2.5 Geology, Seismology, and Geotechnical Engineering

PSEG Site early site permit (ESP) application, Section 2.5, "Geology, Seismology, and Geotechnical Information," of the Site Safety Analysis Report (SSAR), Revision 3, contains information on geologic, seismic, and geotechnical characteristics of the proposed ESP Site. The applicant (PSEG) followed guidance in Regulatory Guide (RG) 1.208, "A Performance Based Approach to Define Site-Specific Earthquake Ground Motion," to define the following four zones around the site and conducted investigations in those zones that became progressively more detailed passing from site region to site location:

- Site region – Area within a 320-kilometer (km) (200-mile (mi)) radius of the site location
- Site vicinity – Area within a 40-km (25-mi) radius of the site location
- Site area – Area within an 8-km (5-mi) radius of the site location
- Site location – Area within a 1-km (0.6-mi) of the proposed plant

The applicant used the updated Final Safety Analysis Reports (UFSARs) for the Salem Generating Station (SGS) and the Hope Creek Generating Station (HCGS), which lie within the PSEG Site area, to provide certain data important for characterizing the geologic setting of the PSEG Site (PSEG, 2007 and PSEG, 2008 for SGS and HCGS, respectively). However, the applicant focused on data developed since publication of the SGS and HCGS UFSARs, as well as data derived from geologic, seismic, and geotechnical engineering investigations performed specifically for characterization of the PSEG Site.

In Revision 0 of the SSAR, dated May 25, 2010, the applicant used seismic source models developed in 1986 and 1989 by the Electric Power Research Institute (EPRI), as the starting point for characterizing potential regional seismic sources and resulting vibratory ground motion, and then updated these seismic source models in light of more recent data and evolving knowledge. The applicant also replaced the original EPRI (1989) ground motion models with more recent (2004 and 2006) EPRI models, and applied the performance-based approach described in RG 1.208, which incorporates probabilistic seismic hazard analysis (PSHA), to develop ground motion response spectra (GMRS) for the site.

As a result of U.S. Nuclear Regulatory Commission (NRC) actions implemented after the March 2011 Fukushima Dai-ichi nuclear power plant accident following the Great Tohoku earthquake and subsequent tsunami in Japan, the NRC formed a Near-Term Task Force (NTTF) that issued a series of recommendations for reevaluating the safety of nuclear power plant facilities located in the U.S. Consequently, on March 12, 2012[1], the NRC issued an information letter requesting that licensees of all operating nuclear power plants in the U.S. reevaluate seismic hazard at their respective plant sites using the most recent data and evaluation methodologies available. The information request letter also stated that licensees of operating nuclear power plant sites in the Central and Eastern United States (CEUS) should use the new seismic source model provided in NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities," to characterize seismic hazard for their respective plants. Therefore, following issuance of the information request letter to licensees of

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1 NRC Letter dated March 12, 2012, "Request for information pursuant to title 10 of the *Code of Federal Regulations* 50.54(f) regarding recommendations 2.1, 2.3, and 9.3, of the near-term task force review of insights from the Fukushima Dai-ichi accident." (Agencywide Documents Access and Management Systems (ADAMS) Accession No. ML12053A340)

operating nuclear power plants, the staff also issued requests for additional information (RAIs) to all combined license (COL) and ESP applicants requesting that they reassess seismic hazard using the newly published NUREG-2115 seismic source model and modify their respective GMRS, if necessary. Accordingly, in SSAR Revision 2, Section 2.5, the applicant replaced the previous EPRI seismic source models with the CEUS Seismic Source Characterization (CEUS-SSC) model presented in NUREG-2115 as the starting point for developing the GMRS for the PSEG Site. With this change in the base seismic source model, some of the RAIs the staff previously asked of the applicant became unnecessary. Therefore, this safety evaluation report (SER) references only the most recent version of the SSAR and the staff's technical evaluation of that version without discussing the replaced portions of the previous ESP SSAR and some of the staff's earlier RAIs, which are now unnecessary and closed without specific resolution. The following sections of this report discuss the RAIs that remain applicable to the staff's review following the change in the base seismic source model, along with the new RAIs related to the most recent version of the SSAR.

Section 2.5 of this report is divided into five main parts that parallel the five SSAR sections prepared by the applicant as part of the PSEG Site ESP application. The five sections in this report are: Section 2.5.1, "Basic Geologic and Seismic Information"; Section 2.5.2, "Vibratory Ground Motion"; Section 2.5.3, "Surface Faulting"; Section 2.5.4, "Stability of Subsurface Materials and Foundations"; and Section 2.5.5, "Stability of Slopes" (including information regarding embankments and dams). These sections present the staff's evaluations and conclusions regarding the geologic, seismic, and geotechnical engineering characteristics of the proposed ESP site. Each section has two parts that consist of a summary and a detailed technical evaluation. The summary section presents the staff's summary of the materials provided by the applicant and the analyses, statements, and conclusions drawn by the applicant as documented in the SSAR. The technical evaluation section presents results of the staff's detailed safety review, the RAIs asked of the applicant by the staff, the staff's evaluation of the RAI responses, and the staff's conclusions and findings.

2.5.1 Basic Geologic and Seismic Information

2.5.1.1 Introduction

SSAR Section 2.5.1 describes basic geologic and seismic information collected by the applicant during site characterization investigations. This information addresses both regional and site-specific geologic and seismic characteristics. The investigations included surface and subsurface field studies, performed at progressively greater levels of detail nearer to the site, within each of the four circumscribed areas corresponding to site region, site vicinity, site area, and site location as defined above in Section 2.5. The applicant conducted these investigations to assess geologic and seismic suitability of the site; to determine whether new geologic or seismic data exist that could significantly impact seismic design based on results of probabilistic seismic hazard analysis (PSHA); and to provide geologic and seismic data appropriate for plant design. The applicant stated that content of SSAR Section 2.5.1 demonstrates compliance with regulatory requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) 100.23(c), which specifically state that geologic, seismic, and engineering characteristics of a site must be investigated in sufficient detail to permit an adequate evaluation of the proposed site; provide sufficient information for estimating the Safe Shutdown Earthquake (SSE) ground motion; and permit adequate engineering solutions for actual or potential geologic and seismic effects at the proposed site.

2.5.1.2 Summary of Application

SSAR Section 2.5.1 contains two main sections: SSAR Section 2.5.1.1, "Regional Geology," describes physiography and geomorphology, geologic history, stratigraphy, tectonic setting, seismic zones, and gravity and magnetic field data of the PSEG Site region. SSAR Section 2.5.1.2, "Site Geology," addresses physiography and geomorphology, stratigraphy and lithology, geologic history, and structural geology of the PSEG Site vicinity and site area, as well as site location for certain of these topics. SSAR Section 2.5.1.2 also evaluates engineering geology of the site vicinity, site area, and site location, as well as potential effects of human activities on the site.

The applicant developed SSAR Section 2.5.1 based on information derived from review of previously published reports prepared for SGS and HCGS (PSEG, 2007 and PSEG, 2008, respectively) and published geologic literature, as well as interpretation of aerial photography, subsurface investigations, geologic mapping, and aerial reconnaissance conducted specifically for characterization of the PSEG Site region, site vicinity, site area, and site location. Sections 2.5.1.2.1 and 2.5.1.2.2, of this report, summarize the basic geologic and seismic information described by the applicant in SSAR Section 2.5.1. The applicant specifically included potential tectonic features of Quaternary age (2.6 million years, or Ma to present) in this information.

2.5.1.2.1 Regional Geology

SSAR Section 2.5.1.1 discusses physiography, geomorphology, geologic history, stratigraphy, and tectonic setting of the PSEG Site region, defined as the area that lies within a 320 kilometers (km) (200 miles (mi)) radius of the site location. The applicant also addressed seismic zones defined by regional seismicity and regional gravity and magnetic data in SSAR Section 2.5.1.1. The following sections summarize information provided by the applicant in SSAR Section 2.5.1.1.

2.5.1.2.1.1 Regional Physiography and Geomorphology.

SSAR Section 2.5.1.1.1 describes physiography and geomorphology of the PSEG Site region. From east to west, the site region contains parts of the following physiographic provinces: The continental rise, continental slope, continental shelf (i.e., the submerged eastward continuation of the Coastal Plain province), Coastal Plain, Piedmont, New England, Blue Ridge, Valley and Ridge, and Appalachian Plateau provinces. Figure 2.5.1-1 of this report (Reproduced from SSAR Figure 2.5.1-4) shows the location of the PSEG Site within the Coastal Plain province.

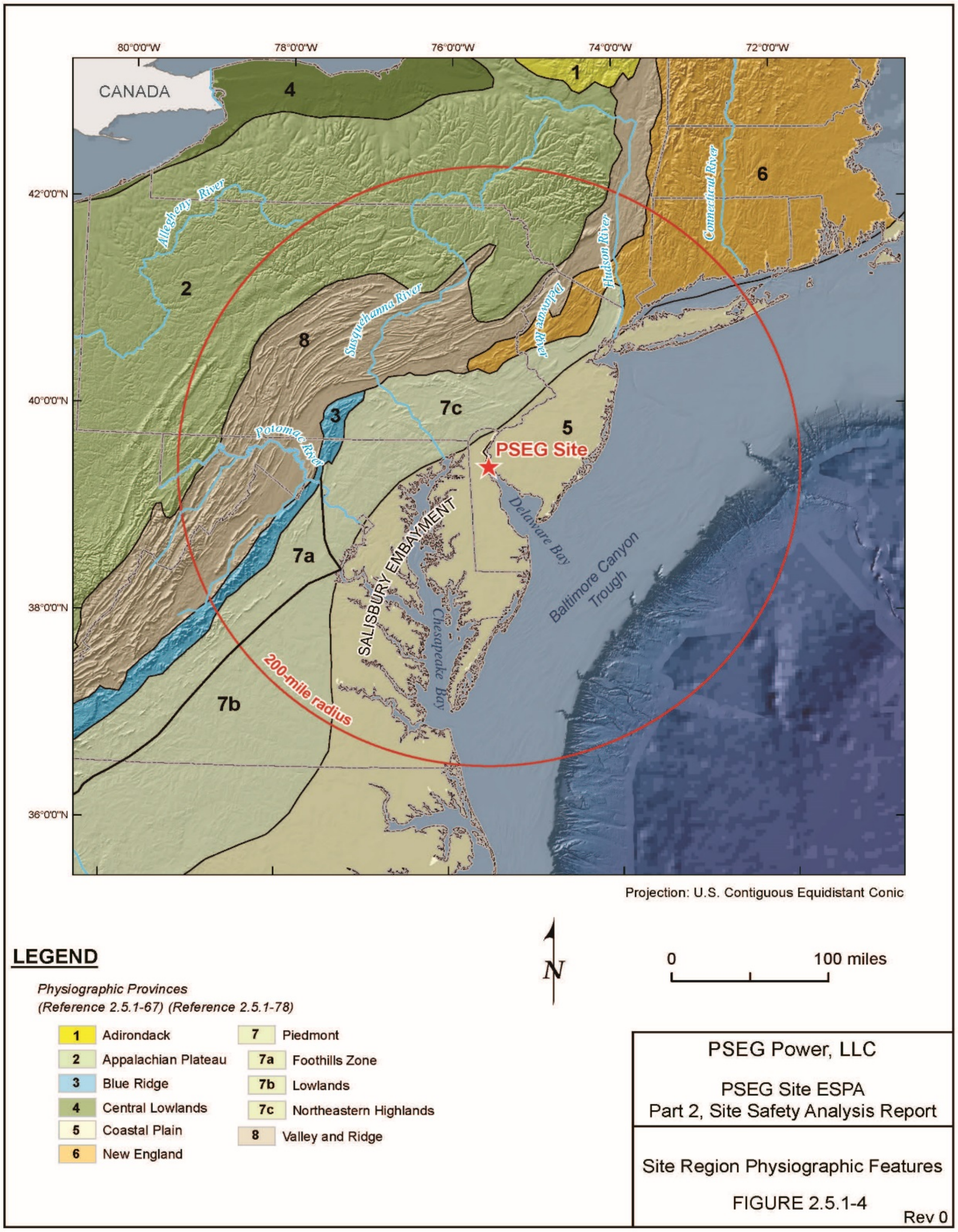

Figure 2.5.1-1 Regional physiographic map showing location of the PSEG Site (Reproduced from SSAR Figure 2.5.1-4)

In SSAR Section 2.5.1.1.1.1, the applicant stated that the Coastal Plain physiographic province characteristically exhibits a low and gently rolling terrain developed on clastic sedimentary sequences of deltaic, shallow marine, and continental shelf deposits made up of unconsolidated to partially consolidated gravels, sands, silts, and clays. These deposits dip gently southeast toward the Atlantic Ocean. The applicant explained that the Coastal Plain surface contains both erosional and depositional landforms associated with several transgressional and regressional marine cycles, and that the entire surface in and around the site vicinity shows the effects of climatic events related to glacial and interglacial periods.

In SSAR Sections 2.5.1.1.1.2 through 2.5.1.1.1.7, the applicant described characteristics of the remaining physiographic provinces that occur in the site region, noting that the Piedmont province lies immediately west of the Coastal Plain. The applicant indicated that the Piedmont Lowlands, the Foothills Zone, and the Northeastern Highlands subprovinces make up the Piedmont physiographic province in the site region (see Figure 2.5.1-1 of this report).

2.5.1.2.1.2 Geologic History.

SSAR Section 2.5.1.1.2 discusses Proterozoic (> 542 Ma), Paleozoic (542 to 251 Ma), Mesozoic (251 to 65.5 Ma), and Cenozoic (65.5 Ma to present) geologic history of the PSEG Site region. (The Quaternary Period is that part of the Cenozoic extending from 2.6 Ma to the present.) The applicant summarized geologic events ranging from deformation and metamorphism of ancestral North America (i.e., an ancient continental land mass known as Laurentia) that occurred during the Middle Proterozoic Grenville orogeny (1,300 to 1,000 Ma) to development of the present-day passive Atlantic coast continental margin during the Cenozoic.

2.5.1.2.1.2.1 *Proterozoic, Paleozoic, and Mesozoic Geologic History.*

In SSAR Sections 2.5.1.1.2.1 through 2.5.1.1.2.6, the applicant discussed Proterozoic, Paleozoic, and Mesozoic geologic history of the PSEG Site region. The applicant stated that, in the Late Proterozoic after deformation and metamorphism related to the Grenville orogeny ceased, Laurentia and ancestral Africa separated to form the proto-Atlantic Iapetus Ocean. During the Paleozoic, the margin of Laurentia experienced multiple phases of contractional deformation, and the Late Paleozoic Alleghany orogeny resulted in final closure of the Iapetus Ocean.

The applicant indicated that extensional rifting during the Mesozoic resulted in opening of the present Atlantic Ocean and development of a series of fault-bounded basins along the Atlantic margin. The applicant noted that, within the site region, the exposed fault-bounded Newark, Gettysburg, and Culpeper basins occur northwest of the site. Figure 2.5.1-2 of this report (Reproduced from SSAR Figure 2.5.1-9) illustrates the locations of both exposed and buried fault-bounded Mesozoic extensional basins in the site region. The applicant stated that, although the spatial distribution of basins and associated normal faults underlying Coastal Plain sediments is uncertain, pre-Mesozoic metamorphic basement rocks underlie the PSEG Site location rather than sediment-filled Mesozoic basins.

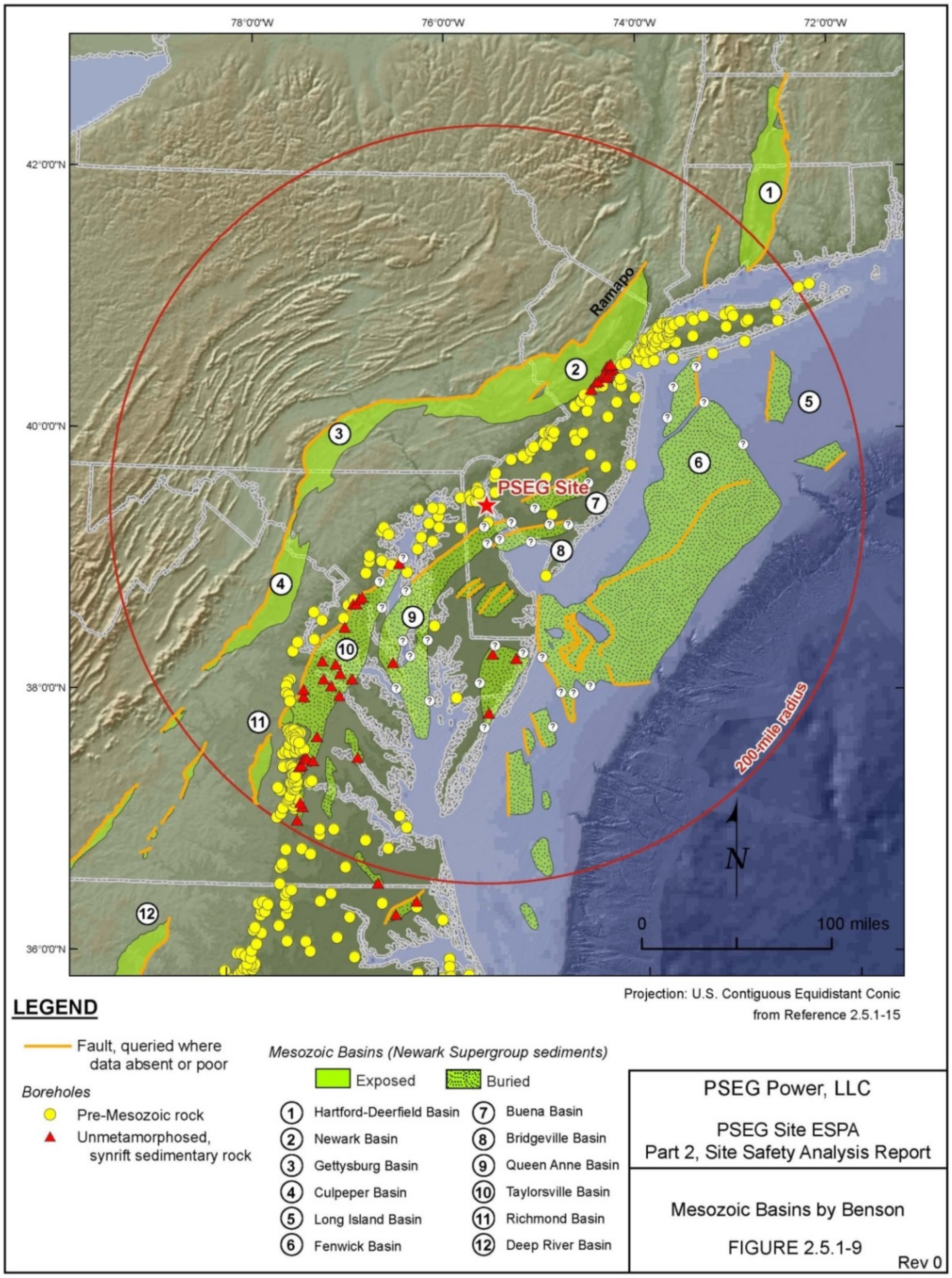

Figure 2.5.1-2 Fault-bounded Mesozoic extensional basins in the site region (Reproduced from SSAR Figure 2.5.1-9)

2.5.1.2.1.2.2 *Cenozoic Geologic History*.

In SSAR Section 2.5.1.1.2.7, the applicant stated that the Atlantic continental margin evolved into a passive, non-tectonic margin during the Cenozoic. This evolution involved cooling and subsidence of previously extended (i.e., during the Mesozoic) continental crust along the margin with a net eastward redistribution of mass related to erosion of the Appalachian Mountains and deposition of sediments above underlying metamorphic basement rocks in the Coastal Plain and offshore. The applicant indicated that these erosional processes resulted in isostatic, non-tectonic flexure of continental crust about a hinge line located approximately along the western edge of the Coastal Plain (i.e., the Fall Zone), with differential subsidence forming local arches and basins such as the South New Jersey Arch and the Salisbury Embayment (Figure 2.5.1-1 of this report). The applicant described the Fall Zone as non-tectonic in character, with lithologic contrast between metamorphic Piedmont rocks and more easily eroded Coastal Plain sedimentary rock units controlling the topographic escarpment that marks the zone.

2.5.1.2.1.3 Regional Stratigraphy.

SSAR Section 2.5.1.1.3 describes pre-Cenozoic (i.e., Late Proterozoic, Paleozoic, and Mesozoic) and Cenozoic (including Quaternary) stratigraphy of the PSEG Site region. The applicant noted that the site region contains portions of the entire Appalachian orogenic sequence, which records sedimentation, igneous activity, and metamorphism resulting from opening and closing of ancestral Atlantic Ocean basins in Late Proterozoic and Paleozoic time followed by opening of the present Atlantic Ocean during the Mesozoic. Sedimentation along the passive Atlantic margin occurred through the Cenozoic, including into the present, with development of the Coastal Plain sedimentary sequences and formation of the continental shelf, slope, and rise.

15.0.3.1.1.1.1 *Pre-Cenozoic (Late Proterozoic, Paleozoic, Mesozoic) Stratigraphy*.

In SSAR Sections 2.5.1.1.3.1 through 2.5.1.1.3.4.1, the applicant discussed development of stratigraphic sequences, including igneous activity, that occurred during the Late Proterozoic, Paleozoic, and Mesozoic, as well as pre-Mesozoic metamorphism. The applicant noted that the Hornerstown Formation contains basal beds of Late Cretaceous (i.e., Late Mesozoic) age (99.6 to 65.5 Ma) and upper beds of Paleocene age (65.5 to 55.8 Ma, Lower Tertiary), so this formation is transitional across the Cretaceous-Tertiary (and, consequently, the Mesozoic-Cenozoic) time boundary.

15.0.3.1.1.1.2 *Cenozoic Stratigraphy*.

In SSAR Section 2.5.1.1.3.4.2, the applicant stated that Cenozoic stratigraphy in the site region reflects an unconformity resulting in the absence of upper Eocene (40.4 to 33.9 Ma) and Lower Oligocene (33.9 to 23 Ma) strata, and that overlying Neogene strata (23 to 2.6 Ma) show a distinct increase of clastic sediments starting in the Lower Miocene (23 to 5.3 Ma). The applicant reported that only two Tertiary (65.5 to 2.6 Ma) formations, the Hornerstown and Vincentown Formations, outcrop north and south of the Delaware River in the site region. The Hornerstown is transitional across the Cretaceous-Tertiary boundary and the Vincentown,

the proposed foundation unit at the PSEG Site, contains both clastic and carbonate components.

15.0.3.1.1.1.3 Quaternary Stratigraphy.

The applicant noted that Quaternary strata in the site region resulted from fluvial and marine processes associated with changes in sea level or terminal glacial processes and glacial outwash. The applicant added that a Holocene (0.01 Ma to present) sea transgression resulted in removal of Pleistocene (2.6 to 0.01 Ma) sediments and deposition of sedimentary fill in the major estuaries within the site region.

2.5.1.2.1.4 Regional Tectonic Setting.

SSAR Section 2.5.1.1.4 describes the tectonic setting of the PSEG Site region. The applicant noted that the site region lies within the CEUS, which is a stable continental region characterized by low rates of tectonic crustal deformation and no active tectonic plate boundaries. SSAR Section 2.5.1.1.4 specifically addresses regional stress; principal regional tectonic structures interpreted to range in age from Late Proterozoic to Cenozoic, including the Quaternary (2.6 Ma to present); seismic zones defined by regional seismicity; and regional gravity and magnetic field data.

The applicant indicated that SSAR Section 2.5.1.1.4 summarizes the present state of knowledge regarding tectonic setting and structures in the site region that are relevant to the assessment of seismic sources, and cross-referenced SSAR Section 2.5.2, which provides an expanded discussion of the seismic source model used for the PSEG Site. The applicant concluded that no evidence exists for late Cenozoic (i.e., Quaternary) seismic activity associated with any tectonic feature or structure in the site region.

2.5.1.2.1.4.1 *Regional Stress*.

In SSAR Section 2.5.1.1.4.1, the applicant stated that analyses of regional tectonic stress in the CEUS conducted since the 1986 studies performed by EPRI, including updates done as part of NUREG-2115, have not significantly altered the interpretation of a northeast-southwest orientation for maximum principal compressive stress in the CEUS. The applicant noted that this orientation for regional stress applies to the PSEG Site region, and that there are no new significant implications for characterization of potential activity on tectonic structures due to the regional stress field.

2.5.1.2.1.4.2 *Principal Tectonic Structures*.

In SSAR Section 2.5.1.1.4.2, the applicant categorized and discussed principal tectonic structures in the site region based on timing of their development from Late Proterozoic through the Cenozoic, including the Quaternary.

Late Proterozoic, Paleozoic, and Mesozoic Tectonic Structures

In SSAR Sections 2.5.1.1.4.2.1 through 2.5.1.1.4.2.3, the applicant stated that Late Proterozoic, Paleozoic, and Mesozoic structures in the site region developed as a result of major plate tectonic events. The applicant indicated that Late Proterozoic structures in the site region include normal faults which formed during post-Grenville orogenic activity, and that Paleozoic structures within the site region include thrust and reverse faults which developed during

contractional orogenic events. The applicant noted that the only Paleozoic structure within the site vicinity is the northeast-striking, mylonitic Rosemont shear zone, located about 27 km (17 mi) northeast of the PSEG Site. The applicant described extensional rift basins and related normal boundary faults associated with formation of the present Atlantic Ocean as the primary Mesozoic tectonic features within the PSEG Site region. Based on a map illustrating locations of known exposed and possible buried Mesozoic extensional basins in the site region produced by Benson (1992), shown in Figure 2.5.1-2 of this report, the applicant stated that the fault-bounded Mesozoic basin nearest to the PSEG Site is the postulated extension of the buried Queen Anne basin, located about 24 km (15 mi) south-southeast of the site. The applicant noted that Benson (1992) indicated the actual extension of the basin to within that distance of the site is uncertain, as shown by the question marks on the boundary of the basin in Figure 2.5.1-2 of this report. The applicant stated that pre-Mesozoic basement lies beneath the site, and cross-referenced SSAR Section 2.5.1.2.4 ("Structural Geology") for a discussion of the evidence for that statement. Section 2.5.1.2.2.4 of this report summarizes this evidence.

Cenozoic Tectonic Structures

In SSAR Section 2.5.1.1.4.2.4, the applicant discussed possible Cenozoic structures that occur within the site region. The applicant described only structures with suggested or demonstrated Cenozoic activity not discussed in the data compilations prepared by Crone and Wheeler (2000) and Wheeler (2005) for assessing potential Quaternary tectonic features in the CEUS. (SSAR Section 2.5.1.1.4.2.5 specifically discusses potential Quaternary tectonic features in the site region as summarized below.) The possible Cenozoic tectonic structures included the hypothesized fault of Pazzaglia (1993); the faults of Hansen (1978); the River Bend Trend interpreted by Marple (2004) to be an extension of the Stafford fault system northeastward from Virginia; the National Zoo faults; the Chesapeake Bay impact structure; and the Brandywine fault system. The applicant indicated that no geologic field evidence exists for the hypothesized fault of Pazzaglia; that geologic data suggest the faults of Hansen are Mesozoic in age; that the river bend trend proposed as marking an extension of the Stafford fault system (Marple, 2004) shows no geologic or geomorphic evidence of Cenozoic, including Quaternary, faulting; that geologic data suggest the National Zoo faults are Tertiary and not Quaternary in age; that the Chesapeake Bay structure resulted from a meteorite impact and not tectonic faulting; and that geologic field relationships show deformation related to the Brandywine fault system ceased in the Miocene (23 to 5.3 Ma) and is, therefore, pre-Quaternary in age.

Potential Quaternary Tectonic Features

In SSAR Section 2.5.1.1.4.2.5, the applicant described the following 17 potential Quaternary tectonic features that occur within the site region (Figure 2.5.1-3 of this report) based on the data compilations prepared by Crone and Wheeler (2000) and Wheeler (2005), which use published information to assess evidence for Quaternary fault activity rather than data derived from direct field examination of the actual features: the New Castle County, Upper Marlboro, Lebanon Church, New York Bight, East Border, Ramapo, Kingston, Mosholu, and Hopewell faults; the Central Virginia and Lancaster seismic zones; the Fall Lines of Weems (1998); the Everona-Mountain Run and Dobbs Ferry fault zones; the Stafford and east coast fault systems; and offset glacial surfaces. The classification scheme presented in the data compilations of Crone and Wheeler (2000) and Wheeler (2005) is as follows:

- Class A Features – Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether exposed or inferred from liquefaction or other deformation features.

- Class B Features – Geologic evidence demonstrates the existence of a fault or suggests Quaternary deformation, but the fault may not be a potential source of significant earthquakes or available data are not strong enough to assign the feature to Class A.

