff's review emphasized the Quaternary Period and included careful analysis of all information presented by the applicant related to determining whether the Pen Branch fault exhibited Quaternary displacement. The applicant's discussion of previous data on the Pen Branch fault cited well-documented geologic information derived from published sources. The applicant provided an extensive list of references for these sources, which the staff examined to ensure the accuracy of the information in the SSAR. However, in the extensive list of references, the applicant did not cite a publication by Hanson et al. (1993) in which the investigators suggested that possible rejuvenation of drainage along projected surface traces of the Pen Branch and Steel Creek faults on the SRS may indicate either local tectonic uplift along these faults at a very low rate of displacement (i.e., 0.002 to 0.009 mm/yr) or nontectonic geologic processes. In RAI 2.5.1-17, the staff asked the applicant to determine whether the concept presented by Hanson et al. (1993), related to the suggestion of possible Quaternary displacement along the Pen Branch fault based on their analysis of drainage morphology at the SRS, held any implications of geologic hazard for the ESP site.

In response to RAI 2.5.1-17, the applicant addressed the suggestion of Hanson et al. (1993) that stream drainage patterns along the trace of the Pen Branch fault on the SRS may suggest local Quaternary tectonic uplift. The applicant summarized results of a 1993 study by Geomatrix that concentrated on collecting and analyzing several types of information in regard to Quaternary tectonic deformation at the SRS. The applicant discussed data derived from a regional slope map, slope profiles, longitudinal stream profiles, and residual maps that Geomatrix (1993) constructed for this analysis. Based on this information, the applicant concluded that no obvious topographic or geomorphic characteristics could be equated with geologic structures or required the occurrence of Quaternary deformation along the Pen Branch fault. The applicant also reviewed data developed from evaluation of drainage basin shape, drainage density, and drainage frequency by Geomatrix (1993). The applicant likewise concluded from this information that none of these aspects of the drainage patterns indicated geologic structures or required Quaternary deformation along the Pen Branch fault. The applicant referred to fluvial terrace studies conducted by Geomatrix (1993), as well as the more refined terrace studies conducted for the ESP application discussed in SSAR Section 2.5.1.2.4.3, as the most conclusive evidence for a lack of Quaternary deformation along the Pen Branch fault.

Based on its review of the applicant's response to RAI 2.5.1-17, the staff concludes that there is no definitive evidence described by Hansen et al. (1993) indicating the existence of Quaternary displacement along the Pen Branch fault in the site area. The staff further concludes that the applicant's response to RAI 2.5.1-17 adequately qualified the conclusion presented by the applicant.

In the discussion of geometry of the Pen Branch fault presented in SSAR Section 2.5.1.2.4.2, the applicant stated that the Pen Branch fault at the ESP site is made up of two specific fault segments trending N45°E and N34°E with a dip of 45°SE. Considering the N50° to 70°E modern-day orientation of maximum principal horizontal compressive stress defined by Moos and Zoback (1992) for the site region in relation to orientations of segments of the Pen Branch fault, the staff asked, in RAI 2.5.1-18, the applicant to determine whether either fault segment is favorably oriented to experience displacement in the existing regional stress field.

In response to RAI 2.5.1-18, considering the N50° to 70°E modern-day orientation of maximum principal horizontal compressive stress defined by Moos and Zoback (1992) for the site region, the applicant chose an average orientation of the maximum horizontal stress as N60°E and determined that planes striking N45°E and N34°E and dipping 45°SE form angles to the maximum horizontal stress of approximately 10° and 20°, respectively. The applicant stated that these orientations are not parallel to the maximum horizontal stress and therefore would experience some amount of resolved shearing stress. However, based on Ramsey and Huber (1987), the applicant indicated that planes of such orientations relative to maximum principal horizontal compressive stress would not experience maximum shearing stress. The applicant pointed out that favorably oriented planes for maximum resolved shearing stress occur at 45° to the maximum horizontal compressive stress direction. Moos and Zoback (1992) further stated that stress magnitudes at shallow depths only approach the frictional strength of favorably oriented reverse faults (i.e., 45°). Therefore, the applicant concluded that stress magnitudes resolved along planes of other orientations will be well below those necessary for displacement in the modern-day stress field. The applicant also concluded that the orientation of the Pen Branch fault segments at the ESP site makes them less favorably oriented for failure in response to the intermediate-depth stress perturbation of N33°E which Moos and Zoback (1992) reported.