- Class C Features – Geologic evidence is insufficient to demonstrate the existence of a tectonic fault or Quaternary deformation associated with the feature.

- Class D Features – Geologic evidence demonstrates that the feature is not a tectonic fault.

The applicant indicated that the Central Virginia seismic zone is a Class A tectonic feature based on information provided by Crone and Wheeler (2000) and Wheeler (2005), while the remaining 16 potential Quaternary tectonic features are all Class C (see Figure 2.5.1-3 of this report (Reproduced from SSAR Figure 2.5.1-17)). The applicant noted that only the Class C New Castle County faults occur in the site vicinity. The applicant stated that investigations performed for the PSEG Site did not identify any potential Quaternary tectonic features in the site region other than the 17 discussed by Crone and Wheeler (2000) and Wheeler (2005). The following paragraphs summarize information about the 17 potential Quaternary tectonic features presented by the applicant in SSAR Section 2.5.1.1.4.2.5. Note that Feature #3, the Cacoosing Valley earthquake, is discussed within the paragraph about the Lancaster Seismic Zone, where it is interpreted as an anthropogenic earthquake, i.e., it is not a Quaternary tectonic feature.

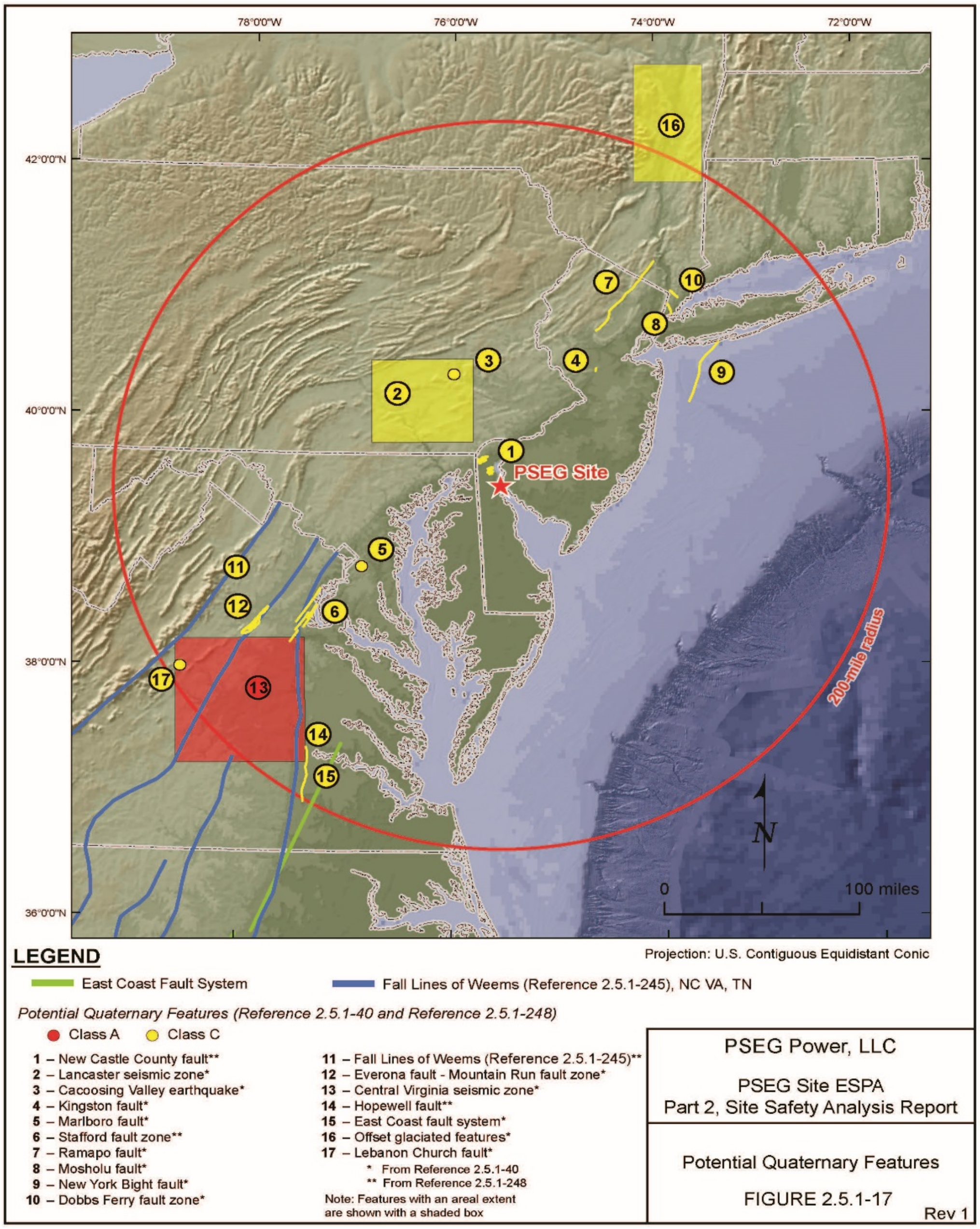

Figure 2.5.1-3 Potential Quaternary tectonic features in the site region (Reproduced from SSAR Figure 2.5.1-17)

Central Virginia seismic zone (Class A)

In SSAR Section 2.5.1.1.4.2.5.1, the applicant located the northernmost boundary of the Central Virginia seismic zone (CVSZ), an area of persistent low-level seismicity within the Piedmont physiographic province, about 274 km (170 mi) southwest of the PSEG Site (see Feature 13 in Figure 2.5.1-3 of this report). The applicant acknowledged that the August 2011 Mineral, VA, earthquake, which had an estimated moment magnitude of **M**5.8, was the largest historical earthquake to occur in the CVSZ. The applicant cross-referenced SSAR Section 2.5.2.1.3 for a detailed discussion of the August 2011 earthquake, but stated that it is difficult to uniquely attribute seismicity in the zone to any known causative geologic structure and that seismicity appears to extend both above and below the regional Appalachian detachment with a depth distribution of earthquake foci ranging between about 3 to 13 km (2 to 8 mi). The applicant indicated that two paleoliquefaction sites identified in the CVSZ by Obermeier and McNulty (1998) reflect prehistoric seismicity in the zone, but also do not define the location of a causative fault.

Lancaster seismic zone (Class C)

SSAR Section 2.5.1.1.4.2.5.2 describes the Lancaster seismic zone of Armbruster and Seeber (1987), which lies in southeastern Pennsylvania about 113 km (70 mi) northwest of the PSEG Site (Feature 2 in Figure 2.5.1-3 of this report). The applicant reported that the seismic zone includes exposed Piedmont rocks, which contain Paleozoic thrust faults, and the fault-bounded Newark-Gettysburg Triassic rift basin, which formed during Mesozoic crustal extension. The applicant stated that seismicity in at least the western part of the Lancaster seismic zone likely results from reactivation of Mesozoic extensional structures in the present-day northeast-southwest regional compressional stress field. The applicant also indicated that activities related to quarrying likely produced some recent earthquakes in the zone (e.g., the January16, 1994 E[**M**]4.1 Cacoosing earthquake, which is the largest instrumentally-recorded earthquake in the Lancaster seismic zone). The applicant noted that the CEUS-SSC seismicity catalog presented in NUREG-2115 does not include the Cacoosing earthquake because the earthquake was anthropogenic (i.e., the result of human activities related to quarrying), rather than tectonic, in origin.

Fall Lines of Weems (Class C)

SSAR Section 2.5.1.1.4.2.5.3 discusses the seven fall lines of Weems (1998) that occur within the Piedmont and Blue Ridge physiographic provinces in North Carolina and Virginia, and notes that the easternmost fall line (i.e., the “Tidewater Fall Line”) terminates about 161 km (100 mi) southwest of the PSEG Site (Feature 11 in Figure 2.5.1-3 of this report). The applicant stated that Weems (1998) favored a tectonic origin for these features, which Weems interpreted to connect an alignment of short stream segments with anomalously steep gradients characterized by knickpoints and development of waterfalls. However, based on numerous studies performed in the Appalachian region that show development of knickpoints related to differential resistance of rock units to erosion rather than to tectonic activity, as well as the results of geologic and geomorphic analyses previously performed for the North Anna ESP application and evaluated by the staff in NUREG-1835, “Safety Evaluation Report for an Early Site Permit at the North Anna ESP Site,” the applicant concluded that the fall lines of Weems (1998) are non-tectonic erosional features controlled by lithologies with different degrees of resistance to erosion.

Everona-Mountain Run fault zone (Class C)

In SSAR Section 2.5.1.1.4.2.5.4, the applicant described the Mountain Run fault zone, which lies about 241 km (150 mi) southwest of the PSEG Site along the eastern margin of the Culpeper Triassic basin in Virginia (Feature 12 in Figure 2.5.1-3 of this report). The applicant stated that the fault zone strikes northeast for a distance of 121 km (75 mi) across the Virginia Piedmont, with the Everona fault located about 0.8 km (0.5 mi) west of the zone. Based on proximity of the Everona fault to the Mountain Run fault zone and the fact that both features have a similar orientation and sense of slip, the applicant agreed with Crone and Wheeler (2000) that these two geologic structures comprise a single fault zone. The applicant cited the following information, derived from field and aerial reconnaissance and geomorphic analyses of features associated with the Mountain Run fault zone performed for the North Anna ESP application (Dominion, 2004), to conclude that the fault zone does not exhibit evidence for Quaternary displacement: (1) scarps observed to occur along the Mountain Run fault zone formed as a result of stream erosion, and (2) undeformed late Neogene (>2.6 Ma, so pre-Quaternary in age) colluvial deposits bury the fault zone between the Rappahannock and Rapidan Rivers.

New Castle County faults (Class C)

SSAR Section 2.5.1.1.4.2.5.5 describes the New Castle County faults (Feature 1 in Figure 2.5.1-3 of this report), located about 24 km (15 mi) north of the PSEG Site in Delaware, as an inferred set of subsurface normal faults that define a northeast-striking graben in buried Paleozoic basement rocks based on borehole data, including geophysical logging results, discussed by Spoljaric (1972 and 1973). The applicant indicated that the studies of Spoljaric (1972 and 1973) provided an estimated age of post-Paleozoic to pre-Cretaceous for the faults, and that McLaughlin et al. (2002) showed Cretaceous and younger strata to be undeformed across the inferred faults. Therefore, the applicant concluded that the New Castle County faults, if they exist, are not Quaternary in age.

Stafford fault system (Class C)

SSAR Section 2.5.1.1.4.2.5.6 discusses the Stafford fault system (Feature 6 in Figure 2.5.1-3 of this report) as a set of en echelon, northwest-dipping thrust faults that occur on or near the Fall Zone separating the Coastal Plain and Piedmont physiographic provinces in northeastern Virginia. The applicant stated that the individual faults in this fault system are 16 to 40 km (10 to 25 mi) long and separated by en echelon left stepovers that are 1.6 to 4.8 km (1 to 3 mi) wide. The applicant reported that most published data indicate this fault system, which lies about 209 km (130 mi) south of the PSEG Site, does not exhibit Quaternary displacement. The applicant noted that geomorphic analyses conducted for the North Anna ESP application (Dominion, 2004) demonstrated a lack of deformation of Neogene (23 to 2.6 Ma) marine deposits and Pliocene (5.3 to 2.6 Ma) and Quaternary (2.6 Ma to present) fluvial terraces along the Rappahannock River across the Stafford fault system in northeastern Virginia within the resolution limits of the data collected. The applicant stated that, in NUREG-1835, the staff agreed with the results of the geomorphic analyses presented in the North Anna ESP application (Dominion, 2004). Therefore, the applicant concluded that the Stafford fault system was not active during the Quaternary.

Upper Marlboro faults (Class C)

In SSAR Section 2.5.1.1.4.2.5.7, the applicant described the Upper Marlboro faults (Feature 5 in Figure 2.5.1-3 of this report), located in Maryland about 257 km (160 mi) southwest of the PSEG Site, as 3 small faults interpreted to offset Coastal Plain sediments in a single road cut. The applicant reported that, although Dryden (1932) proposed a potential displacement of as much as 4.6 m (15 ft) in a Pleistocene (2.6 to 1.8 Ma) unit, he also stated that the apparent faults could be erosional features. The applicant noted that, based on a critical review of published data, Wheeler (2006) interpreted the faults to be the result of surficial landslides because of the low dips and concavity of the failure planes. Therefore, the applicant concluded, as did Crone and Wheeler (2000) and Wheeler (2005) based on their data compilations, that geologic evidence was insufficient to demonstrate the existence of Quaternary deformation associated with the proposed Upper Marlboro faults.

Lebanon Church fault (Class C)

SSAR Section 2.5.1.1.4.2.5.8 describes the Lebanon Church fault (Feature 17 in Figure 2.5.1-3 of this report), located in Virginia about 305 km (190 mi) southwest of the PSEG Site, as a small reverse fault that offsets Miocene-Pliocene (23 to 2.6 Ma) terrace gravels up to about 1.5 m (5 ft) in a single road cut. Therefore, the applicant interpreted the fault to be pre-Quaternary in age.

New York Bight fault (Class C)

SSAR Section 2.5.1.1.4.2.5.9 discusses the New York Bight fault (Feature 9 in Figure 2.5.1-3 of this report), which is about 48 km (30 mi) long and occurs offshore of Long Island, NY, in Coastal Plain strata. The applicant reported that the fault does not offset units younger than Eocene (i.e., <33.9 Ma) within the resolution range of the seismic survey data used to identify this feature (Schwab et al., 1997), and concluded that the feature is pre-Quaternary in age.

East Border fault (Class C)

In SSAR Section 2.5.1.1.4.2.5.10, the applicant indicated that the East Border fault is the easternmost basin-bounding fault of the exposed Mesozoic Hartford Basin that lies in Connecticut and Massachusetts, with the southern end of the basin located about 290 km (180 mi) northeast of the PSEG Site. The applicant stated that the fault clearly offsets Jurassic (201.6 to 145.5 Ma) and Cretaceous (145.5 to 65.5 Ma) strata; but definitive evidence for Quaternary displacement along the fault has not been presented by researchers who postulated that Quaternary deformation may have occurred on this structure (e.g., Thompson et al., 2000). Therefore, the applicant concluded that the East Border fault is most likely Mesozoic in age and does not show this feature in Figure 2.5.1-3 of this report.

Ramapo fault (Class C)

SSAR Section 2.5.1.1.4.2.5.11 discusses the Ramapo fault (Feature 7 in Figure 2.5.1-3 of this report), located in northern New Jersey and southern New York State about 160 km (100 mi) northeast of the PSEG Site. The applicant indicated that this feature extends for about 80 km (50 mi) from Peapack, NJ to the Hudson River and comprises one segment of a system of northeast-striking, southeast-dipping normal faults bounding the northwest side of the Mesozoic Newark Basin (Figure 2.5.1-2 of this report). The applicant acknowledged that some earlier researchers considered the Ramapo fault to be seismically active (e.g., Page et al., 1968;

Aggarwal and Sykes, 1978; Kafka et al., 1985) and to represent a tectonically active Quaternary structure characterized by small slip events. The applicant cited more recent work by Sykes et al. (2008) that shows a concentration of seismicity extending west of the Ramapo fault and occurring in what they refer to as the Ramapo seismic zone, rather than along the known Ramapo fault. (SSAR Section 2.5.1.1.5.1 discusses the Ramapo seismic zone, and Section 2.5.1.2.1.4.3 of this report summarizes the information presented by the applicant in SSAR Section 2.5.1.1.5.1.) Based on interpretations made by Ratcliffe (1982) from rock core samples collected across the Ramapo fault, the applicant stated field evidence exists to indicate the Ramapo fault has not been reactivated since the latest episode of Mesozoic extension (i.e., during the Jurassic at 201.6 to 145.5 Ma). The applicant noted that NUREG-2115 does not include the Ramapo fault as a source of repeated large magnitude earthquakes in the CEUS.

<u>Kingston fault</u> (<u>Class C</u>)

SSAR Section 2.5.1.1.4.2.5.12 describes the Kingston fault (Feature 4 in Figure 2.5.1-3 of this report) as a normal fault offsetting Triassic (251 to 201.6 Ma) and Jurassic (201.6 to 145.5 Ma) rocks within the Mesozoic Newark Basin with undeformed Cretaceous (145.5 to 65.5 Ma) strata overlying the fault. This information, derived by the applicant from Parker and Houghton (1990), suggests a Mesozoic age for the Kingston fault. The applicant reported that Stanford et al. (1995) discussed field data suggesting the fault may have been active during the Pliocene (5.3 to 2.6 Ma) and into Middle Pleistocene (about 1.8 Ma), but that no data from those studies unequivocally demonstrated Quaternary deformation along the fault since variations in thickness of the marker units could be fluvial in character rather than the result of faulting.

<u>Dobbs Ferry fault zone</u> (<u>Class C</u>)

SSAR Section 2.5.1.1.4.2.5.13 discusses the Dobbs Ferry fault zone (Feature 10 in Figure 2.5.1-3 of this report), a northwest-striking 1.9 km (1.2 mi) long fault zone marked by dense fracturing and slickensides north of New York City. The feature lies about 241 km (150 mi) northeast of the PSEG Site. The applicant indicated that additional field work by Dawes and Seeber (1991) extended the fracture zone to the southeast for a total of about 8 to 10 km (5 to 6 mi) and connected epicenters of the 1985 Ardsley earthquake (moment magnitude **M**3.7) and two additional fractured outcrops. The applicant reported that no field data (e.g., liquefaction features or faulted Quaternary deposits) suggest prehistoric seismicity, and that the best estimate for age of faulting along the extended Dobbs Ferry fault zone is Paleozoic or younger based on age of the rock units affected by fault displacement.

<u>Mosholu fault</u> (<u>Class C</u>)

SSAR Section 2.5.1.1.4.2.5.14 describes the Mosholu fault (Feature 8 in Figure 2.5.1-3 of this report), an approximately 12 km (7.5 mi) long, northwest-striking, near-vertical, right-lateral oblique-slip fault mapped in New York City. This feature lies about 201 km (125 mi) northeast of the PSEG Site. The applicant stated that the faulting is not demonstrably of Quaternary age, and the only constraint regarding timing of faulting is that the feature is younger than the Paleozoic deformation in rock units cut by the fault.

<u>Offset glacial surfaces</u> (<u>Class C</u>)

In SSAR Section 2.5.1.1.4.2.5.15, the applicant stated that surfaces with glacial striations exhibit offsets with variable and inconsistent orientations throughout New York, Vermont, New Hampshire, and Canada (Feature 16 in Figure 2.5.1-3 of this report). The applicant

reported a common association of these features with wedge-shaped voids in the outcrops, which Ratcliffe (1982) interpreted as evidence for the features having an origin related to ice wedging or frost heaving rather than tectonic deformation. The applicant indicated that the features are not likely to be of tectonic origin.

Hopewell fault (Class C)

SSAR Section 2.5.1.1.4.2.5.16 describes the Hopewell fault (Feature 14 in Figure 2.5.1-3 of this report) as a 48 km (30 mi) long, north striking, steeply east dipping, reverse fault located in Virginia about 143 km (89 mi) southwest of the PSEG Site. The applicant reported that the fault displaces a Paleocene-Cretaceous contact that is 65.5 Ma in age with an inferred offset of Pliocene (5.3 to 2.6 Ma) strata. Based on results of geologic mapping performed by Mixon et al. (1989), the applicant stated that the Hopewell fault lies buried beneath undeformed Quaternary units.

East Coast fault system (Class C)

SSAR Section 2.5.1.1.4.2.5.17 describes the east coast fault system (Feature 15 in Figure 2.5.1-3 of this report), a feature postulated by Marple and Talwani (2000) to extend for about 595 km (370 mi) in three segments from the area of Charleston, SC northeastward into Virginia. The applicant noted that Marple and Talwani (1993) attributed the southernmost segment, located in South Carolina, to the presence of a buried fault (i.e., the Woodstock fault) interpreted by Marple and Talwani (2000) to be the causative fault for the 1886 Charleston earthquake. The applicant stated that the southern segment of the postulated east coast fault system is the most well-defined segment based on geomorphology and microseismicity. This segment of the fault system has been considered in seismic source characterization studies by the U.S. Geological Survey (Frankel et al., 2002), while the central segment in North Carolina and the northern segment in Virginia have not. The applicant indicated that the central and northern segments of the postulated fault system exhibit little evidence for Quaternary deformation or seismicity, and concluded that the northern segment, which lies approximately 274 km (170 mi) southwest of the PSEG Site, does not show any indication of Quaternary faulting.

2.5.1.2.1.4.3 *Seismic Zones Defined by Regional Seismicity*.

In SSAR Section 2.5.1.1.5, the applicant discussed two potential seismic sources of local interest for the PSEG Site. The applicant described the Ramapo seismic zone (Sykes, et al., 2008) within the PSEG Site region, and the proposed Peekskill-Stamford seismic boundary of Sykes et al. (2008) just outside the site region. SSAR Sections 2.5.1.1.4.2.5.1 and 2.5.1.1.4.2.5.2 discuss, respectively, the Central Virginia and Lancaster seismic zones, both of which lie within the site region, as summarized in Section 2.5.1.2.1.4.2 of this report. The applicant addressed other regional seismic sources (i.e., the Charlevoix, Charleston, and New Madrid seismic zones) in SSAR Section 2.5.2 based on information provided in NUREG-2115. Figure 2.5.1-4 of this report illustrates seismicity within and outside of the site region.

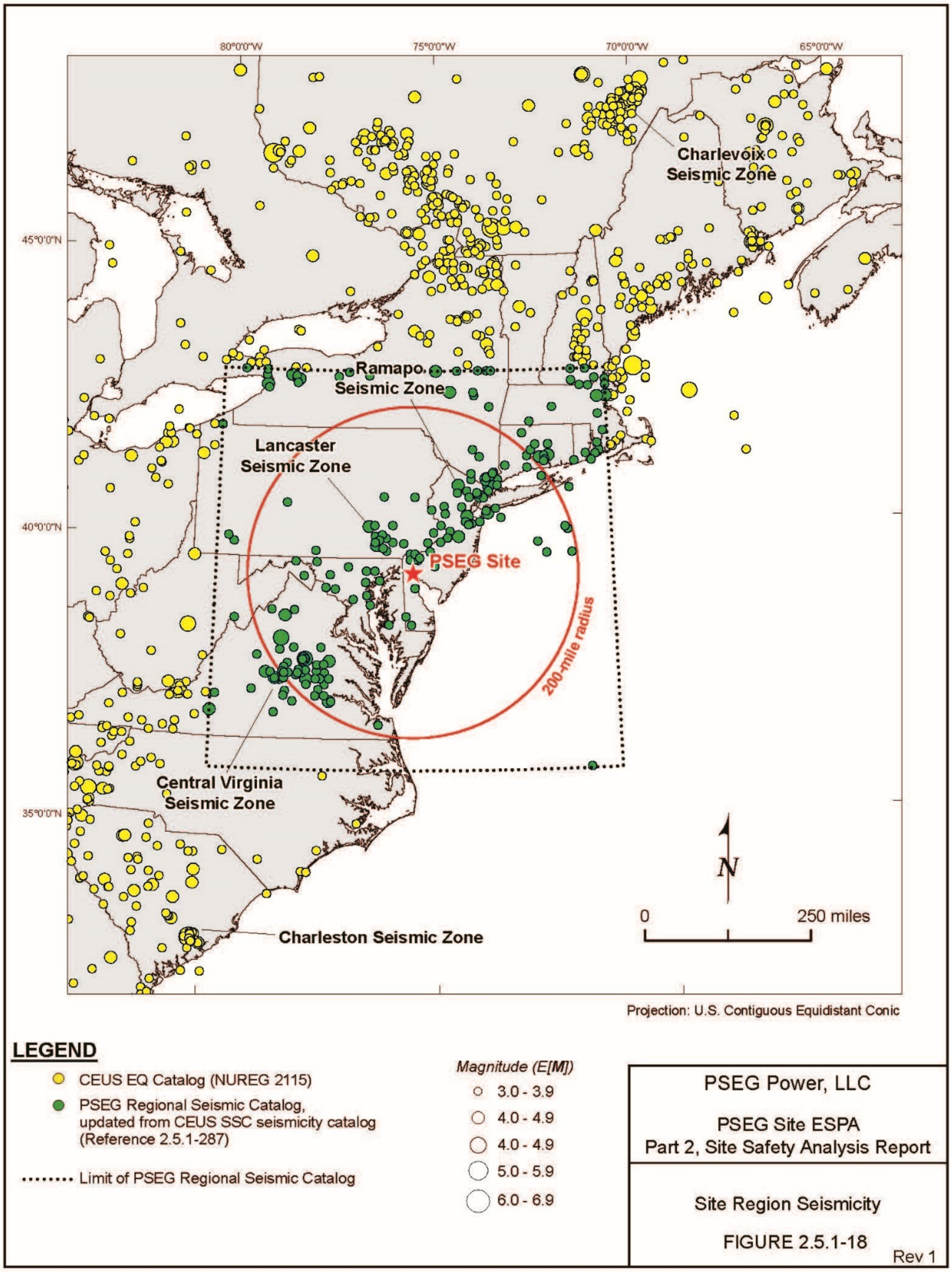

Figure 2.5.1-4 Seismicity within and outside of the site region (Reproduced from SSAR Figure 2.5.1-18)

Ramapo Seismic Zone

In SSAR Section 2.5.1.1.5.1, the applicant stated that the Ramapo seismic zone is a region of increased seismicity located west of the Ramapo fault in northern New Jersey and southern New York. The applicant reported that, although researchers initially proposed that this increased seismicity occurred due to slip on the Ramapo fault (e.g., Page et al., 1968; Aggarwal and Sykes, 1978; Kafka et al., 1985), results of investigations conducted by Ratcliffe et al. (1986) demonstrated that the Ramapo fault has not been active since Jurassic time (201.6 to 145.5 Ma). The applicant indicated that, as described by Sykes et al. (2008), the Ramapo seismic zone trends northeast for about 129 km (80 mi) from northern New Jersey into southern New York State; lies approximately 160 km (100 mi) north of the PSEG Site; and has no known active faults specifically associated with it. The applicant reported that earthquakes within the zone occur within highly deformed Middle Proterozoic to Early Paleozoic crystalline basement west of the Mesozoic Newark basin. The applicant stated that SSAR Section 2.5.2 incorporates data from the seismicity catalogue developed by Sykes et al. (2008) for seismic hazard assessment of the PSEG Site by using the updated CEUS-SSC model and associated seismicity catalogue in NUREG-2115.

Proposed Peekskill-Stamford Seismic Boundary

In SSAR Section 2.5.1.1.5.2, the applicant discussed the Peekskill-Stamford seismic boundary postulated by Sykes et al. (2008). The applicant indicated Sykes et al. (2008) suggest this proposed seismic boundary is subparallel to brittle faults that occur farther south, and, therefore, is a similar fault zone. Sykes et al. (2008) also speculate that these brittle features possibly formed between the Mesozoic Newark, Hartford, and New York bight basins to accommodate Mesozoic extension. The applicant remarked that Sykes et al. (2008) did not present any data or discussion to support their suggestion, and concluded that the seismic source model provided in NUREG-2115 need not be modified to represent potential seismic hazard at the PSEG Site due to the proposed Peekskill-Stamford seismic boundary.

2.5.1.2.1.4.4 *Regional Gravity and Magnetic Fields.*

In SSAR Section 2.5.1.1.6, the applicant described the major anomalous features shown by regional gravity and magnetic field data in the site region. The applicant stated that low amplitude gravity and magnetic anomalies generally indicate the presence of rocks of granitic composition because of their typical low density and magnetization, and that the relatively higher density and magnetization characteristics of mafic lithologies result in coincident high amplitude gravity and magnetic anomalies in the site region.

Regional Gravity Field Data

The applicant explained that two anomalous gravity highs transecting the site region in a northeast-southwest direction are first-order features of the regional gravity field in the site region. The applicant stated that the southeastern-most gravity high anomaly reflects bathymetry defining the continental shelf edge, and that the other gravity high, located northwest of the shelf edge anomaly, is a fundamental component of the gravity field of the Appalachian orogen known as the Piedmont Gravity High. The applicant noted that the regional gravity field obscures the signature of Mesozoic extensional basins on the gravity field in the site region, rendering the basins indistinct in the gravity field patterns in most cases.

Regional Magnetic Field Data

The applicant stated that the regional magnetic field shows a band of linear, short-wavelength, relatively high amplitude magnetic highs and lows through the approximate center of the site region northwest of the Coastal Plain. The applicant noted that these magnetic anomalies impart a well-defined fabric to the magnetic field that is similar to the northeast-southwest Appalachian tectonic fabric for the region. The applicant also noted that the higher frequency magnetic anomalies extend into the Coastal Plain where they are progressively damped to the southeast as thickness of the non-magnetic Coastal Plain sediments increases, indicating that Piedmont basement rocks underlie Coastal Plain stratigraphic sequences.