Based on its review of the applicant's response to RAI 2.5.1-18, the staff concurs with the applicant that neither of the segments of the Pen Branch fault occurring at the ESP site are favorably oriented to experience displacement in the modern-day stress field. As the applicant indicated, shear failure theory predicts that favorably oriented planes for maximum resolved shearing stress occur at 45° to the maximum horizontal compressive stress direction.

The staff concludes that the applicant presented a thorough and accurate description of the Pen Branch and other faults in the site area in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). Furthermore, upon consideration of the information the applicant presented in SSAR Section 2.5.1.2.4, including the applicant's responses to RAI 2.5.1-17 and RAI 2.5.1-18, to support its conclusions about the noncapable nature of the Pen Branch fault, the staff concurs with the applicant that no definitive evidence exists to indicate that the Pen Branch fault (1) shows any surface expression; (2) exhibits Quaternary displacement based on analysis of fluvial terraces and age of stratigraphic units which bound the time of fault displacement; or (3) is a capable tectonic structure. SER Section 2.5.3 contains the staff's complete evaluation of surface faulting near the ESP site in regard to the potential for tectonic deformation and vibratory ground motion due to surface faulting.

The technical bases for the staff's conclusions in regard to site area structural geology, specifically that the Pen Branch fault is not a capable tectonic feature at the ESP site, are related to the evidence which the applicant presented in the SSAR and in its responses to RAIs. The evidence presented by the applicant and summarized below covers information acquired from previous investigations at the SRS and the VEGP site; geomorphic mapping and field reconnaissance, seismic reflection and refraction studies, and investigation of Quaternary fluvial terraces performed by the applicant for the ESP application; and analysis of the regional stress field.

<u>Previous Investigations at the Savannah River Site</u> History of and evidence from previous investigations of the Pen Branch fault conducted at the SRS, which the applicant outlined in SSAR Section 2.5.1.2.4.1, are summarized as follows:

1. Based on seismic data, Snipes et al. (1989) suggested Late Eocene (33.7 mya or older) displacement, but no younger, on the Pen Branch fault and concluded that the fault should not be considered a capable tectonic structure at the SRS.

2. Based on a seismic reflection survey designed to investigate the Pen Branch fault, Berkman (1991) reported deformation of the Cretaceous age (144 to 65 mya) Cape Fear Formation, but no younger units, and concluded that the Pen Branch fault is not a capable tectonic feature.

3. A fluvial terrace study performed by Geomatrix (1993) confirmed no tectonic deformation of terrace surfaces overlying the Pen Branch fault within a resolution of 2 to 3 m (7 to 10 ft), and Geomatrix (1993) concluded that the Pen Branch is not a capable tectonic feature.

4. Snipes et al. (1993) reported that the youngest stratigraphic horizon known from borehole studies to be deformed by fault displacement along the Pen Branch fault is the Dry Branch Formation of Late Eocene (33.7 mya or older) age, and that a Quaternary soil horizon overlying the projected trace of the Pen Branch fault at the SRS showed no offset. The applicant reported this information in SSAR Section 2.5.3.6.

5. Based on results of a drilling project designed to investigate the Pen Branch fault using 18 boreholes, Stieve et al. (1994) concluded that the Pen Branch fault is no younger than 50 mya and is not a capable tectonic feature.

6. Cumbest et al. (1998) integrated information from more than 60 boreholes and 100 miles of seismic reflection profiling and concluded that no faults on the SRS, including the Pen Branch Fault, are capable tectonic features.

7. Based on seismic reflection data, Cumbest et al. (2000) concluded that offset along the Pen Branch fault decreased upward within Coastal Plain sediments to no greater than 9 m (30 ft) at the top of Upper Cretaceous/Lower Paleocene units (i.e., about 66.4 mya).