The applicant stated that the New York-Alabama Lineament in the site region forms an abrupt linear boundary in magnetic field fabric and appears to be a major crustal boundary. The applicant reported that the East Coast magnetic anomaly in the site region is a northeasterly-oriented linear magnetic high near the shelf edge that extends along the Atlantic margin. The applicant explained that the East Coast magnetic anomaly marks the transition from continental to oceanic crust and involves a combination of extended continental crust and magnetized intrusions. The applicant stated that sediments filling the Mesozoic basins are relatively nonmagnetic and generally tend to produce a subdued magnetic field over the basins, although magnetic Mesozoic intrusive and extrusive rocks complicate the generalized model and may be hard to distinguish from basement.

2.5.1.2.2 Site Geology

SSAR Section 2.5.1.2 discusses physiography and geomorphology, stratigraphy and lithology, geologic history, structural geology, and site engineering geology of the PSEG Site vicinity and site area. SSAR Section 2.5.1.2 also discusses certain of these topics specifically for the site location, including assessment of the effects of human activity. The following sections of this report provide a summary of the information presented by the applicant in SSAR Section 2.5.1.2.

2.5.1.2.2.1 Physiography and Geomorphology.

In SSAR Section 2.5.1.2.1, the applicant described physiography and geomorphology of the site area. The applicant stated that the PSEG Site area lies almost completely within the Outer Coastal Plain subprovince of the Coastal Plain physiographic province, with the central portions of the site area occupied by the Delaware River channel (Figure 2.5.1-5 of this report (Reproduced from SSAR Figure 2.5.1-6)). The applicant indicated that eastern portions of the PSEG Site east of the Delaware River generally exhibit an extremely flat, low-lying topography that is only a few feet above sea level and underlain by Holocene (0.01 Ma to present) Delaware Bay estuarine (i.e., tidal salt marsh) deposits, while the portions west of the Delaware River consist of incised Quaternary terrace uplands underlain mainly by the Late Pleistocene (1.8 to 0.01 Ma) Scott Corners formation. The applicant stated that current elevations in the site area range from sea level to about 4.9 m (16 ft) above sea level.

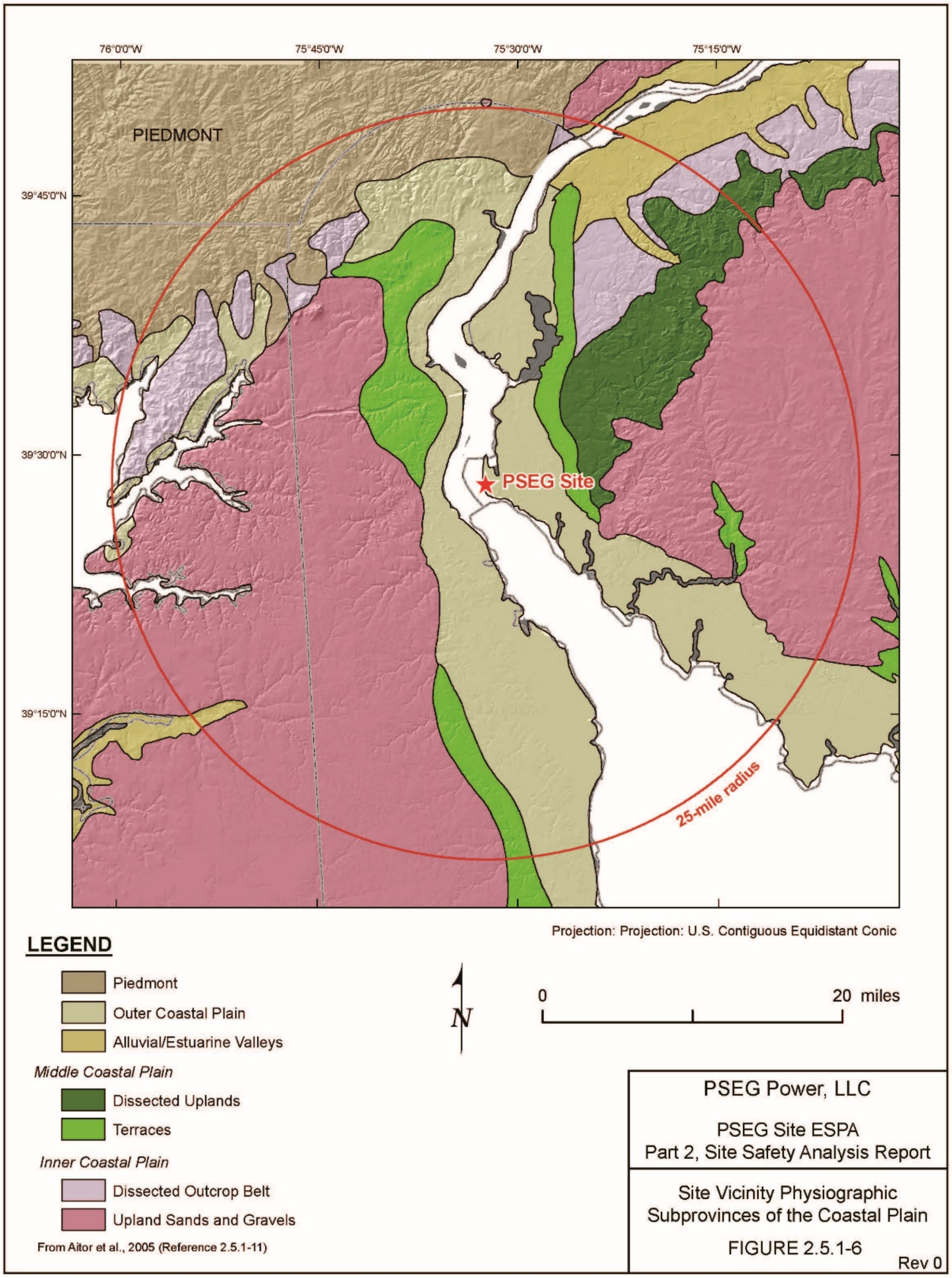

Figure 2.5.1-5 Site vicinity physiographic subprovinces of the Coastal Plain (Reproduced from SSAR Figure 2.5.1-6)

The applicant reported that the PSEG Site location occurs on an artificial island on the eastern bank of the Delaware River. The applicant also reported that the western portions of the site location lie in the Delaware River; artificial fill underlies the eastern portions; and marsh deposits overlying artificial fill occurs in the northeastern parts of the site location. The applicant indicated historical aerial images reveal that the center of the PSEG Site sits atop what was originally a bar in the Delaware River built up from dredging spoil.

2.5.1.2.2.2 Stratigraphy and Lithology.

SSAR Section 2.5.1.2.2 discusses stratigraphy and lithology of the PSEG Site area (SSAR Section 2.5.1.2.2.1) and site location (SSAR Section 2.5.1.2.2.2), stating that the site area occurs entirely within the Salisbury Embayment (Figure 2.5.1-1 of this report) and contains Coastal Plain sediments ranging in age from Early Cretaceous to Holocene (145.5 to 0.01 Ma). The applicant indicated these sediments cover a basement complex of rifted continental crust that lies beneath the pre-Cretaceous (>145.5 Ma) unconformity marking the base of the Coastal Plain stratigraphic sequences. The applicant provided a detailed discussion of the stratigraphic column for the PSEG Site area and site location, including basement complex lithologies and the Coastal Plain stratigraphic sequence. Figure 2.5.1-6 of this report (Reproduced from SSAR Figure 2.5.1-34) shows a stratigraphic column that generally applies for both the PSEG Site area and site location.

		Formation/Unit	Lithologies	Thickness
QUATERNARY	Holocene (recent)	Artificial fill	clays, silts, and sands of various proportions along with clayey and silty gravels	4.1 ± 5.1 feet
		Hydraulic fill	soft clayey silts, sandy silts and organic clays	33.5 ± 12.3 feet
	Pleistocene	Alluvium	fine to coarse sand and gravel; peat and organic rich soils; silt and clay near base	12.7 ± 12.3 feet
		~~ unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		
TERTIARY	Upper Tertiary (Neogene)	Kirkwood Formation	*Upper member:* greenish-gray, silty, fine sand, fine sand and greenish-gray to brown organic clay with organic material and shell fragments; *Lower member:* fine to coarse sand and gravel with variable amounts of silt and clay	*Upper member:* 14.5 ± 7.7 feet; *Lower member:* 7.2 ± 7.8 feet
		~~ unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		
	Lower Tertiary (Paleogene)	Vincentown Formation	greenish-gray, fine to medium grained silty sand with some zones of clayey sand; variably glauconitic; cemented zones	52.0 ± 26.1 feet
		Hornerstown Formation	greenish-gray to dark green silty and clayey quartz and glauconitic sand with indurated zones	18.6 ± 3.2 feet
CRETACEOUS	Upper Cretaceous	Navesink Formation	fossiliferous, dark green to greenish-black glauconitic sand; pelecypod fragments	24.3 ± 2.3 feet
		Mount Laurel Formation	brownish gray to dark green, fine to coarse grained sand; variable amounts of silt and clay; coarsening upward sequence	10.3 ± 3.5 feet
		Wenonah Formation	sandy clay with clayey sand	15 feet
		Marshalltown Formation	glauconitic, silty and clayey fine sand	25 feet
		Englishtown Formation	dark gray to black sandy clay to clayey sand with shell fragments grades to black silt with trace amounts of mica and glauconite	44 feet
		Woodbury Formation	black, micaceous clay	36 feet
		Merchantville Formation	dark greenish-black glauconitic silts and clays with variable amounts of sand	30 feet
		Magothy Formation	interbeds of gray to dark gray, locally mottled silts and clays that are interbedded with sands; trace amounts of lignite and carbonaceous material	52 feet
		~~ unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		
	Lower Cretaceous	Potomac Group (Formation)	red, gray, and white mottled clay	1300 feet (Reference 2.5.1-17) PSEG No. 6 Production Well
		~~ pre-Cretaceous unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		
PRECAMBRIAN TO PALEOZOIC	NeoProterozoic to Paleozoic	**Basement Complex**		
		Philadelphia Terrane	Wissahickon Schist – reported as residual clay (PSEG No. 6 Production Well)	undetermined

PSEG Power, LLC

PSEG Site ESPA
Part 2, Site Safety Analysis Report

Site Location Stratigraphy

FIGURE 2.5.1-34

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Figure 2.5.1-6 Stratigraphic column for the site area and location (Reproduced from SSAR Figure 2.5.1-34)

Unit thicknesses shown may vary from those reported at the site location.

2.5.1.2.2.2.1 *Basement Complex Lithologies*.

The applicant indicated that either Precambrian to Paleozoic age metamorphosed igneous and sedimentary rocks of the Carolina Superterrane or aluminous to quartz-rich gneisses with interlayered amphibolites of the Philadelphia Terrane make up crystalline basement complex lithologies that underlie the Coastal Plain sedimentary sequences in the site area. The applicant noted that a single well drilled about 1 km (0.6 mi) from the center of the PSEG Site (i.e., near the site location) penetrated Wissahickon schist at a depth of 549 m (1,800 ft). The Wissahickon schist represents crystalline basement rock of the Philadelphia Terrane, and this data point indicates depth to basement near the site location. The applicant stated that considerable uncertainty exists regarding the existence and locations of sediment-filled Mesozoic extensional basins, and that these basins may exist in the site area. The applicant noted that buried Mesozoic basins have been interpreted to occur in the site vicinity.

2.5.1.2.2.2.2 *Coastal Plain Stratigraphic Sequences*.

The applicant indicated that units of the Coastal Plain sedimentary sequences, which range in age from Early Cretaceous (145.5 to 99.6 Ma) to Holocene (0.01 Ma to present), are generally similar for both the site area and site location. The applicant reported that the Lower Tertiary (65.5 to 23 Ma) Vincentown formation, the planned foundation-bearing unit, is silty sand with some clayey sand zones. The Vincentown ranges in thickness from 11 to 24 m (35 to 79 ft) at the site location because the top of the formation is an eroded surface, but is approximately 27 m (90 ft) thick over the site area. The applicant stated that Quaternary sediments exposed in the site area consist mainly of estuarine terrace or marsh deposits with isolated exposures of fluvial units, and the marsh deposits primarily comprise muck, peat, silt, clay and sand deposited along the margins of tidal creeks. The applicant also stated that alluvial material ranging in thickness from 1.5 to 7 m (5 to 23 ft), deposited on the bed of the Delaware River and made up of fine to coarse sand and gravels interbedded with peat and organic-rich soils, represents the uppermost strata at the site location. The applicant reported that material derived from dredging operations starting in the early 1900s and structural fill placed during construction of the Hope Creek and Salem Generating Stations overlie the alluvium, and that the structural fill has a variable thickness of up to 3 m (10 ft).

2.5.1.2.2.3 Geologic History.

SSAR Section 2.5.1.2.3 discusses geologic history of the site vicinity and site area. The applicant indicated that the crystalline basement complex which underlies the site formed during Precambrian and Paleozoic time, and that extension and rifting of the basement complex formed the present Atlantic Ocean basin during the Mesozoic. The applicant stated that lithology of the crystalline basement complex in the PSEG Site vicinity and site area is somewhat unclear because the site vicinity and area lie near the boundary between the Philadelphia Terrane and the Carolina Superterrane. The Carolina Superterrane consists of Neoproterozoic (1,000 to 542 Ma) to Early Cambrian (542 to 521 Ma) meta-igneous rocks overlain by metamorphosed clastic sedimentary sequences of Cambrian (542 to 488 Ma) to Ordovician (488 to 444 Ma) age. The Philadelphia Terrane comprises metasedimentary sequences intruded by a diverse suite of igneous rocks between 485 to 475 Ma and again at approximately 434 Ma.

The applicant stated that sedimentary sequences of the Coastal Plain, which range in age from Early Cretaceous (145.5 to 99.6 Ma) into the Quaternary (2.6 Ma to present), overlie the crystalline basement complex. The applicant indicated that, in the site vicinity,

glacial-interglacial cycles resulted in deposition of fluvial sequences, formation of estuarine terraces, and subsequent incision of the terraces and fluvial sequences. The applicant noted interglacial sea level transgressions during the Late Pleistocene resulted in deposition of the Scotts Corners and Cape May Formations, which consist of incised terraces in the eastern and western portions of the site area. The applicant indicated that, beginning in the Late Pleistocene and into the present, the Delaware Bay experienced deposition of estuarine sediments in tidal marsh settings.

2.5.1.2.2.4 Structural Geology.

SSAR Section 2.5.1.2.4 discusses structural geology of the site vicinity (SSAR Section 2.5.1.2.4.1), as well as the site area and site location (SSAR Section 2.5.1.2.4.2). The applicant used the following sources to derive information presented in SSAR Section 2.5.1.2.4: published geologic mapping of Pickett and Spoljaric (1971), Newell et al. (1998), Owens et al. (1999), and Schenck et al. (2000); detailed boring and geophysical logs of southern New Jersey, northern Delaware, and eastern Maryland from Bell et al. (1988) and Sugarman and Monteverde (2008); results of earlier investigations performed at the PSEG Hope Creek site (PSEG, 2008) and the nearby Delmarva Power and Light Summit site (Delmarva P&L, 1974); and results of reconnaissance and subsurface investigations performed specifically for the PSEG ESP application.

2.5.1.2.2.4.1 *Site Vicinity.*

The applicant stated that, although no Mesozoic rift basins have been identified beneath the PSEG Site, such basins occur or have been inferred to occur beneath Coastal Plain sediments in Virginia, Maryland, Delaware, and New Jersey. Since Benson (1992) hypothesized that the northern extension of a buried Mesozoic basin (i.e., the Queen Anne basin) may lie within 24 km (15 mi) of the site, the applicant examined data relevant to the characteristics of basement rock units underlying the site. The applicant reported that more than 6 wells drilled within 16 km (10 mi) of the site did not encounter Triassic rift sediments, but rather revealed Cretaceous Coastal Plain sediments overlying metamorphosed crystalline basement rocks of probable Precambrian or Paleozoic age. The applicant also indicated that seismic velocities derived from a seismic refraction transect east of the PSEG Site were consistent with velocities for crystalline basement rocks rather than Triassic rift basin sediments. The applicant concluded that available data from the site and from multiple wells located within 13-48 km (8-30 mi) of the site do not support the existence of a Mesozoic basin in the site vicinity or area or at the site location.

The applicant noted that two categories of faults occur within the site vicinity, namely, Piedmont faults observed in northernmost Delaware and basement faults underlying Coastal Plain strata. Based on the data sources stated in Section 2.5.1.2.2.4 of this report, the applicant concluded that Tertiary and younger strata within the site vicinity are not deformed by tectonic faulting.

2.5.1.2.2.4.2 *Site Area and Site Location*.

The applicant stated that no evidence exists for tectonic faults or folds within 8 km (5 mi) of the PSEG Site (i.e., within the site area), and that planar, undeformed Cretaceous and Tertiary strata dipping gently to the southeast characterize the site. The applicant noted that the contact of the Vincentown Formation (the probable foundation unit at the PSEG Site) with the overlying Kirkwood Formation traces a channeled erosional surface at the top of the Vincentown with up to 10 m (35 ft) of relief at the proposed site location. The applicant concluded that the existence

of planar and undeformed contacts between stratigraphic units that occur both above and below the irregular Vincentown-Kirkwood contact rule out faulting as the cause of variability in elevation of the top of the Vincentown formation.

2.5.1.2.2.5 Site Engineering Geology Evaluation.

SSAR Section 2.5.1.2.5 presents an evaluation of site engineering geology related to both natural and manmade conditions for the site vicinity, site area, and site location that may pose a potential hazard to the site. The applicant discussed dynamic behavior during prior earthquakes; zones of mineralization, alteration, weathering, and structural weakness; unrelieved residual stresses in bedrock; groundwater conditions; and effects of human activity.

In SSAR Section 2.5.1.2.5.1, the applicant stated that no earthquakes larger than **M**3.77 have been recorded in the site vicinity and that no paleoliquefaction studies in the site region revealed any earthquake-induced liquefaction features. The applicant noted that the area surrounding the site location provides few suitable exposures for evaluating the presence of liquefaction features, but reported that review of aerial photographs and inspections of the site area from low altitude flights for the PSEG ESP application did not reveal any earthquake-induced liquefaction features. The applicant also noted that excavation mapping for the existing Hope Creek unit did not reveal earthquake-induced liquefaction features.

In SSAR Section 2.5.1.2.5.2, the applicant did not report any issues related to engineering properties associated with zones of mineralization, alteration, weathering, or structural weakness at the site location. The applicant stated that the upper 24 m (80 ft) of the materials underlying the site location consist of hydraulic fill, alluvium from the adjacent Delaware River, and silty clays and sands of the Tertiary age Kirkwood formation, which overlies the Vincentown formation. The applicant indicated that these materials will be removed to an elevation within the Vincentown formation, which is the proposed foundation-bearing layer at the site. The applicant reported that characteristics of the Vincentown at the site location were consistent with those described in the Final Safety Analysis Report for the existing Hope Creek unit (PSEG, 2008), including the presence of varying amounts of calcium carbonate, and that extensive boring, aerial photography, and construction excavation mapping for the Hope Creek unit did not reveal karst features in the Vincentown formation. The applicant indicated that the nearest karst terrain, related to dissolution of marble in the metamorphic Cockeysville Formation, is about 32 km (20 mi) northwest of the site. Therefore, the applicant concluded that no hazards exist due to the presence of karst features in the site area or at the site location.

In SSAR Section 2.5.1.2.5.3, the applicant stated that there is no evidence for unrelieved residual stress in the bedrock or overlying sediments that pose a hazard for the site location. The applicant reported that subsidence resulting from isostatic adjustment due to glacial rebound characterizes the site region, and that studies of paleoshorelines on the continental shelf offshore of New Jersey indicate relatively stable isostatic conditions in the site vicinity.

In SSAR Section 2.5.1.2.5.4, the applicant indicated that the groundwater level at the PSEG Site location is a few feet below the surface, and that the area is surrounded by natural estuaries and tidal marshes in addition to artificial channels and drainage cuts. The applicant stated that these features do not represent a hazard for the site location. The applicant cross-referenced SSAR Section 2.5.4.6 for discussion of groundwater conditions during construction excavation.

In SSAR Section 2.5.1.2.5.5, the applicant stated that human activities, including surface and subsurface mining as well as oil and gas extraction and injection, have not been reported in the site area. Therefore, the applicant concluded that no human activities pose a hazard at the PSEG Site location.

2.5.1.3 Regulatory Basis

The applicable regulatory requirements for basic geologic and seismic information that must be included in an ESP application are as follows:

1. 10 CFR 52.17(a)(1)(vi), as it relates to identifying geologic, site characteristics with appropriate consideration of the most severe natural phenomena that have been historically reported for the site and surrounding area, and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2. 10 CFR 100.23, “Geologic and Seismic Siting Criteria,” as it relates to the suitability of a proposed site and the adequacy of the design basis based on consideration of geologic, geotechnical, geophysical, and seismic characteristics of the proposed site. Geologic and seismic siting factors must include the SSE for the site and the potential for surface tectonic and non-tectonic deformation. The site-specific GMRS satisfies requirements of 10 CFR 100.23 with respect to the development of the SSE.

The related acceptance criteria from NUREG-0800, Section 2.5.1 are as follows:

1. Regional Geology: For meeting requirements of 10 CFR 52.17 and 10 CFR 100.23, SSAR Section 2.5.1.1 will be considered acceptable if it contains complete documented discussions of all geologic (both tectonic and non-tectonic), seismic, geophysical, and geotechnical characteristics, as well as conditions caused by human activities, deemed important for safe siting and design of the plant.

2. Site Geology: For meeting requirements of 10 CFR 52.17 and 10 CFR 100.23 and the guidance presented in RG 1.132, “Site Investigations for Foundations of Nuclear Power Plants”; RG 1.138, “Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants”; RG 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites” and RG 1.208, “A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion”; SSAR Section 2.5.1.2 will be considered acceptable if it contains a description and evaluation of geologic features (both tectonic and non-tectonic), seismic conditions, geotechnical characteristics, and conditions caused by human activities at appropriate levels of detail within area defined by circles drawn around the site using radii of 40 km (25 mi) for the site vicinity, 8 km (5 mi) for the site area and 1 km (0.6 mi) for the site location.

In addition, the geologic characteristics should be consistent with appropriate sections from RG 1.208, “A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion”; RG 1.132, “Site Investigations for Foundations of Nuclear Power Plants”; RG 1.138, “Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants”; and RG 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites.”

2.5.1.4 Technical Evaluation

The staff reviewed SSAR, Section 2.5.1 to ensure that the materials provided by the applicant represent the required data related to basic geologic and seismic information. The staff's review confirmed that data contained in the application address the information required for this topic.

The technical information presented in SSAR Section 2.5.1 resulted from the applicant's review of published literature as well as regional and site-specific studies involving aerial reconnaissance; interpretation of aerial photography; surface and subsurface field investigations, including geologic mapping, assessment of possible tectonic structures, geotechnical borings, and geophysical testing; and description of potential seismic source zones conducted specifically for characterization of the PSEG Site. The applicant also provided information applicable to the site derived from the updated FSARs for the SGS and HCGS Generating Stations (PSEG, 2007 and PSEG, 2008), although the primary focus was on data developed since publication of those two updated FSARs. In addition, the applicant performed laboratory tests on samples collected for characterization of material properties at the site. Through review of SSAR Section 2.5.1, the staff determined whether the applicant had complied with applicable regulatory requirements in 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d) and conducted the site characterization investigations at the appropriate levels of detail in accordance with guidance in RG 1.208.

RG 1.208 recommends that an applicant evaluate any significant new geologic, seismic, and geophysical data to determine whether revisions to existing seismic source models and ground motion attenuation relationships are necessary. SSAR Section 2.5.1 includes geologic and seismic information collected by the applicant to support the analysis of vibratory ground motion and development of site-specific GMRS, as discussed in SSAR Section 2.5.2. RG 1.208 also recommends that an applicant evaluate faults encountered at a site to determine whether they are seismogenic or may cause surface deformation. SSAR Section 2.5.1 includes information related to assessment of the potential for future tectonic and non-tectonic deformation at the site, discussed in more detail by the applicant in SSAR Section 2.5.3.

The staff visited the PSEG Site on January 22, 2009, to observe pre-application subsurface investigation activities. A second visit, a site audit performed over September 29-30, 2011, after PSEG had submitted the ESP application, focused on examination of samples of the Vincentown formation and pertinent outcrops, as well as interactions with the ESP applicant and its consultants in regard to the geologic, seismic, geophysical, and geotechnical investigations being conducted for characterization of the proposed site. Regarding the geologic field observations, the staff examined outcrops of estuarine sediments comprising the Early Pleistocene (2.6 to 1.8 Ma) Turkey Point Beds near the boundary of the PSEG Site vicinity west of the site for field evidence of a fault postulated by Pazzaglia (1993) to extend into the Chesapeake Bay west of the site. Pazzaglia (1993) postulated this fault based on interpreted elevation differences between Turkey Point Beds on opposite sides of the Bay. The staff noted no field evidence for this proposed fault.

Sections 2.5.1.4.1, "Regional Geology"; and 2.5.1.4.2, "Site Geology," of this report present the staff's evaluation of information provided by the applicant in SSAR Section 2.5.1 and the applicant's responses to RAIs for that SSAR section. All RAIs posed by the staff and discussed in the following sections of this report assure the applicant's compliance with 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and10 CFR 100.23(d), as well as conformance with NUREG-0800, Section 2.5.1. In addition to the RAIs addressing specific technical issues

related to regional and site geology of the PSEG Site, discussed in detail below, the staff also prepared several editorial RAIs to further clarify certain descriptive statements made by the applicant in the SSAR and to better qualify specific geologic features illustrated in figures in the SSAR. This technical evaluation does not include a discussion of these editorial RAIs.

2.5.1.4.1 Regional Geology

The staff focused the review of SSAR Section 2.5.1.1 ("Regional Geology") on descriptions provided by the applicant for physiography and geomorphology, geologic history, stratigraphy, tectonic setting, seismic zones defined by seismicity, and gravity and magnetic fields within 320 km (200 mi) of the site location (i.e., the site region). The staff particularly concentrated on the descriptions of potential Quaternary tectonic features within the site region, including seismic zones and possible fault systems, fault zones, and faults.

2.5.1.4.1.1 Regional Physiography, Geomorphology, and Geologic History.

In SSAR Section 2.5.1.1.1, the applicant discussed physiography and geomorphology of the PSEG Site region and noted that the PSEG Site lies within the Coastal Plain physiographic province. Figure 2.5.1-1 of this report shows the location of the PSEG Site in the Coastal Plain province relative to the other physiographic provinces which occur in the site region. In SSAR Section 2.5.1.1.2, the applicant discussed geologic history of the site region, covering the Proterozoic (> 542 Ma), Paleozoic (542 to 251 Ma), Mesozoic (251 to 65.5 Ma), and Cenozoic (65.5 Ma to present). The Quaternary Period is that part of the Cenozoic extending from 2.6 Ma to the present.

The staff focused the review of SSAR Section 2.5.1.1.1 on statements in SSAR Section 2.5.1.1.1.3, "Piedmont Physiographic Province," which describe river drainage patterns (including those for the Potomac, Susquehanna, and Delaware Rivers) near the Fall Zone (a boundary that separates the Piedmont physiographic province from the Coastal Plain province) that exhibit complex longitudinal profiles and consistently show right-stepping bends. The applicant did not explain whether tectonic or non-tectonic processes produced these right-stepping bends in the river drainage patterns. In addition, the staff focused its review on SSAR Section 2.5.1.1.2.7, "Cenozoic Passive Margin Development," in which the applicant stated that the Fall Zone is a topographic escarpment controlled mainly by lithologic contrasts rather than faulting, and that differential subsidence, not tectonic deformation, produced local arches and basins (e.g., the South New Jersey Arch and the Salisbury Embayment) within the Coastal Plain. The applicant did not provide references to support the interpretation that the Fall Zone and arches and embayments in the Coastal Plain province near the Fall Zone are non-tectonic in character. To document the non-tectonic character of the Fall Zone and arches and embayments in the Coastal Plain adjacent to the Fall Zone, in RAI 2.5.1-1 the staff requested that the applicant provide references supporting the interpretation that the Fall Zone formed primarily due to lithologic contrasts, rather than faulting; to discuss existing evidence that secondary faulting along the Fall Zone may have enhanced development of the zone; and to provide references supporting the interpretation that uplifts and embayments located near the Fall Zone in the Coastal Plain resulted from differential subsidence. Since the applicant's December 28, 2011, response to RAI 42, Question 02.05.01-1 required further clarification, the staff issued follow-up RAI 63, Question 02.05.01-19 to assist with assessing information provided by the applicant that suggested a non-tectonic origin for both the Fall Zone and arches and embayments in the Coastal Plain adjacent to the Zone. Specifically, in follow-up RAI 63, Question 02.05.01-19, the staff requested that the applicant provide the following materials:

a) Additional information, including consideration of references that propose faulting to be associated with some segments of the Fall Zone (e.g., Pazzaglia and Gardner, 1994), to justify interpretations that the Fall Zone and adjacent arches and embayments are non-tectonic in origin and that no evidence exists for primary or secondary Quaternary faulting associated with the Fall Zone in the site region.

b) A summary of pertinent data derived from references cited in the response to RAI 42, Question 02.05.01-1 and used to suggest that regional geophysical data document a non-tectonic origin for the arches and embayments occurring in the Coastal Plain adjacent to the Fall Zone.

c) Additional information to explain how Cumbest et al. (2000), cited in the response to RAI 42, Question 02.05.01-1, indicates that interpretations of faulting along the Fall Zone result from a sampling bias.

In a September 25, 2012, response to follow-up RAI 63, Question 02.05.01-19, Part (a), and based on information provided by Pazzaglia and Gardner (1994), the applicant reported that relief along the Fall Zone primarily results from contrast in hardness between metamorphic crystalline rocks of the Piedmont and Coastal Plain sediments, and secondarily from non-tectonic flexural upwarping of the Piedmont, rather than faulting. The applicant stated that Pazzaglia and Gardner (1994) provided the best evidence for the Fall Zone being non-tectonic in origin and for uplift in the Piedmont and Fall Zone being the result of epeirogenic (i.e., the product of vertical movement) flexure of the Piedmont lithosphere due to sediment loading to the east in the Coastal Plain. The applicant made this statement because Pazzaglia and Gardner (1994) reproduced paleotopographic profiles along the Susquehanna River as far back as Middle Miocene (about 13.8 Ma) using a model of flexural isostatic bending of the lithosphere, indicating that uplift in the Piedmont near the Fall Zone could occur as a result of sediment loading along the coast in combination with erosion of the Appalachian Mountains. The applicant indicated that the epeirogenic uplift rate calculated by Pazzaglia and Gardner (1994) was about 0.0023 mm (9.055×10^{-5} in) per year near the Fall Zone, a rate consistent with the interpretation that small deformations near the Fall Zone most likely occur due to isostatic bending of Piedmont lithosphere as a result of epeirogenic flexure, rather than tectonic faulting resulting from horizontal stresses.

Also, in the September 25, 2011, response to RAI 63, Question 02.05.01-19, Part (a), the applicant explained that, although some researchers reported a coincidence of Cenozoic faulting with the Fall Zone (e.g., Mixon and Newell, 1977; Mixon and Powars, 1984), no investigations revealed evidence of a Quaternary age for those faults. Examples of Cenozoic tectonic features near the Fall Zone in the site region include the Stafford fault system in Virginia; the National Zoo faults in Washington, D.C.; the hypothesized fault of Pazzaglia (1993); and one of the seven (i.e., the Tidewater fall line) Fall Lines of Weems (1998). The applicant reported that the Stafford fault system and the National Zoo faults are probably Tertiary in age based on observed field relationships, and that studies conducted for the North Anna ESP application (Dominion, 2004) revealed a Pliocene (5.3 to 2.6 Ma) sand unit overlying the Tidewater fall line without deformation. The applicant further reported that the fault of Pazzaglia (1993), postulated to extend up the Chesapeake Bay into the site vicinity because of an apparent 8 m (26 ft) elevation difference in Pleistocene (2.6 to 1.8 Ma) strata outcropping more than 15 km (9 mi) apart on opposite sides of the Chesapeake Bay, is most likely the result of variations in the paleotopographic surface developed on those strata. During the site field audit

conducted over September 29-30, 2011, the staff examined these same strata in the field and found no evidence for Quaternary faulting as postulated by Pazzaglia (1993).

In a September 25, 2012, response to RAI 63, Question 02.05.01-19, Part (b), the applicant reported that researchers have recognized morphology and variations in sediment thickness associated with arches and embayments in the Coastal Plain dominantly reflect properties of underlying basement rocks rather than recent tectonic deformation. Karner and Watts (1982) analyzed gravity anomalies along linear profiles adjacent to passive continental margins around the world, including eastern North America, and predicted the style of basement flexure changes during margin evolution based on isostasy due to sediment loading without any influence from faulting. In addition, Wyer and Watts (2006) used gravity anomaly data to determine that arches and embayments show an association with lithospheric strength (i.e., generally stronger lithosphere under arches and weaker under embayments). Based on the reasoning developed in Karner and Watts (1982) and Wyer and Watts (2006) explaining how geophysical data (i.e., gravity anomalies) support a non-tectonic origin for the arches and embayments occurring in the Coastal Plain adjacent to the Fall Zone in the site region, the applicant concluded that arches and embayments of the Coastal Plain resulted from non-tectonic processes associated with isostasy and strength of the lithosphere.

In a September 25, 2012, response to RAI 63, Question 02.05.01-19, Part (c), the applicant indicated that Cumbest et al. (2000) pointed out the sampling bias for interpretations of faulting along the Fall Zone due to the fact that recognition of faults in Paleozoic crystalline rocks adjacent to the Fall Zone is easier than in younger Coastal Plain sediments east of the Fall Zone. The applicant noted that the structures identified by Cumbest et al. (2000) are Cretaceous and Tertiary in age, not Quaternary, so that study also did not document an increased possibility of Quaternary faulting associated with the Fall Zone.

Based on its review of the December 28, 2011, and September 25, 2012, responses to RAI 42, Question 02.05.01-1 and follow—up RAI 63, Question 02.05.01-19, respectively, and SSAR Sections 2.5.1.1.1.3 and 2.5.1.1.2.7, as well as independent examination of references cited by the applicant, the staff concludes that sufficient field evidence exists to support the interpretation of a non-tectonic origin for the Fall Zone and arches and embayments occurring in the Coastal Plain adjacent to the Fall Zone. The staff makes this conclusion because a preponderance of information derived from analysis of field data by multiple researchers suggests a non-tectonic origin for these features. Accordingly, the staff considers RAI 42, Question 02.05.01-1 and RAI 63, Question 02.05.01-19 resolved.

Based on review of SSAR Sections 2.5.1.1.1 and 2.5.1.1.2 and the applicant’s responses to RAI 42, Question 02.05.01-1 and follow-up RAI 63, Question 02.05.01-19, as well as independent review of literature cited by the applicant in the SSAR, the staff finds that the applicant provided a thorough and accurate description of regional physiography, geomorphology, and geologic setting in support of the PSEG ESP application.

2.5.1.4.1.2 Regional Stratigraphy.

In SSAR Section 2.5.1.1.3, the applicant discussed stratigraphy of the site region, including stratigraphic successions formed during Late Proterozoic, Paleozoic, Mesozoic, and Cenozoic, which encompasses the Quaternary Period. The applicant briefly described characteristics of the Lower Tertiary Vincentown Formation, the proposed foundation unit at the site.

The staff focused the review of SSAR Section 2.5.1.1.3 on the applicant's descriptions of Quaternary stratigraphic units to ensure that no sedimentation patterns suggested Quaternary tectonic deformation in the site region. Based on its review of SSAR Section 2.5.1.1.3 as well as independent review of literature cited by the applicant in that section, the staff concludes that Quaternary deposits in the site region resulted from fluvial and marine processes associated with sea level changes or terminal glacial effects, including glacial outwash. The staff draws this conclusion because considerable field data exist to document characteristics of the Quaternary section in the site region.

Based on its review of SSAR Section 2.5.1.1.3 and independent examination of references cited by the applicant in the SSAR, the staff finds that the applicant provided a thorough and accurate description of regional stratigraphy in support of the PSEG ESP application.

2.5.1.4.1.3 Regional Tectonic Setting

In SSAR Section 2.5.1.1.4, the applicant discussed regional tectonic setting, including regional stress and principal tectonic structures of Late Proterozoic, Paleozoic, Mesozoic, and Cenozoic found in the site region. The principal structures included 17 potential Quaternary tectonic features reported to occur in the site region, as described in SSAR Section 2.5.1.1.4.2.5 and summarized in Section 2.5.1.2.1.4.2 of this report.

The staff focused the review of SSAR Section 2.5.1.1.4 on understanding ages of the principal tectonic structures that occur in the site region, concentrating specifically on Cenozoic and potential Quaternary features, to ensure that none of the features represented tectonic structures that may pose a geologic or seismic hazard to the site.

2.5.1.4.1.3.1 *Principal Tectonic Structures.*

Cenozoic Tectonic Structures

Hypothesized Fault of Pazzaglia

SSAR Section 2.5.1.1.4.2.4.1 describes a fault postulated by Pazzaglia (1993), trending along the northeastern end of the Chesapeake Bay and projecting into the site vicinity, that may offset Early Pleistocene (2.6 to 1.8 Ma) sedimentary Turkey Point Beds near the Fall Zone in Maryland. The applicant stated that Pazzaglia (1993) proposed this fault based on a difference in elevation of the sedimentary beds on opposite sides of the fault along the eastern and western shores of the Chesapeake Bay, a distance of more than 15 km (9 mi), and reported that field and aerial reconnaissance studies performed for the PSEG ESP application did not reveal any evidence for this postulated fault. The applicant concluded that this feature, if it exists, does not pose a hazard to the site. However, the applicant did not present the data specifically used to support this conclusion. Therefore, in RAI 42, Question 02.05.01-4, the staff requested that the applicant discuss the data used to conclude that the proposed fault of Pazzaglia (1993), if it exists, does not pose a hazard to the site since it projects into the site vicinity. The staff also requested that the applicant clarify whether the evaluation of the proposed fault of Pazzaglia (1993) took into account interpretations by other researchers who have postulated the existence of Quaternary faulting along the Fall Zone at other locations.

In a January 13, 2012, response to RAI 42, Question 02.05.01-4, the applicant reiterated that aerial reconnaissance and field examination of outcrops in the site vicinity did not reveal any evidence for the fault proposed by Pazzaglia (1993), reinforcing statements made by Pazzaglia

to the applicant during personal interviews that no physical evidence exists for faulting and original relief on depositional sedimentary surfaces of the Turkey Point beds was equally plausible as the cause of observed differences in elevation of the beds on opposite sides of the proposed fault. The applicant noted further that no information from any other studies conclusively demonstrated the existence of the fault proposed by Pazzaglia (1993). In addition, during the September 2011, site audit, the staff examined Pleistocene estuarine sediments comprising the Turkey Point Beds in the vicinity of the Turkey Point Lighthouse, located on the eastern side of Chesapeake Bay and west of the PSEG Site near the boundary of the site vicinity, and found no field evidence for Quaternary faulting.

Based on its review of SSAR Section 2.5.1.1.4.2.4.1 and the January 13, 2012, response to RAI 42, Question 02.05.01-4, field examination of stratigraphic units in September 2011 that did not exhibit any evidence of Quaternary faulting, and independent examination of literature cited by the applicant, the staff concludes that no definitive field evidence exists for the fault proposed by Pazzaglia (1993). The staff draws this conclusion because no field data support the existence of this fault, and original relief on depositional surfaces of strata is a highly plausible explanation for the observed differences in elevations of strata on opposite sides of the proposed fault. Accordingly, the staff considers RAI 42, Question 02.05.01-4 resolved.

River Bend Trend/Stafford Fault of Marple

SSAR Section 2.5.1.1.4.2.4.3 discusses the River Bend Trend/Stafford Fault of Marple (2004). The applicant stated that trend of the river bends, which Marple (2004) associated with faulting along the northeast-striking Stafford fault of proposed Tertiary age, likely represent migration of the rivers from old entrenched channels in erosion-resistant Piedmont rocks to lower-gradient meandering streams flowing across less erosion-resistant Coastal Plain sediments. In RAI 42, Question 02.05.01-5, the staff requested that the applicant describe the field locations examined to document the conclusion that no relationship exists between the River Bend Trend, which occurs in the site vicinity, and Quaternary faulting. The staff also requested that the applicant provide more complete references to support this conclusion.

In a December 28, 2011, response to RAI 42, Question 02.05.01-5, the applicant reported that aerial reconnaissance and examination of aerial photographs provided the primary means for assessing deformation of Quaternary sediments along the River Bend Trend, but that field reconnaissance of outcrops at Turkey Point just west of the River Bend Trend (and east of the fault proposed by Pazzaglia, 1993) revealed undeformed sedimentary units of the Pliocene (5.3 to 2.6 Ma) Pensauken Formation and overlying Pleistocene (2.6 Ma to 0.01 Ma) Turkey Point beds. The applicant also pointed out that Marple (2004) indicated Pleistocene age river terraces in the Salisbury embayment area showed no deformation along the River Bend Trend, indicating that deformation had ceased by Quaternary time. In addition, the applicant stated that the Preliminary Safety Analysis Report (PSAR, 1970) for the Newbold Island Nuclear Generating Station, located about 100 km (62 mi) northeast of the PSEG Site along the River Bend Trend, did not identify any faulting associated with that trend. As discussed above for the evaluation of RAI 42, Question 02.05.01-4, during the site audit conducted over September 29-30, 2011, the staff examined Pleistocene sediments comprising the Turkey Point beds in the vicinity of the Turkey Point Lighthouse and found no field evidence for Quaternary faulting.

Based on its review of SSAR Section 2.5.1.1.4.2.4.3 and the December 28, 2011, response to RAI 42, Question 02.05.01-5, field examination of stratigraphic units in September 2011 that did

not exhibit any evidence of Quaternary faulting, and independent examination of literature cited by the applicant, the staff concludes that no definitive field evidence exists for the River Bend Trend/Stafford fault of Marple (2004) in the site vicinity. The staff draws this conclusion because no field data support the existence of faulting along the River Bend Trend in the site vicinity. Accordingly, the staff considers RAI 42, Question 02.05.01-5 resolved.

National Zoo Faults

SSAR Section 2.5.1.1.4.2.4.4 describes the National Zoo faults in Washington, DC and states that these faults are probably Tertiary in age. In RAI 42, Question 02.05.01-6, the staff requested that the applicant provide references and field data to document the conclusion that the National Zoo faults are likely Tertiary, not Quaternary, in age. In a December 28, 2011, response to RAI 42, Question 02.05.01-6, the applicant cited Fleming et al. (1994) to document field relationships indicating that Pliocene sediments are the youngest units cut by these faults, qualifying them as pre-Quaternary structures.

Based on its review of SSAR Section 2.5.1.1.4.2.4.4 and the December 28, 2011, response to RAI 42, Question 02.05.01-6, and independent examination of literature cited by the applicant, the staff concludes that the National Zoo faults are pre-Quaternary in age. The staff draws this conclusion because existing field data indicate the youngest stratigraphic units cut by the faults are Pliocene (5.3 to 2.6 Ma). Accordingly, the staff considers RAI 42, Question 02.05.01-6 resolved.

Potential Quaternary Tectonic Features

Ramapo Fault

SSAR Section 2.5.1.1.4.2.5.11 discusses the Ramapo fault and references results of work by Sykes et al. (2008) that indicates the fault is Mesozoic in age and work by Ratcliffe (1982 and 1990) that demonstrates Quaternary units are not offset by the fault. However, the staff notes that Newman et al. (1987) proposed evidence for downfaulting and presented radiocarbon dates that may suggest post-Mesozoic movement on the fault. In RAI 42, Question 02.05.01-7, the staff requested that the applicant discuss information related to the premise that the Ramapo fault may have experienced post-Mesozoic activity.

In a January 13, 2012, response to RAI 42, Question 02.05.01-7, the applicant cited information from multiple investigators who indicated that considerable uncertainty exists for activity of the Ramapo fault based on analysis of seismicity and did not interpret the fault as active fault based on a lack of associated seismicity (e.g., Seborowski et al., 1982, Quittmeyer et al., 1985; Thurber and Caruso, 1985; Kafka and Miller, 1996). With regard to the work by Newman et al. (1987), the applicant reported that their radiocarbon dates from peat deposits have considerable uncertainty and their assessment actually predicts normal faulting, a sense of displacement that does not agree with the current state of stress, which would result in reverse faulting. The applicant reiterated that Sykes et al. (2008) found no evidence for seismicity associated with the Ramapo fault, and Ratcliffe (1982 and 1990) found definitive geologic field evidence demonstrating a lack of Quaternary deformation along the fault (i.e., Quaternary strata cross the fault without any offset).

Based on its review of SSAR Section 2.5.1.1.4.2.5.11 and the January 13, 2012, response to RAI 42, Question 02.05.01-7, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes that the Ramapo fault is pre-Quaternary in

age. The staff draws this conclusion because there is a lack of seismicity associated with the fault and Quaternary strata cross the fault without offset. Accordingly, the staff considers RAI 42, Question 02.05.01-7 resolved.

Everona-Mountain Run Fault Zone

SSAR Section 2.5.1.1.4.2.5.4 discusses the Everona-Mountain Run fault zone, citing Manspeizer et al. (1989) who interpreted the Everona segment of the fault zone to offset Pleistocene (2.6 Ma to 0.01 Ma) stream gravels by about 1.5 m (5 ft) in a reverse motion sense. The applicant described field investigations conducted along the Mountain Run fault zone in support of the North Anna ESP application (Dominion, 2004), but did not address the Everona segment of the fault zone. Therefore, in RAI 42, Question 02.05.01-10, the staff requested that the applicant describe field investigations performed specifically to analyze the Everona segment of the Everona-Mountain Run fault zone, and explain the field data used to assess the Everona segment and conclude that the fault zone does not pose a geologic or seismic hazard to the site. The staff also requested that the applicant describe any evidence that supports or contradicts the interpretation of Manspeizer et al. (1989).

In a December 28, 2011, response to RAI 42, Question 02.05.01-10, the applicant explained that Manspeizer et al. (1989) did not provide enough details about the field observations used to interpret offset of Pleistocene gravels to distinguish their work from that of Pavlides et al. (1983), who indicated that the faulted unit was probably of late Tertiary, rather than Quaternary, age. The applicant noted later work by Pavlides (1994) reports that the Everona segment of the fault zone shows minor late Cenozoic reverse movement, and that Manspeizer et al. (1989) and Pavlides et al. (1983) remarked that this feature has no geomorphic expression. The applicant stated that uncertainty about the age of the faulted strata hinders a refined assessment of the timing of deformation along the Everona segment of the Everona-Mountain Run fault zone, and that age of last movement could be late Tertiary or younger (i.e., Quaternary). The applicant noted that studies conducted for the North Anna ESP application (Dominion, 2004) did not include a detailed assessment of the Everona segment of the fault zone, possibly because of its lack of geomorphic expression.

Based on review of SSAR Section 2.5.1.1.4.2.5.4 and the December 28, 2011, response to RAI 42, Question 02.05.01-10, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes definitive data do not exist for stating that the Everona segment of the Everona-Mountain Run fault zone is Quaternary in age. The staff makes this conclusion because the age of units disrupted by the Everona segment is somewhat uncertain, field evidence for the associated Mountain Run fault zone indicates the fault zone is pre-Quaternary in age (i.e., undeformed pre-Quaternary colluvial deposits bury the fault zone between the Rappahannock and Rapidan Rivers), and there is no geomorphic expression of the Everona segment. Accordingly, the staff considers RAI 42, Question 02.05.01-10 resolved.

New Castle County Faults

SSAR Section 2.5.1.1.4.2.5.5 discusses the inferred pre-Cretaceous New Castle County faults, stating that satellite imagery revealed no evidence of disrupted topography or Quaternary deformation along lineaments identified in the imagery or above any basement faults identified based on subsurface borehole and geophysical data. However, the applicant did not include those images in the SSAR. Therefore, in RAI 42, Question 02.05.01-11, the staff requested that the applicant provide images used to conclude that there is no evidence of surface deformation

along these faults, and explain the specific topographic features used to conclude that there is no Quaternary deformation along the New Castle County faults in the site region.

In a January 13, 2012, response to RAI 42, Question 02.05.01-11, the applicant provided the images used to support the statement that they revealed no evidence of disrupted topography or Quaternary deformation along lineaments identified in the imagery or above any basement faults, including the inferred buried basement features labeled by Spoljaric (1972 and 1973) as the New Castle County faults. The applicant noted that shorelines, stream drainage patterns, and topographic ridges cross lineaments mapped by Spoljaric (1979) in the site area, some of which he described as proposed faults, without deflection or any other geomorphic indication of Quaternary deformation. The applicant also reiterated that the New Castle County faults, inferred from subsurface borehole and geophysical data, are located in the Piedmont of Delaware and exhibit no field evidence for Quaternary deformation.

Based on its review of SSAR Section 2.5.1.1.4.2.5.5 and the January 13, 2012, response to RAI 42, Question 02.05.01-11, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes that satellite imagery revealed no evidence of disrupted topography or Quaternary deformation along lineaments identified in the imagery or above any buried basement faults identified based on subsurface borehole and geophysical data, including the New Castle County faults. The staff makes this conclusion because it is strongly supported by existing data. Accordingly, the staff considers RAI 42, Question 02.05.01-11 resolved.

<u>Dobb’s Ferry Fault Zone</u>

SSAR Section 2.5.1.1.4.2.5.13 discusses the Dobb’s Ferry fault zone and states that the best estimate for timing of displacement along the fault zone (i.e., Paleozoic or younger) is based on the oldest rock deformed. However, the applicant did not describe the field relationships that may suggest an age for youngest displacement along the zone. Therefore, in RAI 42, Question 02.05.01-12, the staff requested that the applicant discuss information on observed field relationships for clarifying age of the youngest rock unit deformed by the fault zone to provide a minimum age for most recent displacement along the zone.

In a December 28, 2012, response to RAI 42, Question 02.05.01-12, the applicant reported that the Dobbs Ferry fault zone occurs in rock units that are Proterozoic to Precambrian and Cambrian-Ordovician in age, and no field relationships indicate Quaternary deformation along the trace of the fault zone. The applicant stated that features observed during site characterization investigations conducted for the PSEG ESP application did not reveal any evidence for Quaternary deformation along the fault zone, and noted that no new literature contains more recent information about timing of deformation along the zone.

Based on its review of SSAR Section 2.5.1.1.4.2.5.13 and the December 28, 2011, response to RAI 42, Question 02.05.01-12, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes that the Dobb’s Ferry fault zone does not reveal any definitive evidence for Quaternary deformation. The staff makes this conclusion in light of the fact that observable deformation related to the fault zone occurs only in Precambrian and Paleozoic age rock units and there is no field evidence for Quaternary displacement along the fault zone. Accordingly, the staff considers RAI 42, Question 02.05.01-12 resolved.

East Coast Fault System

SSAR Section 2.5.1.1.4.2.5.17 describes the postulated characteristics of the proposed northern segment of the East Coast Fault System (ECFS). The applicant reported that the only basis for the existence of the northern segment of the ECFS is a variety of anomalous river features, and that no coincidence with faulting has been demonstrated. Therefore, in RAI 42, Question 02.05.01-13, the staff requested that the applicant describe any observed field relationships used to conclude that the ECFS is not a zone of Quaternary faulting in the site region.

In a December 28, 2011, response to RAI 42, Question 02.05.01-13, the applicant indicated that published geologic mapping (Gilmer and Berquist, 2011; Mixon et al., 1989) within the site region where the proposed trace of the northern segment of the ECFS would extend does not show any evidence for fault-related deformation of Quaternary units.

Based on its review of SSAR Section 2.5.1.1.4.2.5.17 and the December 28, 2011, response to RAI 42, Question 02.05.01-13, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes that the northern extent of the ECFS exhibits no evidence for Quaternary deformation due to faulting. The staff makes this conclusion because geologic mapping in the site region where the northern segment of the ECFS would extend does not reveal any field evidence for fault-related disruption of Quaternary units. Accordingly, the staff considers RAI 42, Question 02.05.01-13 resolved.

Based on its review of SSAR Section 2.5.1.1.4 and responses to RAI 42, Questions 02.05.01-4 through 02.05.01-7 and 02.05.01-10 through 02.05.01-13, as well as independent examination of literature cited by the applicant in the SSAR and the RAI responses, the staff finds that the applicant provided a thorough and accurate description of regional tectonic setting (including regional stress and principal tectonic structures ranging in age from Late Proterozoic to Cenozoic) in support of the PSEG ESP application.

2.5.1.4.1.3.2 Seismic Zones Defined by Regional Seismicity.

Proposed Peekskill Stamford Seismic Boundary

SSAR Section 2.5.1.1.5.2 discusses the proposed Peekskill-Stamford seismic boundary of Sykes et al. (2008), but states that they did not present any data to support the inference regarding the association of this proposed boundary with brittle faults farther south that may have formed to accommodate Mesozoic extension. Therefore, in RAI 42, Question 02.05.01-3, the staff requested that the applicant provide any additional information regarding faulting and potential seismic hazard related to this seismic boundary.

In a January 13, 2012, response to RAI 42, Question 02.05.01-3, the applicant stated that this proposed boundary, which extends between Peekskill, NY and Stamford, CT, is not a tectonic feature, but rather a boundary between a proposed aseismic region along the southern New York and Connecticut border and seismicity further to the south-southeast in the Newark Basin. The applicant indicated that the weak inference of an association with faulting does not stand when compared with investigations (as discussed in SSAR Sections 2.5.1.1.2, 2.5.1.1.4, 2.5.1.1.5, and 2.5.1.1.6) that have not identified any geologic structure associated with this boundary. The applicant reiterated that the seismic source model provided for the CEUS in NUREG-2115 need not be modified to represent potential seismic hazard at the PSEG Site due to the proposed Peekskill-Stamford seismic boundary.

Based on its review of SSAR Section 2.5.1.1.5.2 and the January 13, 2012, response to RAI 42, Question 02.05.01-3, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes that no definitive data exist to equate the Peekskill-Stamford seismic boundary with faulting. The staff makes this conclusion because the preponderance of data does not reveal any faulting associated with this proposed boundary. Accordingly, the staff considers RAI 42, Question 02.05.01-3 resolved.

Based on its review of SSAR Section 2.5.1.1.5 and the response to RAI 42, Question 02.05.01-3 as well as independent examination of references cited by the applicant in the SSAR and the RAI response, the staff finds that the applicant provided a thorough and accurate description of seismic zones defined by regional seismicity (including the Ramapo seismic zone and the proposed Peekskill-Stamford seismic boundary) in support of the PSEG ESP application.

2.5.1.4.1.3.3 *Staff Conclusions Regarding Regional Tectonic Setting and Seismic Zones Defined by Regional Seismicity*

Based on its review of SSAR Sections 2.5.1.1.4, "Regional Tectonic Setting"; and 2.5.1.1.5, "Seismic Zones Defined by Regional Seismicity"; the applicant's responses to RAIs 42, Questions 02.05.01-3 through 02.05.01-7 and 02.05.01-10 through 02.05.01-13, independent review of references cited in the SSAR and the RAI responses, and direct examination of outcrops of Early Pleistocene strata near the boundary of the site vicinity for field evidence of a fault postulated by Pazzaglia (1993) to extend into the Chesapeake Bay west of the PSEG Site, the staff concludes that the applicant provided thorough and accurate descriptions of regional tectonic setting and seismic zones defined by regional seismicity. The staff also concludes that the descriptions provided by the applicant in the SSAR and RAI responses reflect the current state of knowledge and meet the regulatory requirements defined in 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d).

2.5.1.4.1.3.4 *Regional Gravity and Magnetic Fields.*

Regional Gravity Field Data

SSAR Section 2.5.1.1.6.1 states that seismic reflection data show portions of the low gravity anomaly located east of the PSEG Site to be associated with sediments deposited in a Mesozoic extensional basin (Sheridan et al., 1991). SSAR Section 2.5.1.1.6.3 suggests Mesozoic basins other than the Buena Basin may occur east of the site, but the applicant reported that the existence of these other basins has not been proven. It is unclear to the staff whether the gravity low identified east of the site and described in SSAR Section 2.5.1.1.6.1 reflects an extension of the Buena Basin to the southwest, placing it nearer to but east of the PSEG Site, or another Mesozoic extensional basin. Therefore, in RAI 42, Question 02.05.01-14, the staff requested that the applicant clarify whether the Mesozoic basin identified in seismic reflection data reflects the Buena Basin or another Mesozoic extensional basin.