Previous Investigations at the VEGP Site

Henry (1995) collected and interpreted 115 km (70 mi) of seismic reflection data along the Savannah River, including in the vicinity of VEGP Units 1 and 2, and crossing the projected trace of the Pen Branch fault. Henry (1995) concluded that the Pen Branch fault extended into possibly Eocene age (54.8 to 33.7 mya) sediments. The applicant summarized this information in SSAR Section 2.5.1.2.4.1.

In SSAR Section 2.5.3.8.2.1, the applicant indicated that an old garbage trench that crossed the trace of the Pen Branch fault in the ESP site area, mapped by Bechtel in 1994, contained only dissolution collapse features and no tectonic structures that resulted from displacement along the Pen Branch fault. The applicant interpreted these dissolution features to be older than Late Pleistocene (i.e., greater than 10,000 years old) based on stratigraphic units exposed in the trench, providing an upper age limit for deformation due to displacement along the Pen Branch fault. More recent investigations, as discussed in the following paragraph, indicate a minimum age for displacement along the Pen Branch fault greater than 33.7 mya.

Seismic Reflection and Refraction Data Collected for the ESP Application

The applicant discussed seismic reflection and refraction data collected for the ESP application in SSAR Section 2.5.1.2.4.2. The applicant defined orientation of the Pen Branch fault in the ESP site area and concluded that a monoclinal fold in the Blue Bluff Marl marks the up-section effects of the Pen Branch fault on stratigraphic units in the site area, indicating no displacement that is post-Eocene (i.e., older than 33.7 mya).

Geomorphic Mapping and Field Reconnaissance for the ESP Application

In SSAR Sections 2.5.1.2.4.3 and 2.5.3.6, the applicant indicated that geomorphic mapping and field reconnaissance performed for the ESP application as preparation for the terrace study showed no surface expression of Quaternary deformation along the Pen Branch fault in the site region.

Terrace Study Performed for the ESP Application

The applicant discussed results of its analysis of the Ellenton fluvial terrace (i.e., terrace Qte) at the SRS, which was performed to assess the capability of the Pen Branch fault in the site area, in detail in SSAR Section 2.5.1.2.4.3. The applicant concluded that no Quaternary deformation of the terrace is indicated due to displacement along the Pen Branch fault within a resolution limit of 1 meter (3 feet). RAIs described in SER Section 2.5.1.3.1 (i.e., RAI 2.5.1-1, RAI 2.5.1-2, and RAI 2.5.1-3) posed questions to address the conclusion that the applicant drew from the analysis of fluvial terrace Qte, since this analysis was cited by the applicant as the most important piece of evidence indicating no Quaternary displacement along the Pen Branch fault. The staff and its USGS advisors also visited the ESP site to gain firsthand knowledge about the accuracy of the terrace analysis, and observations made during the site visit added credence to the applicant's conclusion that this study indicates that the Pen Branch fault does not exhibit Quaternary displacement and is not a capable tectonic feature at the ESP site.

Orientation of the Pen Branch Fault in the Modern-Day Regional Stress Field

In SSAR Section 2.5.1.1.4.2, the applicant stated, based on information from Moos and Zoback (1992), that maximum horizontal regional compressive stress in the modern-day stress field is oriented N50° to 70°E in the upper 640-meter (2100-foot) depth range. Such an orientation of regional stress (the applicant used a reasonable average of N60°E in its response to RAI 2.5.1-18) is subparallel to the measured strike of the Pen Branch fault, even when the fault is divided into segments striking N45°E and N34°E as the applicant discussed in SSAR Section 2.5.1.2.4.1. Shear failure theory predicts that maximum shear stress occurs on a surface oriented at 45° to maximum principal compressive stress; consequently, the Pen Branch fault surface is not oriented as a favorable plane for shear failure and resulting fault displacement.