In a December 28, 2011, response to RAI 42, Question 02.05.01-14, based on information provided by Saltus and Blakely (2011), the applicant reported that the gravity data would be generally consistent with either extension of the Buena Basin into the site area or the presence of a separate basin containing low-density sedimentary fill. However, the applicant concluded that, due to uncertainties associated with characterizing Mesozoic basins using gravity data, no clear evidence exists for extending the Buena Basin into the area east of the site beyond the

limits currently reported in the literature. Based on its review of published data derived from combined magnetic and gravity studies, the applicant also concluded that no known Mesozoic basins other than those already discussed in the SSAR need be postulated to occur in the site vicinity.

Based on its review of SSAR Section 2.5.1.1.6.1 and the December 28, 2011, response to RAI 42, Question 02.05.01-14, independent examination of references cited by the applicant in the SSAR and the RAI response, and observations made during the September 2011 site field audit, the staff concludes that there is no definitive evidence to support extending the Buena Basin into the area east of the site. The staff makes this conclusion, although existing gravity data would be consistent with either extension of the Buena Basin east of the site into the site area or the presence of a separate basin containing low-density sedimentary fill, because of the inherent uncertainty in characterizing subsurface Mesozoic extensional basins using gravity data. In addition, no results from combined magnetic and gravity studies require an extension of the Buena Basin into the area east of the site. The staff also makes this conclusion because no field, borehole, or geophysical data indicate the presence of fault-bounded Mesozoic basins in the site area or at the site location. Accordingly, the staff considers RAI 42, Question 02.05.01-14 resolved.

Based on its review of SSAR Section 2.5.1.1.6 and the December 28, 2011, response to RAI 42, Question 02.05.01-14, as well as independent examination of references cited by the applicant in the SSAR and the RAI response, the staff finds that the applicant provided a thorough and accurate description of regional gravity and magnetic fields in support of the PSEG ESP application.

2.5.1.4.2 Site Geology

The staff focused the review of SSAR Section 2.5.1.2, “Site Geology,” on descriptions provided by the applicant for physiography and geomorphology, stratigraphy and lithology, geologic history, structural geology, and engineering geology of the PSEG Site vicinity and site area. The staff also focused the review on certain of these topics for the site location, including assessment of the effects of human activity.

2.5.1.4.2.1 Physiography and Geomorphology.

In SSAR Section 2.5.1.2.1, the applicant discussed physiography and geomorphology of the site area. The applicant stated that the PSEG Site location occurs on an artificial island on the eastern bank of the Delaware River.

The staff focused its review of SSAR Section 2.5.1.2.1 on the Outer Coastal Plain subprovince of the Coastal Plain physiographic province, within which the site almost completely lies, as well as the central portions of the site area occupied by the Delaware River channel, to ensure that the descriptions of physiography and geomorphology of the site area included any information related to evidence of possible Quaternary tectonic features. Based on its review of SSAR Section 2.5.1.2.1, as well as independent review of literature cited by the applicant in that section, the staff concludes that neither physiographic nor geomorphic characteristics of the site area reflect Quaternary tectonic features. The staff makes this conclusion because adequate data exist to support the interpretation that no physiographic or geomorphic characteristics of the site area indicate the presence of Quaternary tectonic features.

Based on its review of SSAR Section 2.5.1.2.1 and independent examination of references cited by the applicant in the SSAR, the staff finds that the applicant provided a thorough and accurate description of physiography and geomorphology of the site area in support of the PSEG ESP application.

2.5.1.4.2.2 Stratigraphy and Lithology.

In SSAR Section 2.5.1.2.2, the applicant discussed stratigraphy and lithologies of the site area and site location. The applicant described the stratigraphic column for the PSEG Site area and site location, including basement complex lithologies and Coastal Plain stratigraphic sequences.

The staff focused the review of SSAR Section 2.5.1.2.2 on the Coastal Plain stratigraphic sequences that lie above basement complex rock units in the site area and at the site location, including the Lower Tertiary Vincentown Formation, the planned foundation-bearing unit at the PSEG Site. This focus ensured that no features in the stratigraphic sequences which occur in the site area and at the site location suggested the presence of Quaternary tectonic structures. Based on its review of SSAR Section 2.5.1.2.2, as well as independent review of literature cited by the applicant in that section and direct examination of stratigraphic units in the field during the September 2011 site audit, the staff concludes that no geologic features in the stratigraphic sequences show any evidence for Quaternary tectonic deformation in the site area or at the site location. The staff makes this conclusion because adequate data exist to strongly support it.

Based on its review of SSAR Section 2.5.1.2.2 and independent examination of references cited by the applicant in the SSAR, the staff finds that the applicant provided a thorough and accurate description of stratigraphy and lithology (including basement complex lithologies and Coastal Plain stratigraphic sequences) for the site area and site location in support of the PSEG ESP application.

2.5.1.4.2.3 Geologic History.

In SSAR Section 2.5.1.2.3, the applicant discussed the geologic history of the site vicinity and site area. The applicant indicated that the crystalline basement complex, which underlies Coastal Plain sediments in the site vicinity and site area, formed during Precambrian and Paleozoic time, and that extension and rifting of the basement complex formed the present Atlantic Ocean basin during the Mesozoic. The applicant reported that deposition of Coastal Plain sedimentary sequences occurred from Early Cretaceous time into the Quaternary, and that Pleistocene (1.8 to 0.01 Ma) glacial-interglacial cycles resulted in deposition of fluvial sequences, development of estuarine terraces, and subsequent incision of the terraces and fluvial sequences.

The staff focused the review of SSAR Section 2.5.1.2.3 on geologic history in regard to tectonic deformation and other relevant geologic events in the site vicinity and site area to ensure that no tectonic or non-tectonic features developed that may detrimentally affect the site. Based on its review of SSAR Section 2.5.1.2.3, as well as independent review of literature cited by the applicant in that section and direct examination of geologic features in the field during the September 2011 site audit, the staff concludes that no evidence exists for potentially detrimental tectonic or non-tectonic features in the site vicinity and site area. The staff makes this conclusion because the independent literature review and direct field observations strongly support it.

Based on its review of SSAR Section 2.5.1.2.3 and independent examination of references cited by the applicant in the SSAR, the staff finds that the applicant provided a thorough and accurate description of geologic history of the site vicinity and site area in support of the PSEG ESP application.

2.5.1.4.2.4 Structural Geology.

In SSAR Section 2.5.1.2.4, the applicant discussed structural geology of the site vicinity, site area, and site location. The applicant stated that no fault-bounded Mesozoic extensional basins have been identified beneath the site location, although known or inferred buried Mesozoic basins occur beneath Coastal Plain sediments in Virginia, Maryland, Delaware, and New Jersey to include the site vicinity; that borehole data from the site location and from wells located between about 13 to 48 km (8 to 30 mi) from the site refute the existence of a Mesozoic basin in the site area; and that no tectonic faults or folds occur within the site area. In addition, as discussed in Section 2.5.1.4.1.3.4, "Regional Gravity and Magnetic Fields," of this report, in the December 28, 2011, response to RAI 42, Question 02.05.01-14, the applicant stated that due to uncertainties associated with characterizing Mesozoic basins using gravity data, no clear evidence exists for extending a basin (specifically the Buena Basin but also the Queen Anne Basin, for which the extension east of the PSEG Site is highly uncertain as discussed in Section 2.5.1.2.1.4.2 of this report) into the area east of the site beyond the limits currently reported in the literature. Figure 2.5.1-2 of this report shows the locations of fault-bounded Mesozoic extensional basins in the site region based on Benson (1992).

The staff focused the review of SSAR Section 2.5.1.2.4 on understanding the interpreted locations of buried, fault-bounded Mesozoic extensional basins to ensure that none occurred beneath the site location or in the site area. Based on its review of SSAR Section 2.5.1.2.4 as well as independent review of references cited by the applicant in that section, direct examination of geologic features in the field during the September 2011 site audit, and review of information provided by the applicant in the December 28, 2011, response to RAI 42, Question 02.05.01-14 (as discussed in Section 2.5.1.4.1.3.4 of this report), the staff concludes that no definitive evidence exists for the presence of buried fault-bounded Mesozoic basins in the site area or at the site location. The staff makes this conclusion because no field, borehole, or geophysical data indicate the presence of such basins in the site area or at the site location.

Based on its review of SSAR Section 2.5.1.2.4, independent examination of references cited by the applicant in the SSAR, direct examination of geologic features in the field during the September 2011 site audit, and review of information provided by the applicant in the December 28, 2011, response to RAI 42, Question 02.05.01-14 as discussed above in Section 2.5.1.4.1.3.4 of this report, the staff finds that the applicant provided a thorough and accurate description of the structural geology of the site vicinity, site area, and site location in support of the PSEG ESP application.

2.5.1.4.2.5 Site Engineering Geology Evaluation.

In SSAR Section 2.5.1.2.5, the applicant discussed engineering geology of the site vicinity, site area, and site location. The applicant addressed dynamic behavior during earthquakes; zones of mineralization, alteration, weathering, and structural weakness; unrelieved residual stresses in bedrock; groundwater conditions, and effects of human activity.

The staff focused the review of SSAR Section 2.5.1.2.5 on the applicant's discussions of dynamic behavior during earthquakes (SSAR Section 2.5.1.2.5.1) and zones of mineralization,

alteration, weathering, and structural weakness (SSAR Section 2.5.1.2.5.2). In SSAR Section 2.5.1.2.5.1, the applicant stated that no field investigations (e.g., regional studies in NUREG/CR-5613), examination of aerial photography, inspection from low-altitude overview flights, or excavation mapping at the existing Hope Creek unit revealed the presence of earthquake-induced liquefaction features. SSAR Section 2.5.1.2.5.1 also states that SSAR Section 2.5.4.7.3, "Effects of Prior Earthquakes on Site," indicates there is little exposure for evaluating the presence of liquefaction features. The applicant did not discuss susceptibility of materials surrounding the PSEG Site to earthquake-induced liquefaction, or what, if any, field studies conducted for the site analyzed the presence or absence of liquefaction features. Therefore, in RAI 42, Question 02.05.01-17, the staff requested that the applicant describe materials around the site that may be susceptible to earthquake-induced liquefaction and to discuss any field investigations conducted for the site for assessing the presence of liquefaction features in the site region, site vicinity, and site area and at the site location.

In a December 28, 2011, response to RAI 42, Question 02.05.01-17, the applicant stated that surficial soils east and south of the plant location consist of artificial fill and that salt marsh deposits (i.e., clays, silts, and sands with varying amounts of clay and silt) occur to the northeast. The applicant noted that the fill, emplacement of which started in the early 1900s, has not experienced historical earthquakes large enough to liquefy the fill materials. The applicant indicated that constant reworking of the salt marsh deposits, which are also relatively young, obscures surficial evidence of liquefaction. The applicant explained that examination of marsh deposits and fill in the site area and at the site location did not reveal any evidence for earthquake-induced liquefaction. In addition, based on aerial and ground reconnaissance in the low topographic relief site area and site vicinity and review of published literature, the applicant reported that no liquefaction features occurred. The applicant did not conduct specific field investigations for assessing the presence or absence of liquefaction beyond the site vicinity.

Based on its review of SSAR Section 2.5.1.2.5 and the December 28, 2011, response to RAI 42, Question 02.05.01-17, as well as independent examination of the reference cited by the applicant in the SSAR (i.e., NUREG/CR-5613) and field observations made during the September 2011 site audit, the staff concludes that no field evidence exists for liquefaction features in the site region, site vicinity, and site area or at the site location. The staff makes this conclusion because the field evidence derived from multiple sources strongly supports it. Accordingly, the staff considers RAI 42, Question 02.05.01-17 resolved.

In SSAR Section 2.5.1.2.5.2, the applicant stated that karst terrain associated with dissolution of marble in the Cockeysville Formation occurs about 32 km (20 mi) northwest of the site in the Delaware Piedmont (i.e., within the site vicinity). SSAR Section 2.5.1.2.5.2 further states that karst is not a hazard for the PSEG Site area or site location, but the applicant did not address whether the Cockeysville Formation underlies the site at depth, which could result in zones of subsurface dissolution. Therefore, in RAI 42, Question 02.05.01-18, the staff requested that the applicant clarify whether or not the Cockeysville Formation, which is greater than 444 Ma in age, underlies the site at depth.

In a December 28, 2011, response to RAI 42, Question 02.05.01-18, the applicant stated that data defining the rock units associated with the lithotectonic terranes beneath the PSEG Site (i.e., the Carolina Superterrane or the Philadelphia Terrane, as discussed in SSAR Section 2.5.1.2.2 and summarized in Section 2.5.1.2.2.2.1 of this report) indicate the Cockeysville Formation does not underlie the site location.

Based on its review of SSAR Section 2.5.1.2.5 and the December 28, 2011, response to RAI 42, Question 02.05.01-18, as well as independent examination of references cited by the applicant in the SSAR and the RAI response, the staff concludes that the Cockeysville Formation does not underlie the PSEG Site location. The staff makes this conclusion because data related to which rock units comprise lithotectonic terranes beneath the site location indicate that the formation does not underlie the site location at depth. Accordingly, the staff considers RAI 42, Question 02.05.01-18 resolved.

Based on its review of SSAR Sections 2.5.1.2.5 and the December 28, 2011, responses to RAI 42, Question 02.05.01-17 and Question 02.05.01-18, as well as independent review of literature cited by the applicant in the SSAR and the RAI responses, the staff finds that the applicant provided a thorough and accurate description of engineering geology of the site vicinity, site area, and site location in support of the PSEG ESP application.

2.5.1.5 Permit Conditions

There are no Permit Conditions related to SSAR Section 2.5.1. However, in Section 2.5.3.5, "Geologic Mapping Permit Condition," of this report, the staff identified Permit Condition 3 related to detailed geologic mapping of safety-related excavations at the PSEG Site as the responsibility of the COL or CP applicant.

2.5.1.6 Conclusion

As documented in Sections 2.5.1.1 through 2.5.1.4 of this report, the staff reviewed and evaluated the basic geologic and seismic information submitted by the applicant in SSAR Section 2.5.1. This review and evaluation made it possible for the staff to confirm that this information provides an adequate basis for concluding that no tectonic or nontectonic features occur in the site region, site vicinity, and site area or at the site location with the potential for adversely affecting suitability and safety of the PSEG Site.

The staff also concludes that the applicant identified and appropriately characterized all seismic sources significant for determining the SSE for the PSEG Site, in accordance with regulatory requirements stated in 10 CFR 100.23(c) and 10 CFR 100.23(d) and guidance provided in RG 1.208 and NUREG-0800, Section 2.5.1. In addition, based on results of the investigations presented in SSAR Section 2.5.1, the staff concludes that the applicant properly characterized geology of the site region (including physiography and geomorphology, geologic history, stratigraphy, tectonic setting and principal tectonic structures, seismic zones defined by regional seismicity, and gravity and magnetic fields) and geology of the site vicinity, site area and site location (including physiography and geomorphology, stratigraphy and lithology, geologic history, structural geology, and engineering geology).

The staff further concludes that the applicant appropriately assessed the potential for possibly detrimental effects of human activity within the site area, including surface and subsurface mining, oil and gas extraction or injection, and groundwater injection or withdrawal that could compromise the safety of the site. Since the applicant documented a lack of any of these activities in the site area based on published information, the staff concludes that no potential exists for detrimental effects at the site location as a result of human activity.

Finally, based on results of the review and evaluation of SSAR Section 2.5.1, the staff concludes that the applicant provided a thorough and accurate description of the basic geologic and seismic characteristics of the proposed PSEG Site (including the site region, site vicinity,

site area, and site location) in full compliance with regulatory requirements in 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d) and in accordance with guidance in RG 1.208.

2.5.2 Vibratory Ground Motion

2.5.2.1 Introduction

The vibratory ground motion is evaluated based on seismological, geological, geophysical, and geotechnical investigations carried out to determine the site-specific ground motion response spectrum, which must meet the regulations for the safe shutdown earthquake provided in 10 CFR 100.23. The GMRS is defined as the free-field horizontal and vertical ground motion response spectra at the plant site. The development of the GMRS is based upon a detailed evaluation of earthquake potential, taking into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the site subsurface material. The specific investigations necessary to determine the GMRS include the seismicity of the site region and the correlation of earthquake activity with seismic sources. Seismic sources are identified and characterized, including the rates of occurrence of earthquakes associated with each seismic source. Seismic sources that have any part within 320 km (200 mi) of the site must be identified. More distant sources that have a potential for earthquakes large enough to affect the site must also be identified. Seismic sources can be capable tectonic sources or seismogenic sources. The staff's review covers the following specific areas: (1) Seismicity; (2) geologic and tectonic characteristics of the site and region; (3) correlation of earthquake activity with seismic sources; (4) probabilistic seismic hazard analysis and controlling earthquakes; (5) seismic wave transmission characteristics of the site; (6) site-specific ground motion response spectrum; and (7) any additional information requirements prescribed within the "Contents of Application" sections of the applicable 10 CFR Part 52 Subparts.

2.5.2.2 Summary of Application

SSAR Section 2.5.2 describes the potential vibratory ground motion at the PSEG Site. To estimate the vibratory ground motion at the site, the applicant chose to use the NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities," seismic source model and EPRI 2004 and 2006 Ground Motion Prediction Equations (GMPE) in its PSHA analysis. The applicant stated that it developed the GMRS based on the performance-based approach recommended by RG 1.208. In the SSAR, the applicant presented the following information related to the vibratory ground motion at the PSEG Site.

2.5.2.2.1 Seismicity

SSAR Section 2.5.2.1 states that the applicant used the most recent earthquake catalog published as part of NUREG-2115 in its seismic hazard assessment at the PSEG Site. The NUREG-2115 earthquake catalog covers earthquakes in the CEUS region from 1568 through 2008. Since the NUREG-2115 earthquake catalog covers only through 2008, the applicant developed a separate earthquake catalog covering from 2009 until the end of 2011. After declustering this new earthquake catalog to eliminate dependent earthquakes, the applicant merged the two catalogs and used the updated catalog in its seismic hazard evaluation at the PSEG Site. The updated catalog identified 19 additional earthquakes in the 320 km (200 mi) site region. The applicant indicated that among the earthquakes listed in the 2009-2011 earthquake catalog, the Mineral, VA, earthquake with a moment magnitude of **M**5.8

that occurred on August 23, 2011, was the most significant earthquake. Beyond the Mineral, VA earthquake of 2011, the applicant identified eight other moderate-sized earthquakes within the 320 km (200 mi) site region. The magnitudes of these moderate-sized earthquakes range from 4.5 to 5.1. The applicant also noted that all of the new earthquakes identified in the region had magnitudes lower than the seismic sources' assigned maximum magnitudes and that the updated earthquake catalog did not impact for the NUREG-2115 seismic source model parameters. Figure 2.5.2-1 of this report shows the seismicity of the PSEG Site region and its surroundings.

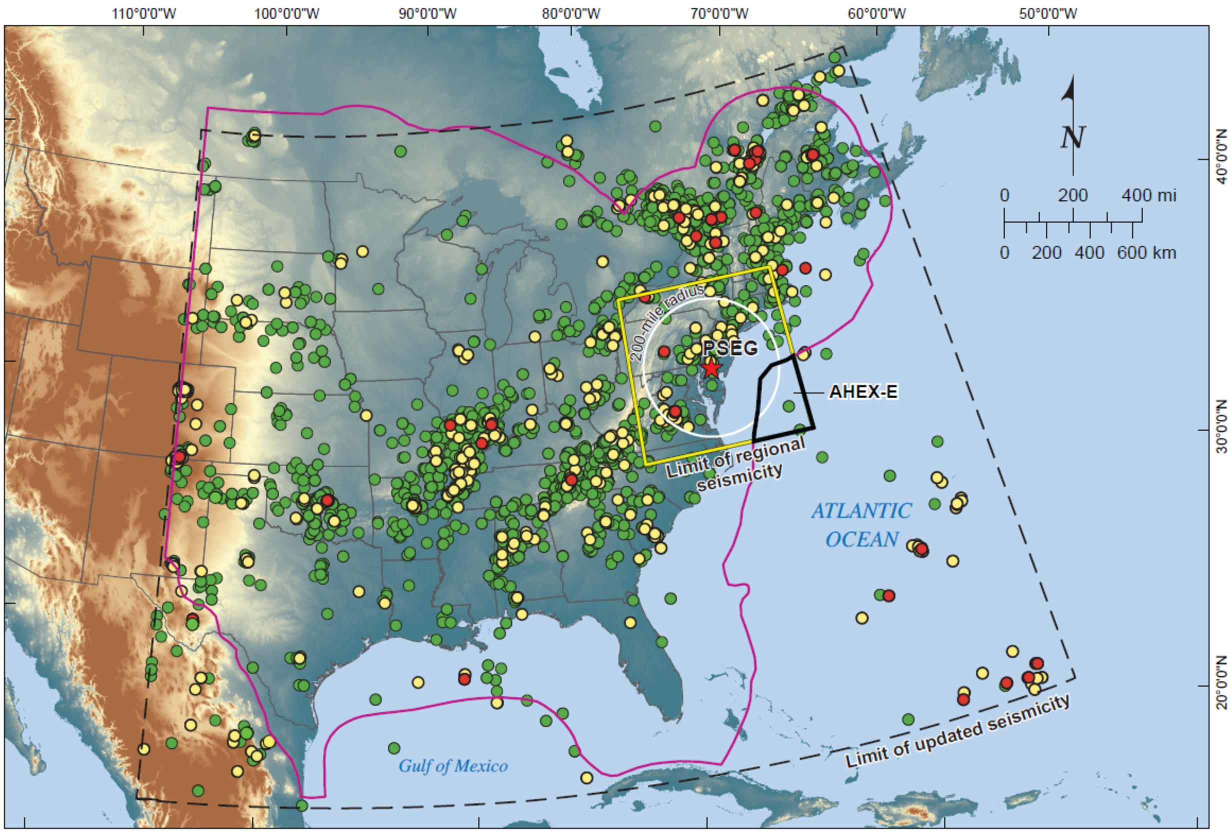


Figure 2.5.2-1 Map showing the earthquake activity in the CEUS region and the PSEG Site. The yellow box around the PSEG Site represents the area in which the applicant updated the original NUREG-2115 earthquake catalog to extend the temporal coverage from 2009 through 2011. Green, yellow, and red circles represent earthquakes with magnitudes less than 4, 4 to 5, and greater than 5, respectively. (Ref. SSAR Revision 3, Figure 2.5.2-57)

2.5.2.2.2 Geologic and Tectonic Characteristics of the Site and Region

SSAR Section 2.5.2.2 describes the seismic sources and seismic model parameters that the applicant used to calculate the seismic ground motion hazard at the PSEG Site. The applicant used the NUREG-2115 regional seismic source characterization model developed for the CEUS region as a starting point for its seismic ground motion hazard. The NUREG-2115 seismic source model is a model published in January 2012. The model development followed the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 procedures as outlined in NUREG/CR-6372, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on

Uncertainty and Use of Experts." The NUREG-2115 states that this is a regional seismic source model to be used as a starting model in seismic hazard calculations for nuclear facilities in the CEUS region. The applicant stated that it conducted a review of the CEUS-SSC model to identify whether there is a need to update any of the seismic sources. Based on its review results, the applicant stated that the regional model, as published, is adequate for use in seismic hazard calculations for the PSEG Site. The following describes a summary of the CEUS-SSC model.

Summary of the NUREG-2115 Seismic Source Model

The ESP applicant stated that the CEUS-SSC model described in NUREG-2115 contains two types of seismic sources: (1) Distributed seismicity sources; and (2) repeated large magnitude earthquake sources (RLME). While the distributed seismicity sources were developed based on available earthquake locations and regional geologic/tectonic characterizations, the RLME sources were based on geologic and paleo-earthquake records. The RLME sources represent the zones of repeated (two or more) large magnitude earthquakes (**M**>6.5) in the CEUS region.

The CEUS-SSC model categorizes the distributed seismicity sources into two subgroups: M_{max} zones and seismotectonic zones. These subgroups represent uncertainties in source characterizations and differences of opinions in seismic source identification in this region. In hazard estimates, the M_{max} and seismotectonics sources are weighted by 40 percent and 60 percent, respectively, to determine their contributions to the total seismic hazard at the site. The M_{max} zones are broad seismic sources identified based on limited tectonic information and represent potential seismic sources of future earthquakes. The seismotectonic sources are those developed by extensive analyses of regional geology, tectonics, and seismicity in the CEUS region. Both the M_{max} and the seismotectonics zones also include alternative source geometries, accommodating inherent uncertainty in seismic source characterization. The RLME sources are superimposed on the distributed seismicity sources.

2.5.2.2.3 Correlation of Earthquake Activity with Seismic Sources

SSAR Section 2.5.2.3 describes the applicant's correlation of updated seismicity with the NUREG-2115 seismic source model. The applicant provided the following conclusions regarding the correlation of earthquake activity with the seismic sources.

- The updated seismicity catalog does not contain any earthquakes within the site region that can be positively associated with a known geologic structure.

- The updated seismicity catalog does not show a pattern of seismicity different from that of the CEUS-SSC catalog that would suggest a new seismic source in addition to those included in the CEUS-SSC characterizations. For the PSEG ESP application, a new seismic source zone (AHEX-E) is created, as this small area in and adjacent to the PSEG Site Region is not included in the original CEUS-SSC catalog.

- The updated seismicity catalog does show a similar spatial distribution of earthquakes to that of the CEUS-SSC catalog, suggesting that no significant revisions to the geometry of seismic sources defined in the CEUS-SSC characterization is required.

- The updated seismicity catalog does not contain any earthquakes that suggest revisions to the M_{max} distributions for CEUS-SSC zones is required.

- Seismicity rates determined from the updated catalog are not significantly different than those determined from the original CEUS-SSC catalog.

2.5.2.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

SSAR Section 2.5.2.4 presents the results of the applicant's PSHA for the PSEG Site. In performing this analysis, the applicant followed the guidance provided in RG 1.208 to determine the seismic hazard curves and controlling earthquakes for the PSEG Site. The applicant based its analyses on the NUREG-2115 seismic source model and the EPRI (2004, 2006) ground motion prediction equations. The PSHA curves generated by the applicant represent generic hard rock conditions characterized by a shear wave velocity (V_S) in excess of 2.8 kilometers per second (km/s) (9,200 feet per second (fps)). The applicant also described the earthquake potential for the site in terms of a Uniform Hazard Response Spectra (UHRS) and the controlling earthquakes, the most likely earthquake magnitudes and source-site distances. The applicant determined the low- and high-frequency controlling earthquakes by deaggregating the PSHA curves at selected probability levels. The summary of the applicant's PSHA study is described below.

2.5.2.2.4.1 PSHA Inputs.

To conduct the PSHA and obtain the UHRS at the site, it is necessary to study the site location and its surrounding regions to determine geological and seismological properties, as outlined in RG 1.208. This requires determinations of active seismic source zones in the area, the seismic sources' model parameters, and appropriate GMPE for the region. The following subsections summarize the applicant's efforts in these areas.

2.5.2.2.4.1.1 Seismic Source Models and Parameters.

The input model for the PSEG PSHA study is primarily the NUREG-2115 seismic source model. Since the NUREG-2115 model does not cover the PSEG Site region fully (a radius of 320 km (200 mi)), the applicant developed a small regional seismic source to be added onto the NUREG-2115 model to cover the site area fully. The applicant named this new source 'Atlantic Highly Extended crust (AHEX-E)' and developed earthquake recurrence rates within this source using the same process utilized in the NUREG-2115 model. The applicant's AHEX-E source is shown as the black polygon in Figure 2.5.2-1 of this report.

SSAR Section 2.5.2.2.1 describes how the applicant updated its seismicity catalog to create a comprehensive list of earthquakes for the PSEG Site to assess the overall seismicity in the region and also to assess the validity of the earthquake recurrence rates described in NUREG-2115. The applicant found no significant changes in the seismicity rates that would necessitate changes to the seismicity rates published in NUREG-2115.

2.5.2.2.4.1.2 Ground Motion Models.

In SSAR Section 2.5.2.4.3, the applicant stated that it used the CEUS ground motion prediction model developed by EPRI in 2004 for its PSHA calculations, with the updates published by EPRI in 2006. These models were reviewed by the staff as part of the prior ESP and COL applications' reviews and the staff concluded that they adequately represent the expected ground motions in the CEUS region.