2.5.1.3.5 Site Area Geologic Hazard Evaluation—Faulting, Earthquakes, and Seismicity

In SSAR Section 2.5.1.2.5, the applicant stated that no geologic hazards, effectively including any related to faulting, earthquakes, and seismicity, occur within the ESP site area. The applicant provided detailed discussions on surface faulting in SSAR Section 2.5.3 and seismic hazards in SSAR Section 2.5.2. The applicant provided results of the detailed analysis of the Pen Branch fault specifically, which demonstrate that the Pen Branch is not a capable structure in the site area, in SSAR Section 2.5.1.2.4. In SSAR Section 2.5.1.2.6.4, the applicant also stated that extensive studies of alluvial terraces and floodplain deposits showed no evidence of post-Miocene (i.e., greater than 5.3 mya) earthquake activity as discussed in SSAR Section 2.5.1.2.4. Based on information presented in SSAR Sections 2.5.1.2.4, 2.5.1.2.5, and 2.5.1.2.6.4, the applicant concluded that the ESP site exhibits no geologic hazards resulting from faulting, earthquakes, or seismicity that occur in the site area. Consequently, the applicant considered the site suitable in regard to geologic hazards related to faulting, earthquakes, and seismicity, including the Pen Branch fault, in the site area. However, the applicant does incorporate new information from other investigators on source geometry and earthquake recurrence rate for the Charleston seismic source into PSHA source models for the ESP site, as discussed in SSAR Section 2.5.2.2.2.4. The staff's evaluation of SSAR Section 2.5.1.2.5 in regard to potential hazards due to faulting, earthquakes, and seismicity is presented below.

Based on its review of the information that the applicant presented in SSAR Sections 2.5.1.2.4, 2.5.1.2.5, and 2.5.1.2.6.4, the staff concludes that the applicant presented a thorough and accurate description of faulting, earthquakes, and seismicity in the site area in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). The staff concurs with the applicant that the ESP site exhibits no geologic hazards resulting from faulting, earthquakes, or seismicity that occur in the site area.

2.5.1.3.6 Site Area Nontectonic Deformation Features

In SSAR Section 2.5.1.2.5, the applicant stated that nontectonic surface depressions associated with dissolution of the Utley Limestone member of the Clinchfield Formation which overlies the Blue Bluff Marl do not pose a geologic hazard at the ESP site. The applicant plans to remove this unit from the site excavation, and the Blue Bluff Marl will form the foundation-bearing layer. These units are discussed in SSAR Section 2.5.1.2.3.2, and the surface depressions are discussed in detail in SSAR Section 2.5.3.8.2.1. In SSAR Section 2.5.1.1.1, the applicant indicated that Carolina Bays, which occur in the site area, are related to eolian erosion resulting from strong, unidirectional, southwesterly winds and not from dissolution. The applicant also indicated in SSAR Section 2.5.1.2.5 that any structures founded above the Blue Bluff Marl will require subsurface exploration to define low bearing strength layers associated with dissolution in units overlying the Blue Bluff Marl. Based on information presented in SSAR Section 2.5.1.2.5, the applicant concluded that the ESP site exhibits no hazard resulting from nontectonic deformation features. Consequently, the applicant considered the site suitable in regard to geologic hazards related to these features in the site area. The staff's evaluation of SSAR Section 2.5.1.2.5 in regard to potential hazard from nontectonic deformation is presented below.

Based on its review of the information presented in SSAR Section 2.5.1.2.5 and the SSAR sections (i.e., Section 2.5.3.8.2.1 for dissolution features and 2.5.1.1.1 for Carolina Bays) in which the applicant discussed surface depressions in detail, the staff concludes that the applicant presented a thorough and accurate description of nontectonic deformation features in the ste area in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). The staff concurs with the applicant that the ESP site exhibits no geologic hazards resulting from nontectonic deformation features.

2.5.1.3.7 Human-Induced Effects on Site Area Geologic Conditions

In SSAR Section 2.5.1.2.6.5, the applicant stated that no mining operations other than borrow of surficial soils, excessive extraction of injection of ground water, or impoundment of water exists in the site area that will detrimentally affect geologic conditions. Based on information presented in SSAR Section 2.5.1.2.6.5, the applicant concluded that the ESP site exhibits no hazard resulting from human-induced effects on site geologic conditions. Consequently, the applicant considered the site suitable in regard to geologic hazards related to human-induced effects in the site area. The staff's evaluation of SSAR Section 2.5.1.2.6.5 is presented below.

Based on its review of the information presented in SSAR Section 2.5.1.2.6.5, the staff concludes that the applicant presented an accurate description of human-induced effects in the site area in support of the ESP application, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d). The staff concurs with the applicant that the ESP site exhibits no hazard resulting from human-induced effects on site geologic conditions.

2.5.1.3.8 Site Area Engineering Geology Evaluation

In SSAR Section 2.5.1.2.6, the applicant addressed engineering soil properties and behavior of foundation materials (Section 2.5.1.2.6.1), zones of alteration, weathering, and structural weakness (Section 2.5.1.2.6.2), and deformational zones (Section 2.5.1.2.6.3). The applicant addressed ground water conditions in SSAR Section 2.5.1.2.7. Regarding engineering properties (including index properties, static and dynamic strength, and compressibility), the applicant indicated that this information is discussed in detail in SSAR Section 2.5.4. In regard to zones of alteration, weathering, and structural weakness, the applicant indicated that some desiccation of the Blue Bluff Marl is expected and that desiccation, weathered zones, and fractures will be mapped and evaluated. Regarding deformational zones, the applicant stated that none were reported from previous studies for VEGP Units 1 and 2, but the applicant will evaluate any such zones detected during excavation mapping. In regard to site ground water conditions, the applicant indicated that a detailed discussion of these conditions is provided in SSAR Section 2.4.12. The staff's evaluation of SSAR Section 2.5.1.6, including SSAR Sections 2.5.1.2.6.1, 2.5.1.2.6.2, 2.5.1.2.6.3, and 2.5.1.2.7, is presented below.

Based on its review of the information that the applicant presented in SSAR Sections 2.5.1.2.6 and 2.5.1.2.7, the staff concludes that the applicant presented an accurate description of site area engineering geology, as far as existing data will allow, in support of the ESP application, as required by 10 CFR 100.23(c). The staff's detailed analysis of engineering properties of soil and rock is presented in SER Section 2.5.4, and the analysis of site ground water conditions is presented in SER Section 2.4.12.

Based on its review of SSAR Section 2.5.1.2 and the applicant's responses to RAIs as set forth above, the staff concludes that the applicant identified and properly characterized all site area geologic features, including the Pen Branch fault. The staff also concludes that SSAR Section 2.5.1.2 provides an accurate and thorough description of site area geologic features, with an emphasis on the Quaternary Period, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d).

2.5.1.4 Conclusions

As discussed in SER Sections 2.5.1.1, 2.5.1.2, and 2.5.1.3, the staff carefully reviewed the basic geologic and seismic information submitted by the applicant in SSAR Section 2.5.1. The staff concurs that the data and analyses presented by the applicant in the SSAR provide an adequate basis to conclude that no capable tectonic faults exist in the plant site area that have the potential to generate surface or near-surface fault displacement.

In addition, the staff concludes that the applicant has identified and appropriately characterized all seismic sources significant for determining the SSE for the ESP site, in accordance with the guidance provided in RG 1.70, RG 1.165, and Section 2.5.1 of NUREG-0800. Because ground motion hazard at the ESP site is dominated by the Charleston seismic source, the staff concurs with the applicant's decision to update the EPRI (1986) source model for this seismic source in light of new information on source geometry and earthquake recurrence rate. No capable tectonic feature has as yet been linked to the Charleston seismic source. Based on information from the applicant's thorough review of the literature on regional geology, and the applicant's literature review and geologic, geophysical, and geotechnical investigations of the site vicinity and site area, the staff further concludes that the applicant has properly characterized regional and site lithology, stratigraphy, geologic and tectonic history, and structural geology, as well as subsurface soils and rock units at the site. The staff also concludes that there is no potential for the effects of human activity (i.e., mining activity or ground water injection or withdrawal) that will compromise the safety of the ESP site.

On the basis of the foregoing, the staff concludes that the applicant has provided a thorough and accurate characterization of the geologic and seismic characteristics of the site, as required by 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d).