2.5.2.2.4.2 PSHA Methodology and Calculation.

Using the updated NUREG-2115 seismic source characteristics and the EPRI 2004 ground motion models with updated uncertainties as inputs (EPRI 2006), the applicant performed PSHA calculations for peak ground acceleration (PGA) and spectral acceleration at ground motion frequencies of 0.5, 1.0, 2.5, 5, 10, and 25Hz. The applicant performed PSHA calculations for the PSEG Site assuming generic hard rock conditions at the site with V_S of 2.8 km/s (9,200 fps). The applicant first calculated mean and fractile rock seismic hazard curves at particular spectral frequencies (0.5, 1.0, 2.5, 5, 10, 25, and PGA (100 Hz)) and annual frequencies of exceedance (10^{4}, 10^{-5}, and 10^{-6}). Then, the applicant deaggregated the results as described in RG 1.208 to calculate the controlling earthquakes for low-frequency (LF) and high-frequency (HF) ground motions. Finally, the applicant used the PSEG controlling earthquakes, and hard rock spectral shapes for CEUS earthquake ground motions recommended in NUREG/CR-6728 to calculate the final PSEG generic hard rock UHRS.

2.5.2.2.4.3 PSHA Results.

In SSAR Section 2.5.2.4.4, the applicant stated that local earthquakes are the major contributor to seismic hazard at the PSEG Site for both high frequencies (5 and 10 Hz) and low frequencies (1 and 2.5 Hz). However, there is some contribution from the large seismic sources outside the site region, such as the New Madrid seismic zone. The applicant identified that hazard contributions of the other large seismic sources in the CEUS regions, such as the Charleston and the Charlevoix seismic sources, to the total hazard is minimal.

The applicant also calculated the controlling earthquakes' distances and magnitudes for the high-and low-frequency earthquakes using the generic rock hazard curves. Table 2.5.2-1 of this report shows the results of the applicant's calculations.

Table 2.5.2-1 Controlling earthquakes for the PSEG Site (Ref. SSAR Revision 3, Table 2.5.2-34)

Structural Frequency	Annual Frequency of Exceedence	All R		R < 100 km		R > 100 km	
		M	R, km	M	R, km	M	R, km
5 & 10 Hz	1E-04	5.9	27	5.8	22	6.7	180
1 & 2.5 Hz	1E-04	6.6	68	6.2	21	7.3	540
5 & 10 Hz	1E-05	6.0	12	6.0	12	7.1	140
1 & 2.5 Hz	1E-05	6.6	27	6.4	16	7.6	570
5 & 10 Hz	1E-06	6.3	9	6.3	9	7.5	130
1 & 2.5 Hz	1E-06	6.7	13	6.7	12	7.7	420

a) Light-gray cells indicate high frequency controlling earthquakes and dark-gray cells indicate low frequency controlling earthquakes.

Following the calculations of the controlling earthquake distances and magnitudes, the applicant determined the smoothed UHRS at the generic rock level (Figure 2.5.2-2 of this report).

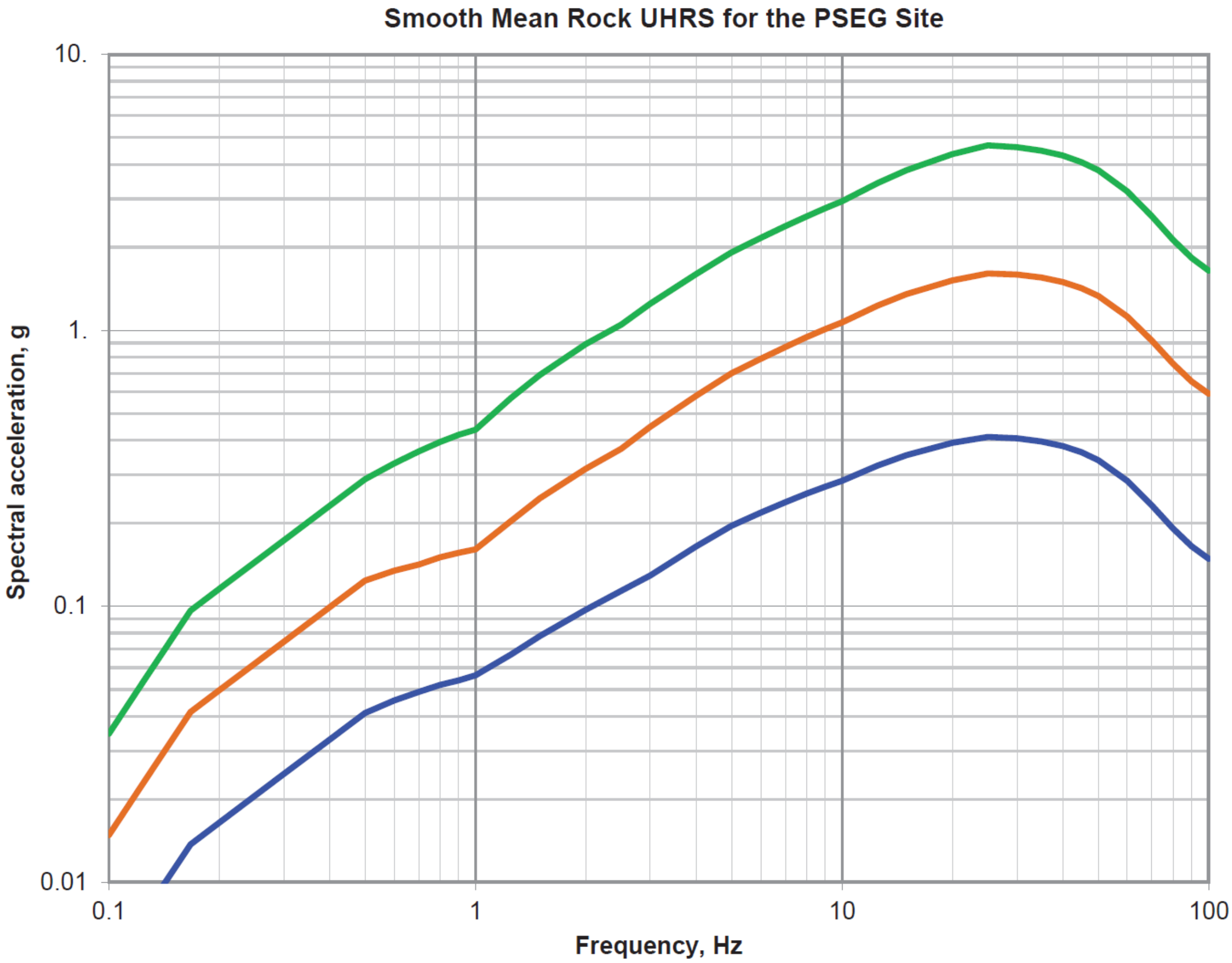


Figure 2.5.2-2 Smooth uniform hazard response spectra for the generic rock conditions at the PSEG Site. PSHA results calculated using the NUREG-2115 seismic source model and the EPRI (2004 and 2006) ground motion prediction models at the seven defined frequencies were used in calculating these UHRA curves for 10^{-4}, 10^{-5}, and 10^{-6} annual exceedance levels (blue, red, and green, respectively. These curves were then smoothed to obtain the spectra shown above (Ref. SSAR Revision 3, Figure 2.5.2-76).

2.5.2.2.5 Seismic Wave Transmission Characteristics of the Site

SSAR Section 2.5.2.5 describes the applicant's development of a site-specific seismic velocity model to address seismic wave transmission characteristics at the PSEG Site. The EPRI (2004) ground motion prediction models are representative of vibratory ground motion at hard rock sites, which are characterized as sites with seismic shear wave velocities of about 2.8 km/s (9,200 fps). For the PSEG Site, these hard rock conditions exist at a depth of approximately 550 m (1,800 ft) beneath the ground surface; while rock of lower velocities exists in the upper 550 m (1,800 ft). The applicant conducted a site response analysis to determine the impacts of the lower velocity rocks on the calculated seismic hazard values. The applicant first developed a site response model and then used the random vibration theory (RVT) methodology to calculate the site amplification functions to transfer the generic hard rock hazard

curves to the GMRS elevation. The following sections summarize the applicant's site response calculation procedures.

2.5.2.2.5.1 Site Response Model.

The applicant developed a site-specific mean V_S profile for the upper 550 m (1800 ft) of the PSEG Site. Below this depth, the applicant determined that rocks with shear wave velocities of at least 2,800 m/s (9,200 ft/s) exist. The mean V_S profile is based on the results of four compression (P) and shear (S) wave P-S suspension logging surveys ranging to a depth of approximately 91 to 192 m (300 to 630 ft), two crosshole velocity testing boreholes extending to a depth of approximately 61 m (200 ft), one down-hole seismic velocity measurement to a depth of approximately 61 m (200 ft), and one deep production well extending to the top of basement (at approximately 550 m (1800 ft)) located approximately 1 km (0.6 mi) from the center of the PSEG Site. The applicant divided its site-specific V_S profile into a shallow profile from the surface to approximately 122 m (400 ft) and a deep profile from 122 m (400 ft) to basement. The shallow profile represents the depth to which extensive characterization was performed. As provided In SSAR Section 2.5.4.5, the applicant determined that the top of the competent layer has a mean depth of 20 m (67 ft), so following RG 1.208, the applicant only used the soil properties above this depth for the purposes of confining stress. The applicant will excavate to the competent layer elevation during construction. Figure 2.5.2-3 of this report shows the applicant's site-specific mean V_S profile and 60 alternative (randomized) profiles used in the site response calculations to be consistent with RG 1.208.

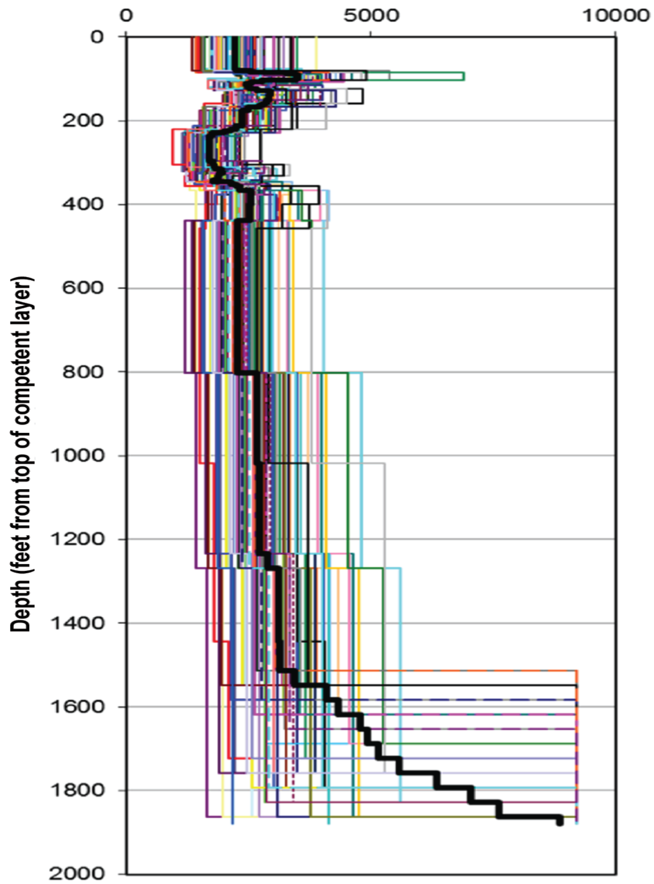


Figure 2.5.2-3 The log mean (black) and 60 randomized shear wave velocity (ft/s) profiles used in the site response calculations for the PSEG ESP Site (Ref. SSAR Revision 3, Figure 2.5.2-34)

2.5.2.2.5.2 <u>Site Response Methodology and Results</u>.

Consistent with RG 1.208, the applicant first generated 60 randomized site model profiles and associated shear moduli and damping parameters that represent possible departures from the base seismic model. Then the applicant calculated site response amplification functions for each randomized profile using the RVT methodology and used the rock UHRS at 10^{-4}, 10^{-5}, and 10^{-6} annual exceedance frequencies as the input ground motions in these analyses. The use of RVT in site response calculations is mentioned in RG 1.208 as a possible methodology that can be used. Similar to the time series methodology, RVT analysis produces an amplification function that is then applied to the rock spectra to obtain the response spectra defined at the ground surface (or at any intermediate point within the soil profile), which accounts for the effects of soil amplification (or deamplification) on the input base hard rock ground motion.

The applicant's site response calculations resulted in six median amplification functions for LF and HF input ground motions defined at the 10^{-4}, 10^{-5}, and 10^{-6} annual exceedance frequencies. Figure 2.5.2-4 of this report shows the amplification functions for low-frequency ground motions.

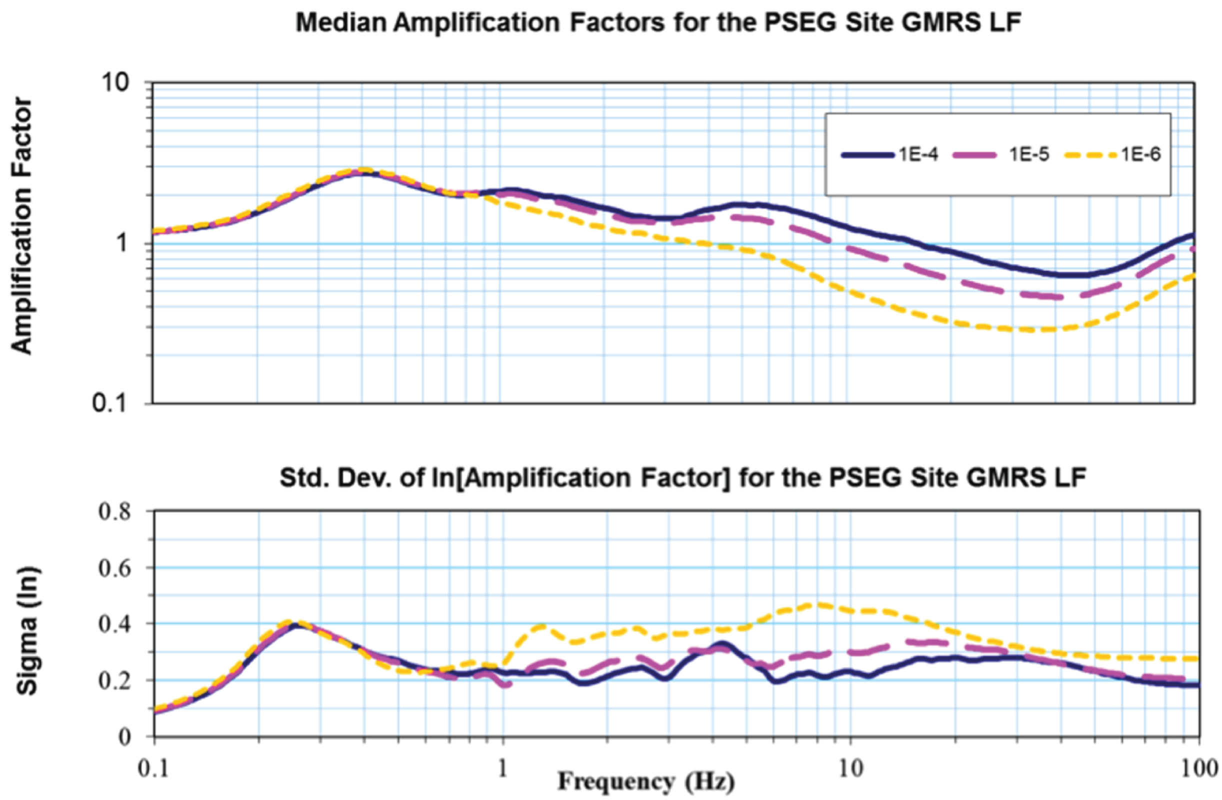


Figure 2.5.2-4 LF site median amplification functions for 10-4 (blue), 10-5 (dashed purple), and 10-6 (dashed yellow) annual exceedance frequencies (top) and the standard deviations for the same annual exceedance frequencies (below) (Ref. SSAR Revision 3, Figure 2.5.2-43)

2.5.2.2.6 Ground Motion Response Spectra

SSAR Section 2.5.2.6 describes the method used by the applicant to develop the horizontal and vertical site-specific GMRS. The applicant first developed the horizontal GMRS and then obtained the vertical GMRS using vertical-to-horizontal (V/H) ratios. The applicant stated that it did not use the Cumulative Absolute Velocity (CAV) model in its final hazard calculation.

2.5.2.2.6.1 Horizontal GMRS.

The applicant calculated a horizontal, site-specific, performance-based GMRS using the method described in RG 1.208. The performance-based method achieves the annual target performance goal (P_F) of 10^{-5} per year for frequency of onset of significant inelastic deformation. This damage state represents a minimum structural damage state, or essentially elastic behavior, and falls well short of the damage state that would interfere with functionality.
The GMRS is calculated using the following relationship.

GMRS = UHRS * DF

where

UHRS = Mean 10^{-4} UHRS
DF = max {1.0, 0.6 $(A_R)^{0.8}$}
A_R = 1E-05 UHRS / 1E-04 UHRS

RG 1.208 also states, if A_R, as defined above, is greater than 4.2, then this relationship is no longer valid. In this case, RG 1.208 recommends setting the GMRS to 45 percent of the 10^{-5} site-specific surface UHRS curve. Figure 2.5.2-5 of this report shows the horizontal GMRS curve calculated for the PSEG Site.

2.5.2.2.6.2 Vertical GMRS.

In SSAR Section 2.5.2.6.1.2, the applicant calculated the vertical GMRS by deriving frequency-dependent V/H spectral ratios and applying them to the horizontal GMRS. The applicant used three alternative methodologies to estimate V/H ratios. First, the applicant used the V/H ratio function defined in NUREG/CR-6728 for PGA values between 0.2g and 0.5g for the PSEG Site. Then, the applicant obtained two other V/H ratios estimated from empirical studies. The applicant determined a V/H ratio function by enveloping all three alternative V/H ratio values. The PSEG vertical GMRS was then computed by multiplying the horizontal GMRS by the V/H ratio function. The resulting vertical GMRS is shown in Figure 2.5.2-5 of this report.

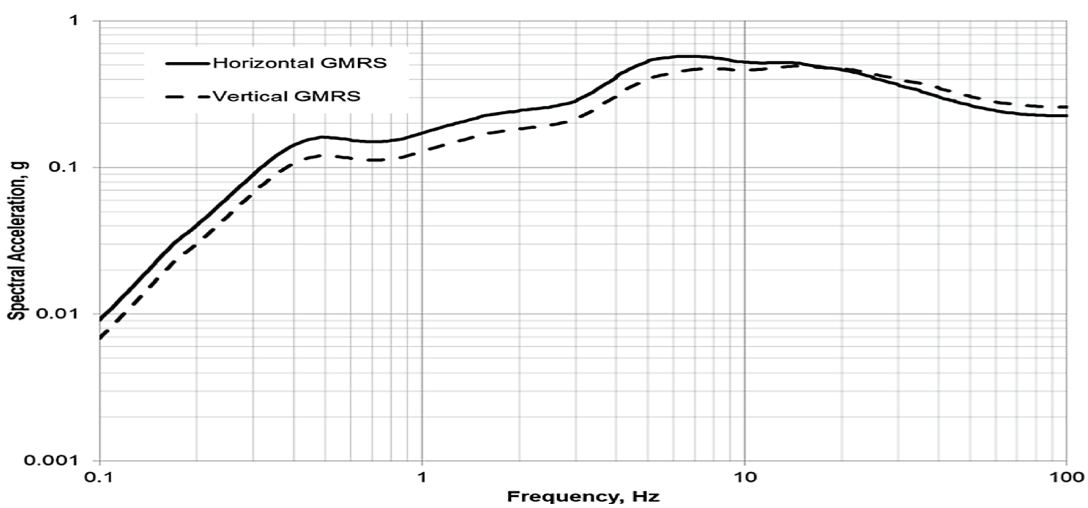


Figure 2.5.2-5 Horizontal (solid line) and vertical (dashed line) GMRS (Ref. SSAR Revision 3, Figure 2.5.2-54)

2.5.2.3 Regulatory Basis

The applicable regulatory requirements for reviewing the applicant's discussion of vibratory ground motion are as follows:

- 10 CFR 100.23, as it relates to obtaining geologic and seismic information necessary to determine site suitability and ascertain that any new information derived from site-specific investigations does not impact the GMRS derived by a probabilistic seismic hazard analysis.

- 10 CFR 52.17(a)(1)(vi), as it relates to consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity and period of time in which the historical data have been accumulated.

In addition, the related acceptance criteria from NUREG-0800, Section 2.5.2 are summarized as follows:

- Seismicity: To meet the requirements in 10 CFR 100.23, this section is accepted when the complete historical record of earthquakes in the region is listed and when all available parameters are given for each earthquake in the historical record.

- Geologic and Tectonic Characteristics of Site and Region: Seismic sources are identified and characterized.

- Correlation of Earthquake Activity with Seismic Sources: To meet the requirements in 10 CFR 100.23, acceptance of this section is based on the development of the relationship between the history of earthquake activity and seismic sources of a region.

- Probabilistic Seismic Hazard Analysis and Controlling Earthquakes: For CEUS sites relying on NUREG-2115 methods and data bases, the staff will review the applicant's PSHA, including the underlying assumptions and how the results of the site investigations are used to update the existing sources in the PSHA, how they are used to develop additional sources, or how they are used to develop a new data base.

- Seismic Wave Transmission Characteristics of the Site: In the PSHA procedure described in RG 1.208, the controlling earthquakes are determined for generic rock conditions.

- Ground Motion Response Spectra: In this section, the staff reviews the applicant's procedure to determine the GMRS. In addition, the geologic and seismic characteristics should be consistent with appropriate sections from: RG 1.60, “Design Response Spectra for Seismic Design of Nuclear Power Plants”; RG 1.132; RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition)”; and RG 1.208.

2.5.2.4 Technical Evaluation

The staff reviewed SSAR Section 2.5.2 to verify that the information represented the complete scope of information relating to this review topic. The staff’s review confirmed that the PSEG ESP application addresses the required information related to the vibratory ground motion.

Section 2.5.2.4 of this report provides the staff’s evaluation of the seismic, geologic, geophysical, and geotechnical investigations carried out by the applicant to determine the site-specific GMRS leading to the estimation of the SSE ground motion for the PSEG Site. The development of the GMRS is based upon a detailed evaluation of earthquake potential, taking into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the PSEG Site subsurface material.

On January 22, 2009, during the early site investigation stage, the staff visited the site and interacted with the applicant regarding the geologic, seismic, and geotechnical investigations conducted for the ESP application. The staff made an additional visit to the PSEG Site in September 2011, to confirm interpretations, assumptions, and conclusions presented by the

applicant related to potential geologic and seismic hazards. As discussed at the beginning of, this report (Section 2.5, "Geology, Seismology, and Geotechnical Engineering"), the staff issued several RAIs to the applicant and evaluated the responses received during the review process. However, following the Fukushima accident in Japan in March 2011, and the subsequent NRC Near-Term Task Force (NTTF) recommendations as well as the NRC March 12, 2012, letter, "Request for information pursuant to Title 10 of the *Code of Federal Regulations* 50.54(f) regarding recommendations 2.1, 2.3, and 9.3 of the near-term task force review of insights from the Fukushima Dai-ichi accident," (ADAMS Accession No. ML12053A340) requesting the operating nuclear power plants to re-assess seismic hazards at their sites using the most recent seismic source models, the staff issued an RAI to all COL and ESP applicants (RAI 61, Question 02.05.02-10 was issued to PSEG) to reassess the seismic hazard at their sites using the new seismic source models. In its December 20, 2012 and January 11, 2013, responses, the applicant revised the SSAR significantly, especially, SSAR Section 2.5.2 related to seismic hazard calculations. As part of this SSAR revision, the applicant replaced the EPRI (1986) seismic source models previously used in the seismic hazard calculations at the site with the newly published NUREG-2115 CEUS-SSC model. With this change in the base seismic source model, many of the earlier RAIs became irrelevant and were closed. The staff's evaluations of many of these earlier RAIs are not part of this report. However, a few of the original RAIs are still applicable to the staff's review and these are discussed below along with the new RAIs that the staff developed in response to the revised SSAR.

2.5.2.4.1   Seismicity

SSAR Section 2.5.2.1 states that the earthquake catalog used for the PSEG Site seismic hazard assessment is the NUREG-2115 earthquake catalog. The earthquake catalog published as part of the NUREG-2115 seismic source model covers the entire CEUS region from 1568 through 2008 and includes a uniform moment magnitude scale for all earthquakes listed in the catalog. Since the staff reviewed the NUREG-2115 earthquake catalog previously, the staff's technical evaluation of SSAR Section 2.5.2.1 focused on the applicant's efforts to update the NUREG-2115 earthquake catalog for use in the PSEG Site PSHA. Since the NUREG-2115 earthquake catalog covers the seismicity in the region through 2008, the applicant provided a quantitative analysis of earthquakes occurring within 320 km (200 mi) of the site from 2009 through 2011 in the SSAR. In addition to documenting the seismic activity within the site region, the earthquake catalog also provides critical data to assess seismic source model parameters used in the PSEG PSHA study. Seismic source model parameters, such as M_{max} and earthquake recurrence rates, are primarily determined based on information available in the earthquake catalog.

As part of its confirmatory analysis, the staff developed a supplementary earthquake catalog covering the CEUS region from 2009 through October 15, 2013. The staff used this earthquake catalog to confirm the applicant's updated catalog and to determine whether there are new earthquakes in the CEUS region since the submission of the PSEG ESP application that might impact either the maximum magnitude distribution of the seismic sources identified in the NUREG-2115 model or the earthquake recurrence rates calculated for each of the seismic sources used in the PSEG Site PSHA study. The staff used the United States Geological Survey (USGS) Advanced National Seismic Network earthquake catalog (ANSS)[2] for this analysis. The staff searched for earthquakes with magnitudes 3.0 and above within the time

[2] Advanced National Seismic System (ANSS), ANSS Catalog Search, http://www.ncedc.org/anss/catalog-search.html.

window covering 2009 through October 15, 2013, throughout the CEUS as defined by NUREG-2115. The staff's supplementary earthquake catalog confirmed that the applicant adequately updated its catalog from 2009 through 2011. In addition, the staff's catalog showed that there are 173 earthquakes in the CEUS region (Figure 2.5.2-6 of this report) that occurred between 2012 and October 15, 2013. None of these earthquakes have moment magnitudes (**M**) equal to or greater than **M**5.0. The staff identified 15 earthquakes in the range between **M**4.0 and 4.9 distributed over the CEUS region. The majority of the earthquakes (158 of the 173) in the updated catalog are small magnitude earthquakes (**M** < 4.0). Therefore, the staff concludes from its confirmatory analysis that the earthquakes in the staff's supplementary catalog are located within identified active CEUS seismic regions and do not add any new information to the catalog used by the applicant.

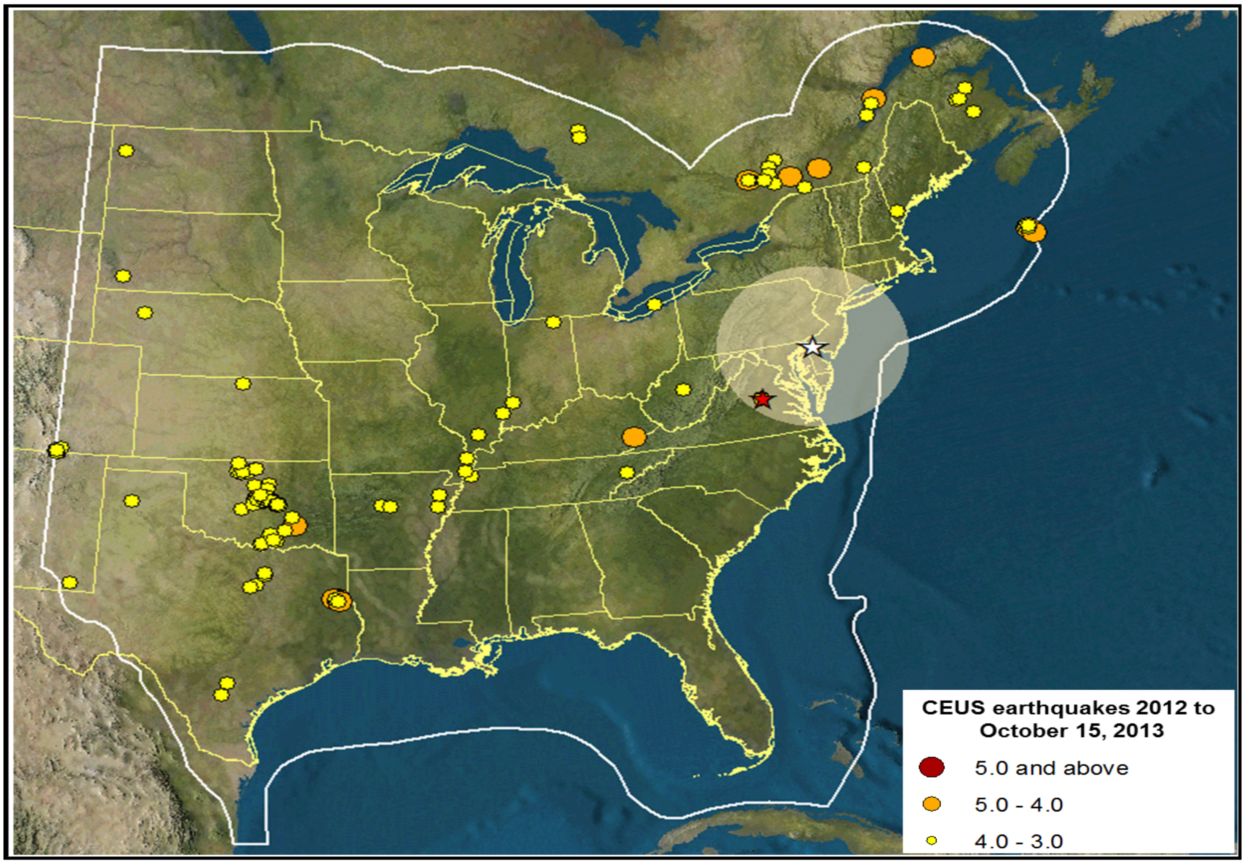


Figure 2.5.2-6 Earthquakes with moment magnitudes (M) equal to or greater than 3.0 in the CEUS between 2012 and October 15, 2013. The white star is the PSEG Site location, the beige circle is the 320 km (200 mi) site radius, and the red star is the location of the August 23, 2011, M5.8 Mineral, VA earthquake.

Staff Conclusions Regarding Seismicity

Based upon its review of the applicant's SSAR Section 2.5.2.1 and the staff's supplemental seismicity catalog, the staff concludes that the applicant developed a complete and accurate earthquake catalog for the region surrounding the PSEG Site. The staff concludes that the seismicity catalog as described by the applicant in SSAR Section 2.5.2.1 forms an adequate

basis for the seismic hazard characterization of the site and meets the requirements of 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.23.

2.5.2.4.2 Geologic and Tectonic Characteristics of the Site and Region

SSAR Section 2.5.2.2 describes the seismic sources and seismicity parameters used by the applicant to calculate the seismic ground motion hazard for the PSEG Site. Specifically, the applicant described the seismic source model published as part of NUREG-2115 in 2012. The staff previously reviewed the NUREG-2115 seismic source model and approved its use as a starting regional model for nuclear power plant applications. However, the NUREG-2115 model is a regional model and NUREG-2115 specifically states that it should be compared against the local data and information, and if needed, appropriate local adjustments must be conducted. As such, the staff primarily focused on the applicant's investigation of potential local seismic source and source parameter adjustments to the NUREG-2115 model.

2.5.2.4.2.1 Modifications to NUREG-2115 model due to updated earthquake catalog.

The applicant's updated earthquake catalog identified nine moderate-sized earthquakes ranging from **M**4.5 to 5.8 within the 320 km (200 mi) site region. The most significant earthquake identified is the Mineral, VA, earthquake with a moment magnitude of **M**5.8 that occurred on August 23, 2011, and was located approximately 270 km (170 mi) southwest of the PSEG Site. All new earthquakes in the region had magnitudes lower than the seismic sources' assigned maximum magnitudes and the applicant concluded that these updated earthquakes did not impact the NUREG-2115 seismic source model parameters.

However, due to the large magnitude of the **M**5.8 Mineral, VA earthquake, the staff inquired further and issued to the applicant two RAIs regarding the impact of the 2011, Mineral, VA earthquake on the PSEG Site seismic hazard analysis. Specifically, in RAI 71, Question 02.05.02-11, the staff requested that the applicant assess the impact of the 2011, Mineral, VA earthquake on the PSEG Site seismic hazard analysis regarding potential changes in earthquake recurrence rates in the vicinity of the earthquake's hypocenter, and their potential impacts on the site's calculated hazard. In an August 29, 2013, response to RAI 71, Question 02.05.02-11, the applicant performed sensitivity calculations to demonstrate that using updated earthquake recurrence rate parameters, to include the **M**5.8 Mineral, VA earthquake, had no significant effect on the seismic hazard at the PSEG Site. The applicant performed the sensitivity calculations using the four NUREG-2115 seismic source zones (ECC-AM, MESE-N, MESE-W and STUDY-R) that host the **M**5.8 Mineral, VA earthquake. The applicant compared calculations of the mean annual earthquake recurrence rate per degrees squared (for magnitudes greater than 5) and the b-values for the three NUREG-2115 magnitude weighting cases for the four source zones. The applicant concluded that trends in b-values and recurrence rates in the comparisons showed little difference around the **M**5.8 Mineral, VA earthquake. Additionally, the applicant compared its original calculations of mean background hazard and mean total hazard at the PSEG Site for 1, 10, and 100 Hz (PGA) with those calculations including the **M**5.8 Mineral, VA earthquake. In the August 29, 2013, response to RAI 71, Question 02.05.02-11, the applicant stated:

> The results from this sensitivity analysis show that the change in total mean background and total mean site hazard at the PSEG Site, when the four largest contributing background sources are re-run using updated earthquake recurrence parameters, is minimal. The largest differences in total mean

background hazard and total mean site hazard are 1.4% and 0.9%, respectively, indicating that the percent difference is within the levels of precision.

Based on the staff's review of the applicant's assessment of the **M**5.8 Mineral, VA earthquake in the SSAR and in its August 29, 2013, response to RAI 71, Question 02.05.02-11, the staff concludes that the effect of the **M**5.8 Mineral, VA earthquake on the mean background hazard and the total mean site hazard at the PSEG Site is negligible and that the applicant's use of the original CEUS-SSC model earthquake recurrence parameters is acceptable. Accordingly, the staff considers RAI 71, Question 02.05.02-11 resolved.

2.5.2.4.2.2 Modifications to NUREG-2115 seismic source model.

NUREG-2115, Chapter 9, "Use of the CEUS-SSC Model in PSHA", details a few model simplification tests that applicants may implement when using NUREG-2115 CEUS-SSC model. However, NUREG-2115 also states that site-specific sensitivity studies should be conducted to confirm that such simplifications are appropriate for use at specific sites. Therefore, in RAI 71, Question 02.05.02-12, the staff requested that the applicant describe any implemented model simplifications used for the PSEG seismic hazard analysis and to provide justification for using those simplifications. In an August 27, 2013, response to RAI 71, Question 02.05.02-12, the applicant stated it implemented the full CEUS-SSC model without simplifications to the RLME seismic source parameters and that it implemented one simplification in modeling the background sources. The simplification applied to the background sources was to apply the point source model as described in NUREG-2115, Section 9.3.1.11, instead of the finite rupture mode that used multiple fault orientations, dips, and crustal thicknesses. The applicant performed sensitivity calculations and compared the hazard from using the simplified point source model for background sources in the PSHA analysis to the hazard from using the finite rupture model. Table 2.5.2-2 of this report shows the applicant's comparison at 1 Hz, 10 Hz, and PGA for the four largest contributing background sources at the PSEG Site. For ground motions with a frequency of exceedance of 10^{-4}, the difference in hazard is ≤ 3.5 percent. For ground motions with a frequency of exceedance of 10^{-5}, the difference in hazard is < 10 percent with the exception of the ECC-AM source. For the ECC-AM source at 10^{-5}, the difference 10-15 percent. The staff notes that the results shown in Table 2.5.2-2 of this report are for individual seismic sources' contributions, and the overall percentage increases in the total seismic hazard values at the site will be lower. Further, for the GMRS calculations 10^{-4} and 10^{-5} annual frequency of exceedances are the key levels of interest. Therefore, the staff considers the differences calculated in this sensitivity study to be within the uncertainty in the overall PSHA calculations. Accordingly, the staff considers RAI 71, Question 02.05.02-12, resolved.

Table 2.5.2-2 Percent difference between the point source and finite rupture model for the four largest contributing background sources at the PSEG Site (Response to RAI 71, Question 02.05.02-12, Table RAI 71-12-5)

ECC-AM		
Frequency	AFE	% Difference
1 Hz	10^{-4}	2.7%
	10^{-5}	10.4%
	10^{-6}	27.2%
10 Hz	10^{-4}	3.5%
	10^{-5}	13.7%
	10^{-6}	33.9%
PGA	10^{-4}	3.5%
	10^{-5}	14.7%
	10^{-6}	37.9%

STUDY-R		
Frequency	AFE	% Difference
1 Hz	10^{-4}	0.6%
	10^{-5}	5.1%
	10^{-6}	16.3%
10 Hz	10^{-4}	1.4%
	10^{-5}	7.0%
	10^{-6}	22.1%
PGA	10^{-4}	1.4%
	10^{-5}	6.4%
	10^{-6}	24.3%

MESE-N		
Frequency	AFE	% Difference
1 Hz	10^{-4}	0.7%
	10^{-5}	5.4%
	10^{-6}	17.2%
10 Hz	10^{-4}	1.5%
	10^{-5}	7.4%
	10^{-6}	22.9%
PGA	10^{-4}	1.5%
	10^{-5}	6.4%
	10^{-6}	25.4%

MESE-W		
Frequency	AFE	% Difference
1 Hz	10^{-4}	-0.3%
	10^{-5}	2.3%
	10^{-6}	9.5%
10 Hz	10^{-4}	0.1%
	10^{-5}	3.4%
	10^{-6}	12.8%
PGA	10^{-4}	0.1%
	10^{-5}	3.3%
	10^{-6}	13.7%

2.5.2.4.2.3 Staff Conclusions Regarding Geologic and Tectonic Characteristics of the Site and Region.

Based upon its review of SSAR Sections 2.5.2.2 and 2.5.2.4 and the applicant's responses to RAI 71, Questions 02.05.02-11 and 02.05.01-12, the staff concludes that the applicant adequately assessed the NUREG-2115 seismic sources as the input to its PSHA for the PSEG Site. In addition, the staff concludes that the applicant adequately considered modifications to the NUREG-2115 seismic sources for the PSEG Site. The staff concludes that the applicant's use of NUREG-2115 seismic source models as described by the applicant in SSAR Sections 2.5.2.2 and 2.5.2.4 forms an adequate basis for the seismic hazard characterization of the site and meets the requirements of 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.23.

2.5.2.4.3 Correlation of Earthquake Activity with Seismic Sources

SSAR Section 2.5.2.3 describes the correlation of seismicity in the region with the seismic source model used in the PSEG PSHA study. The applicant noted that the NUREG-2115 model uses earthquake locations and characteristics in defining the seismic source geometries. The applicant compared the NUREG-2115 seismicity catalog and the applicant's updated

catalog to assess any changes in the patterns of seismicity or if there exists any correlation between geologic structures and seismicity not identified within the CEUS-SSC study that needs to be accounted for at the PSEG Site. Based on the applicant's assessment, the staff's updated seismicity catalog, the staff's confirmatory analysis described in Section 2.5.2.4.1 of this report, and the applicant's August 29, 2013, response to RAI 71, Question 02.05.02-11 described in Section 2.5.2.4.2 of this report, the staff concludes that the applicant's characterization of the correlation of earthquake activity is adequate.

2.5.2.4.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

In SSAR Section 2.5.2.4, the applicant stated that it used the NUREG-2115 seismic model in the probabilistic seismic hazard calculations at the PSEG Site and the procedures outlined therein. Using the NUREG-2115 CEUS-SSC model sources, the applicant's additional AHEX-E source (described in Section 2.5.2.4.4.1 of this report), and the EPRI (2004 and 2006) GMPEs, the applicant calculated generic hard rock seismic hazard curves at the seven frequencies defined by the EPRI (2004, and 2006) GMPEs. Using the hard rock seismic hazard curves, the applicant obtained uniform hazard response spectra at the annual frequency of exceedances of 10^{-4}, 10^{-5}, and 10^{-6}. Using the procedures outlined in RG 1.208, the applicant also developed the controlling earthquakes' magnitudes and distances. The following describes the staff's assessment of the applicant's PSHA calculations and the determination of the controlling earthquakes and their parameters.

2.5.2.4.4.1 PSHA Inputs.

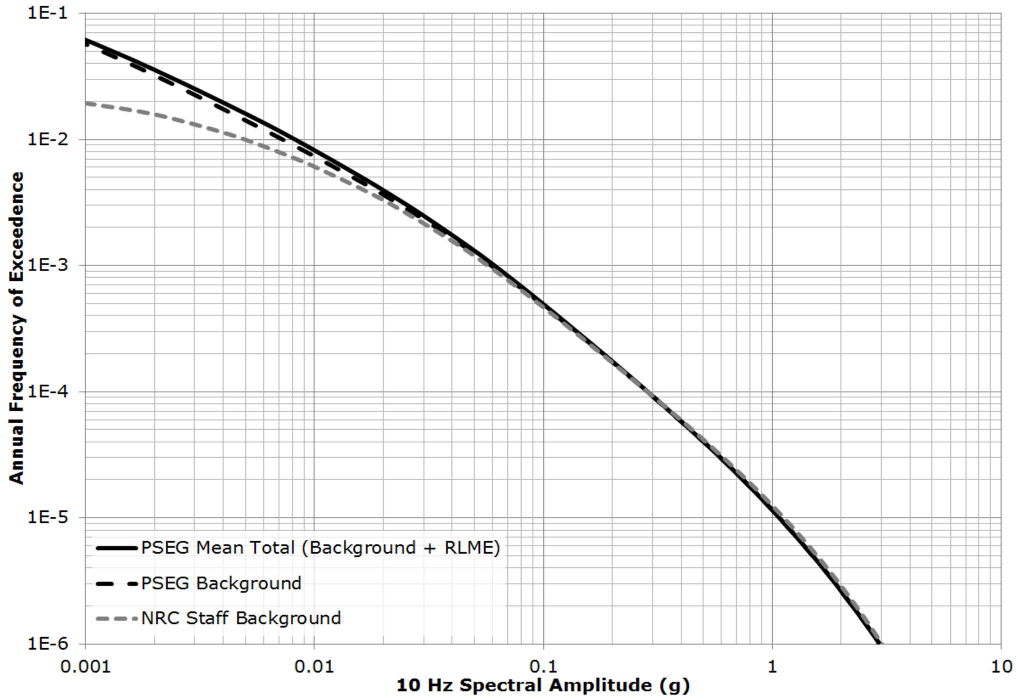
As described in Section 2.5.2.2.4 of this report, the applicant implemented the entire NUREG-2115 model with no modifications and with one addition. Since the NUREG-2115 model does not cover the 320 km (200 mi) PSEG Site region, the applicant developed a small regional seismic source to be added onto the NUREG-2115 model to cover the site area fully. The applicant named the source AHEX-E, as shown in Figure 2.5.2-1 of this report, and developed earthquake recurrence rates within this source using the same process utilized in the NUREG-2115 model. The staff evaluated this small new source developed by the applicant and concluded that because of very limited seismicity in this region, any potential contribution from this source is quite limited and there is no significant impact on the total seismic hazard calculations. With this small source addition, the applicant's PSHA inputs are consistent with RG 1.208; therefore, the staff concludes that the applicant's PSHA inputs are adequate.

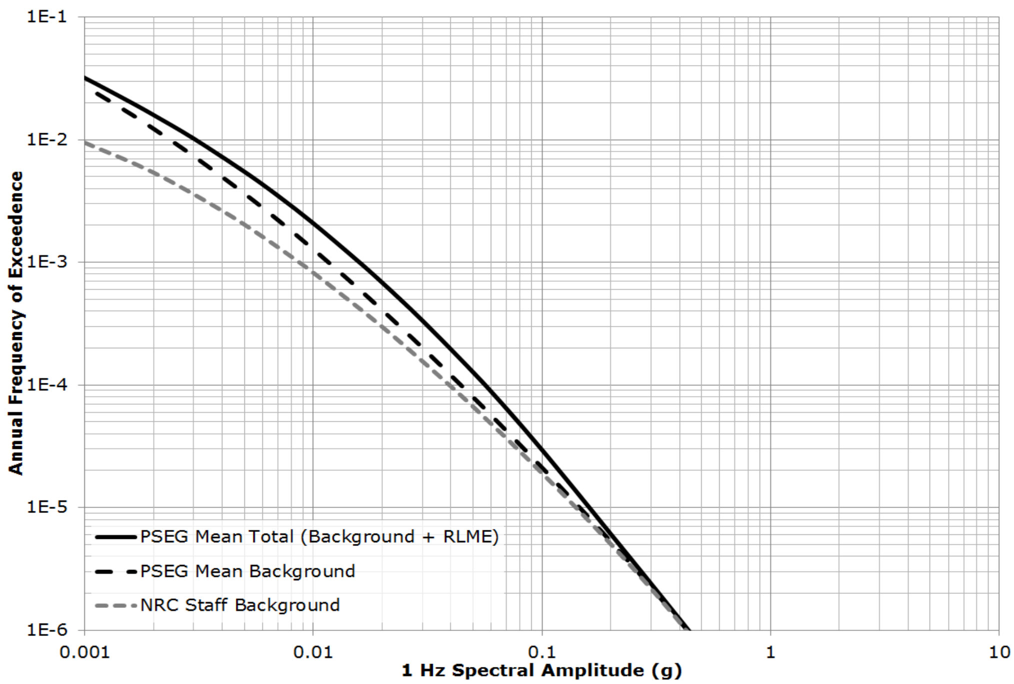
2.5.2.4.4.2 PSHA Calculation and Confirmatory Analysis.

Using the NUREG-2115 CEUS-SSC model, the applicant's additional AHEX-E source, and the EPRI (2004, 2006) GMPEs, the applicant performed PSHA calculations for PGA and ground motion frequencies of 25, 10, 5, 2.5, 1, and 0.5 Hz. As described in Section 2.5.2.4.2 of this report, the applicant implemented a simplification in the seismic hazard calculations of the background seismic sources used to determine total seismic hazard at the site. The applicant's simplification was to implement the point source model as described in NUREG-2115, Section 9.3.1.11, when calculating the hazard of background sources instead of the finite rupture model. As described in Section 2.5.2.4.2.2 of this report, the applicant's sensitivity study conducted in response to RAI 71, Question 02.05.02-12 clarified for the staff that the applicant's simplification was reasonable and would result in the adequate calculation of seismic hazard at the PSEG Site.

During the development of the applicant's response to RAI 61, Question 02.05.02-10, the staff conducted software audits to distinct seismic hazard calculation software being used by the industry to respond to the NTTF Recommendation 2.1 seismic RAIs submitted to all COL and ESP applicants. The purpose of these audits was to review seismic hazard software and examine the implementation of the new seismic source models described in NUREG-2115. The objective was to gain in-depth understanding of the seismic software being used and review the implementation of the new seismic source model into the existing codes. The applicant contracted Fugro Consultants, Inc. (Fugro), to perform its seismic hazard calculations. The Fugro software audit took place on September 25 and 26, 2012. The staff's software audit summary is available in ADAMS Accession No. ML12311A341. During the software audit, the staff reviewed software runs and reviewed several quality assurance documents related to Fugro's seismic hazard code.

As part of its confirmatory analysis, the staff used the NUREG-2115 CEUS-SSC model background (distributed seismicity) sources and independently calculated the seismic hazard curves at the PSEG Site for all seven ground motion frequencies defined in the EPRI (2004, 2006) ground motion prediction models. The staff's confirmatory calculations did not include the RLME sources. These sources exist at distances beyond 800 km (500 mi) from the PSEG Site and are expected to contribute only at low frequencies such as 0.5 and 1 Hz. From the NUREG-2115 seismic source model, the staff first selected all background seismic sources that are within the 320 km (200 mi) the site region. For those seismic sources which are partly within the 320 km (200 mi) site region, but with boundaries extending beyond the site region, the staff used a distance cut off of 500 km (312 mi). Beyond that distance, their hazard contributions will be negligible. Figure 2.5.2-7 of this report shows the staff's results as compared to the applicant's for PGA and ground motion frequencies of 10 and 1 Hz. The staff's confirmatory calculations show that for the annual frequency of exceedances of 10^{-4}, 10^{-5}, and 10^{-6}, the staff's seismic hazard curves are in good agreement with the applicant's background seismic hazard curves. The difference observed between the background seismic source hazard curves and the total seismic hazard curve at 1Hz shown in Figure 2.5.2-7 of this report is attributed to the contribution of the RLME seismic sources at large distances. As shown in SSAR Figures 2.5.2-25 through 2.5.2-30, at low frequencies, such as 2.5, 1, and 0.5 Hz, distant RLME sources contribute to the hazard at the site. In contrast, at high frequencies only local sources contribute to the hazard. Based on this analysis, the staff concludes the applicant adequately characterized the mean seismic hazard at the PSEG Site.


1E-1
1E-2
1E-3
1E-4
1E-5
1E-6
Annual Frequency of Exceedence
0.001
0.01
0.1
1
10
10 Hz Spectral Amplitude (g)
PSEG Mean Total (Background + RLME)
PSEG Background
NRC Staff Background


1E-1
1E-2
1E-3
1E-4
1E-5
1E-6
Annual Frequency of Exceedence
0.001
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1 Hz Spectral Amplitude (g)
PSEG Mean Total (Background + RLME)
PSEG Mean Background
NRC Staff Background

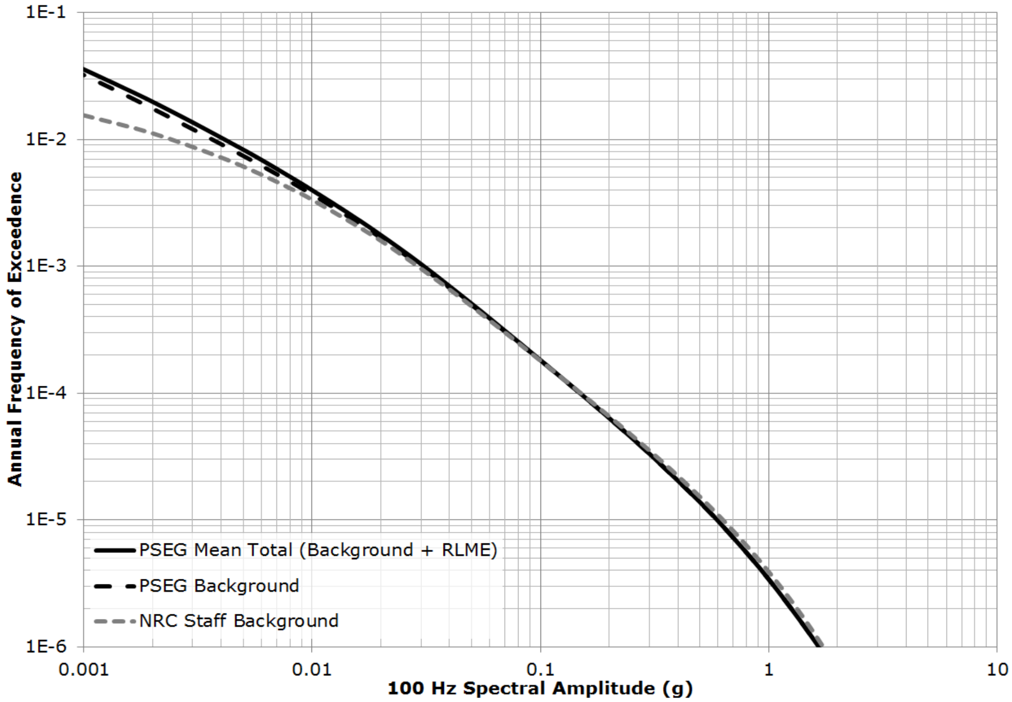

Figure 2.5.2-7 Staff confirmatory analysis of PSHA calculations for PGA (100 Hz) and ground motion frequencies of 10 and 1 Hz. The solid black lines represent the applicant's mean total hazard with contributions from both background and RLME sources. The black dashed lines represent the applicant's mean hazard from background sources only. The gray dashed lines represent the staff's confirmatory calculation of the contributions to hazard from the background sources out to 500 km (310 mi).

2.5.2.4.4.3 Controlling earthquakes.

To determine the low- and high-frequency controlling earthquakes' magnitudes and distances, the applicant used a procedure called deaggregation of the seismic hazard. The applicant followed the deaggregation procedures outlined in RG 1.208, Appendix D. The deaggregation results showed that local seismic sources within 30 km (18 mi) of the PSEG Site are the primary contributors to the high-frequency seismic hazard at the site, while the RLME sources as well as regional sources were contributors to the low-frequency seismic hazard at the PSEG Site. Table 2.5.2-1 of this report shows the applicant's deaggregation results for the mean 10^{-4}, 10^{-5}, and 10^{-6} PSHA results. The applicant calculated the controlling earthquakes for three different cases: Overall hazard; hazard from earthquakes located less than 100 km (62 mi) away; and hazard from earthquakes located beyond 100 km (62 mi). As shown in the deaggregation, Table 2.5.2-1 of this report, for the high-frequency hazard, the controlling earthquakes are those with magnitudes about **M**6 occurring at short distances. For the low frequency hazard, the controlling earthquakes are several hundred kilometers away with magnitudes greater than **M**6.5. The applicant selected the gray shaded values shown in Table 2.5.2-1 of this report as representative of the controlling earthquakes for the PSEG Site.

Since the applicant used the guidance outlined in RG 1.208 to determine the controlling earthquakes and their magnitudes and distances, the staff concludes that the procedures used by the applicant are adequate and the resultant controlling earthquake parameters are representative of the controlling earthquakes in this region.

2.5.2.4.4.4 Staff Conclusions Regarding PSHA and Controlling Earthquakes.

After its review of the applicant's PSHA and controlling earthquake determination, the applicant's response to RAI 71, Question 02.05.02-12, the staff's confirmatory calculations, and the staff's review of the code used by PSEG during the software audit, the staff concludes that the applicant's PSHA adequately characterizes the seismic hazard for the PSEG Site and that the controlling and deaggregation earthquakes determined by the applicant are representative of earthquakes that would be expected to contribute the most to the hazard.

2.5.2.4.5 Seismic Wave Transmission Characteristics of the Site

SSAR Section 2.5.2.5 describes the method used by the applicant to develop the PSEG Site free-field soil UHRS. The seismic hazard curves calculated by the applicant are defined for generic hard rock conditions characterized by a shear wave (S-wave) velocity of at least 2.8 km/s (9,200 ft/s). The applicant stated that these hard rock conditions exist at a depth of approximately 550 m (1,800 ft) below the ground surface at the PSEG Site. To determine the impact of the soil column between the hard rock and the surface, the applicant performed a site response analysis. The output of the applicant's site response analysis are the site amplitude functions, which are then used to determine the soil UHRS at three hazard levels (10^{-4}, 10^{-5}, and 10^{-6} annual frequency of exceedances).

2.5.2.4.5.1 Site Response Inputs and Methodology.

In SSAR Sections 2.5.4.2, 2.5.4.4 and 2.5.4.7, the applicant summarized the low strain S-wave velocity, material damping, and strain-dependent properties of the base case soil and rock profile, which the applicant used as the input model to its site response calculations. The applicant stated that the upper portion of the profile of the PSEG Site subsurface was investigated using test borings, and geophysical methods. For the deeper sedimentary rocks, the applicant obtained the information from nearby wells and geological data sets.

The applicant used the RVT methodology to calculate the site response amplification function at the PSEG Site. The use of RVT in site response calculations is mentioned in RG 1.208 as an acceptable alternative to the time series approach. RG 1.208 specifically states, "…, RVT methods are acceptable as long as the strain dependent soil properties are adequately accounted for in the analysis." Following RG 1.208, the staff focused its review on the input parameters used in the site response calculations. Inputs to the RVT method include response spectra which are based on the hard rock UHRS, 60 randomized soil profiles, effective strain ratio, and strong motion duration. The applicant estimated the strong-motion durations to be used in the site response calculations using the mean magnitudes and distances from the ESP site's controlling earthquakes and the relationship provided in Rathje and Ozbey (2006). The staff's sensitivity studies indicated that site response amplification functions are not overly sensitive to the duration value as long as the value used is within a certain expected range. Having reviewed the applicant's duration values, the staff concludes that the applicant's selection of duration values is adequate for site response calculations at the PSEG Site.

The applicant stated that it calculated the effective strain ratios using the formulation provided in Idriss (1992) and confirmed the resultant values with the possible range of values determined by empirical calculations described in Kramer (1996). The staff confirmed these values and concludes that the input effective strain ratios determined by the applicant are within the acceptable values commonly used by the engineering community.

2.5.2.4.5.2 NRC Site Response Confirmatory Analysis.

To determine the adequacy of the applicant's site response calculations, the staff performed its own confirmatory site response calculations. As input, the staff used the static and dynamic soil properties provided in SSAR Section 2.5.4. To represent the input rock motions, the staff used the applicant's low- and high-frequency 10^{-5} rock spectra. The staff performed its site response calculations using the Strata software (Kottke and Rathje 2008). The staff's site amplification function results are compared with the applicant's results in Figure 2.5.2-8 of this report, which shows that the staff's calculation is similar to the applicant's site amplification factor across the frequency range typically important for engineering purposes (i.e., 0.5 to 10 Hz) and they are within the limits of uncertainties expected from these calculations. Based on this assessment, the staff concludes that the applicant's site response calculations adequately characterize the site effects at the PSEG Site.

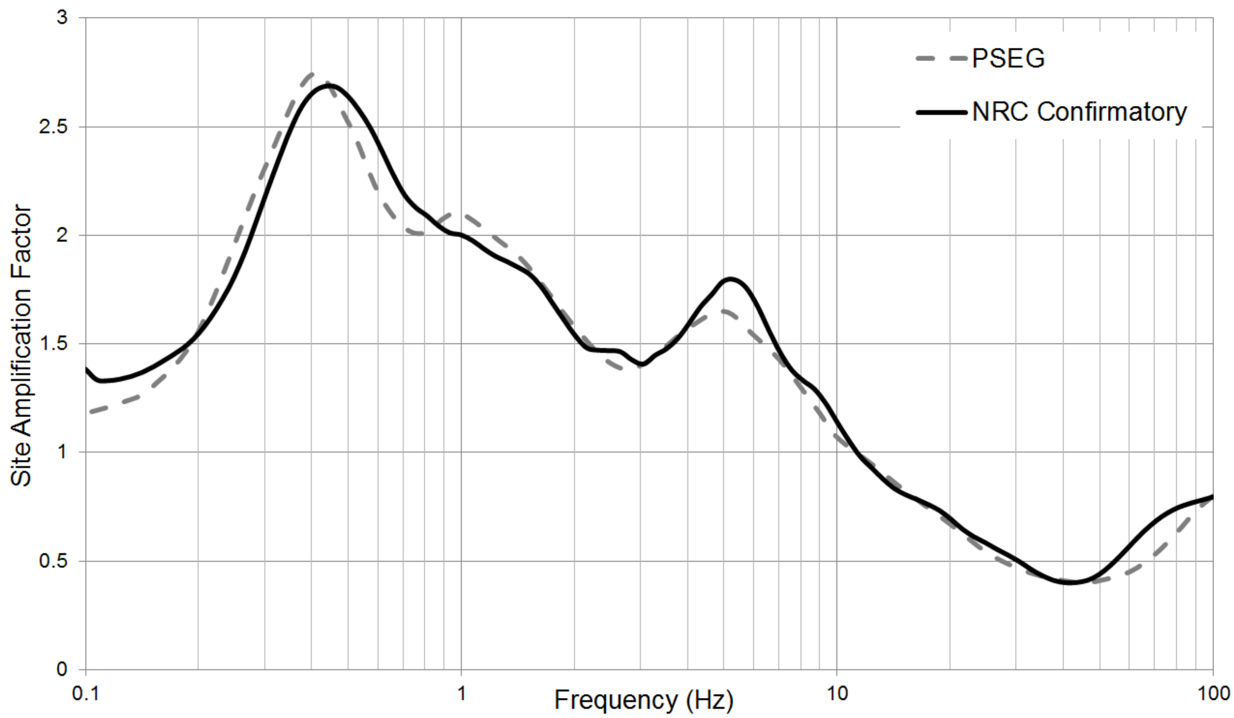

Figure 2.5.2-8 Comparisons of the staff's site response amplification function with the amplification function determined by the PSEG applicant for the 10-5 annual frequency of exceedance

2.5.2.4.5.3 Staff Conclusions Regarding Seismic Wave Transmission Characteristics of the Site.

The staff concludes that the applicant's site response methodology and results are acceptable since the applicant followed the general guidance provided in RG 1.208 in its site response calculations and used an adequate range of input parameters. The staff's confirmatory analysis also showed that the applicant's calculations are accurate.

2.5.2.4.6 Ground Motion Response Spectra

SSAR Section 2.5.2.6 describes the method used by the applicant to develop the horizontal and vertical, site-specific, GMRS. To obtain the horizontal GMRS, the applicant used the performance based approach described in RG 1.208 and American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) Standard 43 05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities." SSAR Section 2.5.2.6, states that the horizontal GMRS (for each spectral frequency), is obtained by scaling the 10^{-4} soil UHRS by the design factor specified in RG 1.208. The final GMRS is shown in Figure 2.5.2-5 of this report.

In SSAR Section 2.5.2.6.1.2, the applicant stated that it multiplied the horizontal GMRS by a frequency-dependent scaling factor in order to obtain the vertical GMRS. The applicant used the envelope of three V/H ratios calculated using three different methods as its final V/H ratio to calculate the vertical GMRS. Since the applicant used an accepted methodology presented in NUREG/CR-6728, Appendix J, along with two other methods, and enveloped the results to obtain a conservative result for its final V/H ratio function, the staff concludes that the applicant's V/H ratios are adequate for the use of the PSEG Site vertical GMRS.

Staff Conclusions Regarding Ground Motion Response Spectra

Since the applicant used the standard procedures outlined in RG 1.208 to calculate the final horizontal GMRS, and conservatively estimated the vertical GMRS, the staff concludes that the applicant's GMRS adequately represents the site ground motion and that the GMRS calculated meets the requirements of 10 CFR 100.23.

2.5.2.5 Conclusion

The staff reviewed the PSEG ESP application. The staff confirmed that the applicant addressed the required information relating to vibratory ground motion, and that there is no outstanding information expected to be addressed in the SSAR related to this subsection. Accordingly, the staff considers RAI 61, Question 02.05.02-10, which is the RAI issued after the NTTF recommendation following the Fukushima accident in Japan in March 2011, resolved.

As set forth above, the staff reviewed the seismic information submitted by the applicant in SSAR Section 2.5.2. On the basis of its review of SSAR Section 2.5.2, the staff finds that the applicant provided a thorough characterization of the seismic sources surrounding the site, as required by 10 CFR 100.23. In addition, the staff finds that the applicant adequately addressed the uncertainties inherent in the characterization of these seismic sources through a PSHA, and that this PSHA follows the guidance provided in RG 1.208. The staff concludes that the controlling earthquakes and associated ground motion derived from the applicant's PSHA are consistent with the seismogenic region surrounding the PSEG Site. In addition, the staff finds that the applicant's GMRS, which was developed using the performance-based approach, adequately represents the regional and local seismic hazards and accurately includes the effects of the local site subsurface properties. The staff concludes that the proposed ESP site is acceptable from a geologic and seismologic standpoint and meets the requirements of 10 CFR 100.23.

2.5.3 Surface Faulting

2.5.3.1 Introduction

SSAR, Section 2.5.3 evaluates the potential for tectonic and non-tectonic surface deformation at the PSEG Site. The applicant stated that SSAR Section 2.5.3 demonstrates compliance with regulatory requirements in 10 CFR 100.23 by providing information on the following topics: geologic, seismic, and geophysical investigations (SSAR Section 2.5.3.1); geologic evidence, or absence of evidence, for tectonic surface deformation (SSAR Section 2.5.3.2); correlation of earthquakes with capable tectonic sources (SSAR Section 2.5.3.3); ages of most recent deformations (SSAR Section 2.5.3.4); relationship of tectonic structures in the site area to regional tectonic structures (SSAR Section 2.5.3.5); characterization of capable tectonic sources (SSAR Section 2.5.3.6); designation of zones of Quaternary deformation in the site region (SSAR Section 2.5.3.7); and potential for tectonic surface deformation or non-tectonic deformation at the site (SSAR Section 2.5.3.8). Based on this information, the applicant concluded there are no faults within the site vicinity that can generate both tectonic surface deformation and vibratory ground motion, which the applicant indicated would represent a capable fault (i.e., a capable tectonic source) after the definition in RG 1.208, Appendix A. The applicant also concluded that no potential exists for non-tectonic surface deformation within the site vicinity or for tectonic or non-tectonic surface deformation in the site area or at the site location.

2.5.3.2 Summary of Application

The applicant developed SSAR Section 2.5.3 based on review of existing information in the following primary sources related to the potential for tectonic and non-tectonic surface deformation at the PSEG Site: Geologic maps of onshore and offshore areas published by the USGS, state geological surveys, and other researchers; literature published in journals and field trip guidebooks, with emphasis on materials published since the 1986 studies conducted by EPRI, including instrumental and historical seismicity data; reports on previous site investigations for the SGS (PSEG, 2007) and HCGS (PSEG, 2008), respectively; and the CEUS-SSC model presented in NUREG-2115. In addition to the review of this existing information, the applicant also performed the following activities to further assess the potential for tectonic and non-tectonic surface deformation within the site area: examination and interpretation of aerial photographs and remote sensing imagery, conduct of aerial and geologic field reconnaissance, and collection of subsurface data from boreholes. Sections 2.5.3.2.1 through 2.5.3.2.8 of this report summarize the information described by the applicant in the eight sections of SSAR, Section 2.5.3.

2.5.3.2.1 Geologic, Seismic and Geophysical Investigations

SSAR Section 2.5.3.1 discusses the geologic, seismic, and geophysical investigations performed by the applicant to evaluate the potential for tectonic (i.e., due to faulting and folding) and non-tectonic (e.g., collapse resulting from karst development and human-induced activities) surface deformation in the site vicinity and site area and at the site location.
Sections 2.5.3.2.1.1 through 2.5.3.2.1.7 of this report summarize the results of these investigations.

2.5.3.2.1.1 Published Geologic Mapping.

SSAR Section 2.5.3.1.1 indicates the published geologic maps reviewed by the applicant to evaluate the potential for tectonic and non-tectonic surface deformation in the site vicinity. The applicant referred to geologic maps of Delaware (Picket and Spoljaric, 1971), Maryland (Higgins and Conant, 1990), and New Jersey (Owens et al., 1999; Newell et al., 2000) and concluded that none of these maps show faults of Quaternary age (2.6 Ma to present) in the site vicinity.

2.5.3.2.1.2 Regional Geologic Studies.

SSAR Section 2.5.3.1.2 discusses regional geologic investigations that proved useful for evaluating the potential for tectonic and non-tectonic surface deformation in the site vicinity. Based on Benson (2006), the applicant reported a possible buried fault offset, located about 24 km (15 mi) north-northwest of the PSEG Site, which does not disrupt Quaternary strata. Figure 2.5.3-1 of this report shows the location of the surface projection of this inferred subsurface fault offset as a blue triangle. The applicant also referred to the fault data compilations of Crone and Wheeler (2000) and Wheeler (2005), which indicated that the only potential Quaternary tectonic features in the site vicinity are the New Castle County faults postulated by Spoljaric (1972, 1973, 1974, and 1979). Figure 2.5.3-2 of this report illustrates the locations of the postulated New Castle County faults, which include both buried basement faults inferred by Spoljaric (1972 and 1973) and surficial lineaments identified by Spoljaric (1974 and 1979) from satellite imagery that he suggested could possibly be associated with faulting. The applicant stated that existing field evidence suggests these faults, if they exist, are not Quaternary in age and concluded that they are not capable of producing tectonic surface deformation in the site vicinity.

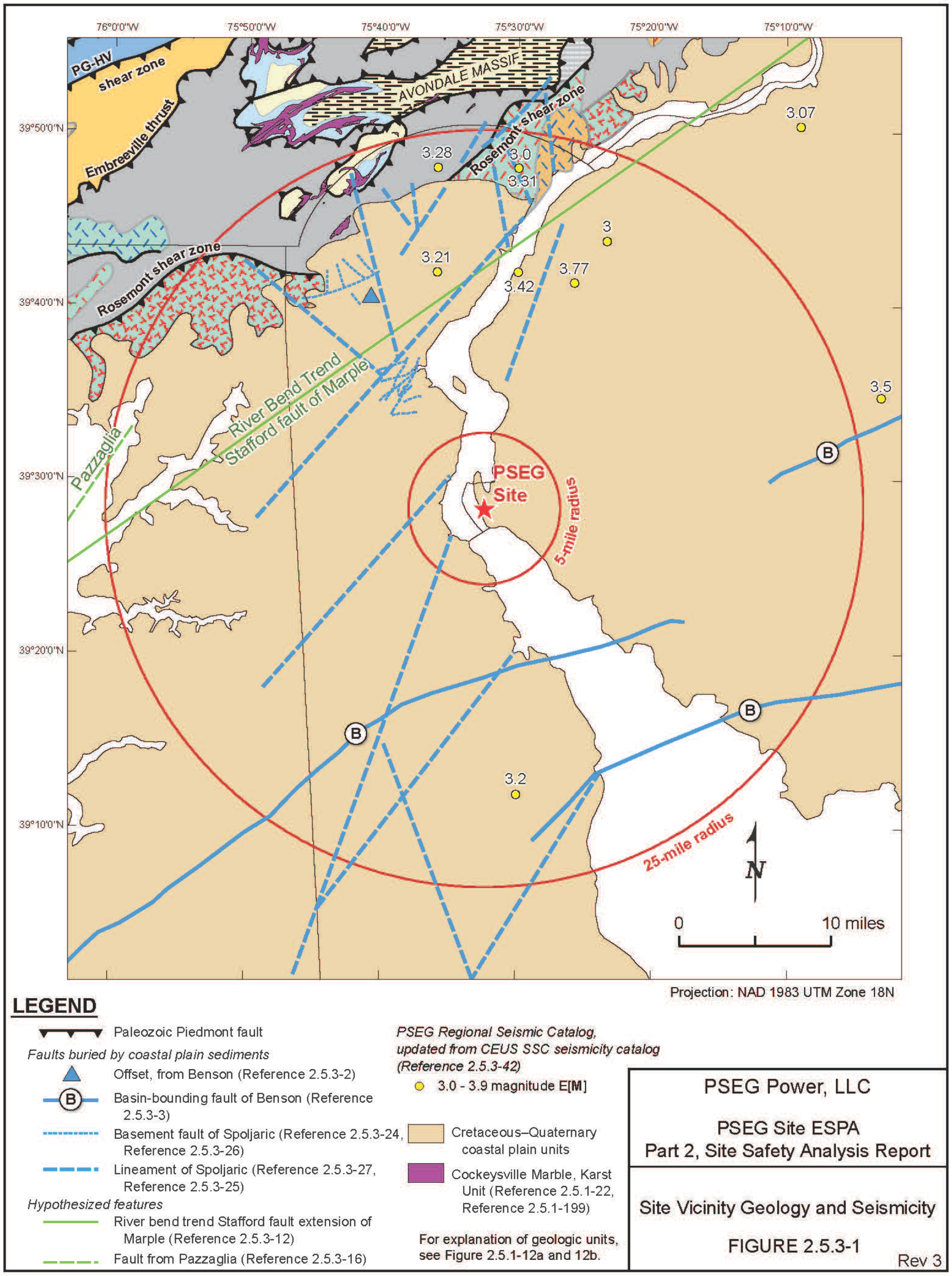

Figure 2.5.3-1 Site vicinity and site area geology and seismicity (Reproduced from SSAR Figure 2.5.3-1)

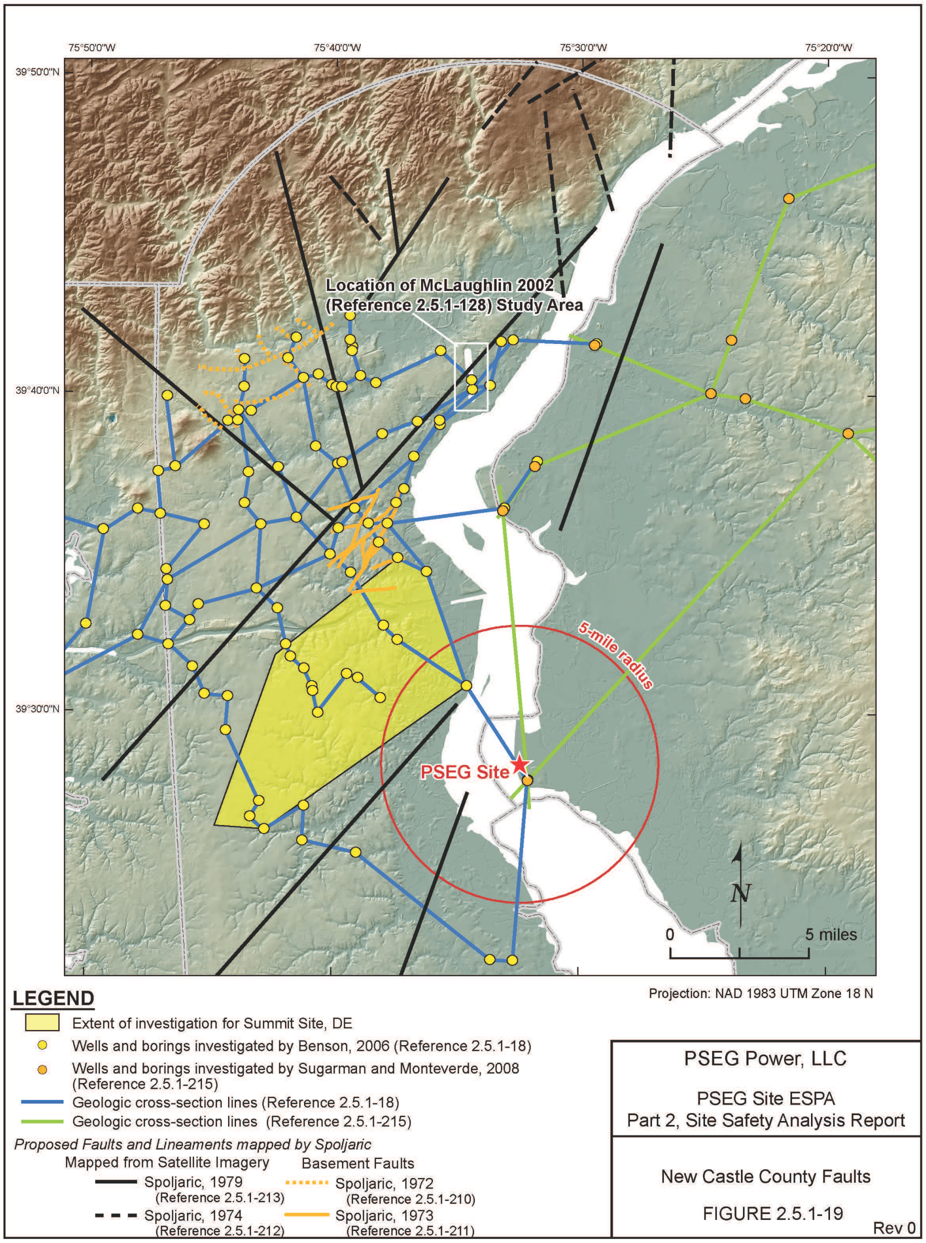

Figure 2.5.3-2 New Castle County faults and location of the McLaughlin et al. (2002) study area (Reproduced from SSAR Figure 2.5.1-19)

2.5.3.2.1.3 Seismicity Data.

SSAR Section 2.5.3.1.3 addresses seismicity data derived from the CEUS-SSC study as presented in NUREG-2115. Figure 2.5.3-1 of this report illustrates that there are no earthquake locations in the site area, and that eight earthquakes with expected moment magnitude (E[**M**]) estimates of 3.0 or greater occurred in the site vicinity. The applicant noted that the largest earthquake in the site vicinity was the instrumentally-recorded E[**M**] 3.77 event, which occurred

about 30.6 km (19 mi) north of the site on February 28, 1973. Based on information collected for the HCGS updated FSAR (PSEG, 2008) and data presented by Sbar et al. (1975), the applicant reported that none of the seismic events can be associated with any faults postulated to occur in the site vicinity.

2.5.3.2.1.4 Previous Site Investigations.

SSAR Section 2.5.3.1.4 presents the conclusions drawn based on previous site investigations conducted for the SGS (PSEG, 2007) and HCGS (PSEG, 2008). The applicant indicated that these investigations resulted in the following conclusions: (1) No surficial faulting or folding exists in the site area; (2) Surficial materials in the site area revealed no evidence of prior earthquakes; and (3) Stratigraphic units are planar and show no disruption by tectonic faulting or folding at the site location.

2.5.3.2.1.5 Aerial Imagery Analysis.

SSAR Section 2.5.3.1.5 discusses the results of analyses performed by the applicant to identify surficial features that could indicate the presence of surface or near-surface tectonic structures (i.e., warping, folds, or faults) in the site area. In combination with topographic maps, the applicant examined historical black and white aerial photographs from the 1930s, more recent color aerial photographs from 2007, and modern high-resolution light detection and ranging (LIDAR) elevation data from 2007 and 2008 for the site area. The applicant identified a total of 58 lineaments in the site area related to type, density, and distribution of vegetation; reaches of rivers, creeks, and streams; geomorphic features associated with topography; differences in tonal contrast; and curvilinear paleoshorelines separating differences in topography. Since many of the lineaments identified from the imagery and topographic maps were not directly accessible in the field due to the low-relief marshy landscape that characterizes the site area, the applicant attempted to further evaluate the linear features either on the ground from nearby vantage points or by aerial reconnaissance. The applicant concluded that none of the linear features investigated within the site area exhibited any evidence for surface or near-surface tectonic deformation related to faulting, folding, or warping.

2.5.3.2.1.6 Current Aerial and Field Reconnaissance.

SSAR Section 2.5.3.1.6 describes the aerial and field reconnaissance investigations conducted by the applicant in the site vicinity and site area. The applicant indicated that the field reconnaissance activities included observing landscape morphology and examining pertinent outcrops; visiting locations of accessible lineaments identified on aerial imagery; and evaluating continuity of paleoshorelines west of the site location. The applicant did not identify any evidence for tectonic surface deformation as a result of the field reconnaissance investigations.

During the aerial reconnaissance investigations, the applicant examined lineaments identified in both historical and modern aerial images, including those linear features that were not accessible on the ground; inspected the land surface around the potential tectonic structures postulated by Pazzaglia (1993) and Marple (2004), located on Figure 2.5.3-1 of this report; and searched for evidence of other faults and earthquake-induced paleoliquefaction features. The applicant did not identify any anomalous features clearly associated with tectonic deformation, including faulting, in the site area as a result of the aerial reconnaissance investigations. However, the applicant did identify elliptical to rounded, light-colored patches northeast of the site location that could have resulted from earthquake-induced paleoliquefaction. The applicant reported that a broad distribution of these features occurs in

the Delaware Bay area, and indicated that researchers attributed them to periglacial processes (i.e., processes occurring at the immediate margins of former and existing glaciers and ice sheets that may extend beyond the periphery of the ice due to periglacial climatic conditions) based on information presented by French and Demitroff (2001) and French et al. (2003, 2005, and 2007). The applicant also reported that the land surface adjacent to portions of the Chesapeake Bay and the Susquehanna and Delaware Rivers near the postulated features of Pazzaglia (1993) and Marple (2004) showed no evidence for faulting.

2.5.3.2.1.7 Current Site Subsurface Investigations.

SSAR Section 2.5.3.1.7 describes subsurface investigations conducted by the applicant to evaluate subsurface stratigraphy and structural geology at the site location. The applicant supplemented the more than 130 borings previously completed for the HCGS and SGS site investigations with 16 new geotechnical borings. Based on data derived from the borings, the applicant reported planar, undisrupted sedimentary layering beneath the site location and concluded that the boring data confirmed a lack of near-surface faulting at the site location.

2.5.3.2.2 Geologic Evidence, or Absence of Evidence, for Tectonic Surface Deformation

SSAR Section 2.5.3.2 addresses the presence or absence of evidence for tectonic surface deformation in the site vicinity and site area. The applicant discussed Paleozoic (542 to 251 Ma) structures exposed in the Piedmont west of the site; Mesozoic (251 to 65.5 Ma) faults overlain by undeformed Coastal Plain sediments of Cretaceous (145.5 to 65.5 Ma) or Tertiary (65.5 to 2.6 Ma) age; and hypothesized tectonic features with no recognized surface expression. Figure 2.5.3-1 of this report illustrates the known and postulated geologic features, both exposed and buried, identified in the site vicinity. Sections 2.5.3.2.2.1 through 2.5.3.2.2.3 of this report summarize the information presented by the applicant in SSAR Section 2.5.3.2 on Paleozoic structures exposed in the Piedmont faults buried beneath Coastal Plain sediments, and hypothesized faults.

2.5.3.2.2.1 Paleozoic Structures Exposed in the Piedmont.

SSAR Section 2.5.3.2.1 describes two primary tectonic structures of Paleozoic age mapped within the site vicinity, namely, the Rosemont shear zone and thrust faults bordering exposures of the Baltimore gneiss (e.g., in the Avondale massif), as shown in Figure 2.5.3-1 of this report. Based on field relationships, the applicant reported that these tectonic features have not been active since the Paleozoic, and concluded that they do not pose a surface faulting hazard at the site location.

2.5.3.2.2.2 Faults Buried beneath Coastal Plain Sediments.

SSAR Section 2.5.3.2.2 discusses buried, basin-bounding Mesozoic faults overlain by undeformed sedimentary Coastal Plain strata of Cretaceous age and younger in the site vicinity. Benson (1992) proposed these faults based on information derived from gravity and magnetic field data, boreholes, and seismic lines. Based on data from Benson (1992), the applicant described three buried Mesozoic basin-bounding faults that may extend into the southern part of site vicinity as illustrated in Figure 2.5.3-1 of this report. The applicant noted that, regardless of whether these basin-bounding faults extend into the site vicinity or not, no evidence exists that they deform Cretaceous strata. Therefore, the applicant concluded that there is no potential for surface deformation at the site location related to the postulated buried basin-bounding faults of Benson (1992).

In addition, the applicant reported a buried fault inferred by Benson (2006), based on geophysical well log data, to offset Cretaceous strata in the subsurface at the location of the blue triangle shown in Figure 2.5.3-1, of this report. The applicant stated that undeformed Quaternary units overlie this inferred buried fault and concluded that, even if the feature exists, it is pre-Quaternary in age and does not pose a hazard from tectonic surface deformation at the site location.

SSAR Section 2.5.3.2.2 also describes the New Castle County faults postulated by Spoljaric (1972, 1973, 1974 and 1979) to occur in the site vicinity and site area. The New Castle County faults include subsurface faults offsetting buried crystalline basement rocks as interpreted from borehole data (Spoljaric, 1972 and 1973), as well as lineaments and inferred faults derived from satellite imagery (Spoljaric, 1974 and 1979). Figure 2.5.3-1 of this report illustrates the locations of the lineaments, two of which extend into the site area and the buried basement faults, both of which collectively comprise the New Castle County faults. Regarding the inferred basement faults, based on data reported by Spoljaric (1972 and 1979) and Hansen (1978) documenting that these faults do not cut overlying Cretaceous or Tertiary strata, the applicant indicated that offset along these faults, if they exist, is demonstrably pre-Cretaceous in age. Regarding the lineaments, the applicant reported the following field evidence to counter the interpretation that they represent faults: (1) Borings that cross the projection of the lineaments failed to identify offsets in near-surface strata based on data from Benson (2006); and (2) trenches, borings, and a seismic line located near one of the lineaments north of the site revealed unfaulted Cretaceous and Quaternary strata at the surface based on McLaughlin et al. (2002). Figure 2.5.3-2 of this report illustrates the location of the area investigated by McLaughlin et al. (2002) relative to the lineaments defined by Spoljaric (1974 and 1979), as well as his inferred buried basement faults (Spoljaric, 1972 and 1973). In addition, the applicant found no evidence that the lineaments represented faults based on the analyses of aerial photographs and satellite imagery conducted for the PSEG ESP application. The applicant pointed out that Spoljaric (1979) stated no evidence existed for surface faulting related to the lineaments. The applicant also reported that results of other investigations (Ramsey, 2005 and PSEG, 2008) do not support a faulting interpretation for the lineaments. Therefore, the applicant concluded there are no basement faults buried beneath Coastal Plain sediments or faults associated with lineaments that pose a hazard due to tectonic surface deformation at the site location.

2.5.3.2.2.3 <u>Hypothesized Features</u>.

SSAR Section 2.5.3.2.3 discusses two additional faults postulated to occur in the site vicinity, namely, the River Bend Trend/Stafford Fault of Marple (2004) and the fault of Pazzaglia (1993). Figure 2.5.3-1 of this report shows the proposed traces of these two hypothesized features, which extend into the site vicinity northwest of the site. The applicant reported that Marple (2004) defined his feature based on an interpreted extension of the Stafford fault northeastward from Virginia connecting the southwest-trending portions of the Delaware and Susquehanna Rivers. The applicant stated that both field and aerial reconnaissance studies conducted for characterizing the PSEG Site confirmed a lack of observable faulting in rock units located along the trace of this postulated tectonic feature, including within the site vicinity. The applicant cited multiple references that provided a similar interpretation regarding a lack of faulting along the trace of this postulated feature based on detailed geologic mapping (e.g., Schenck et al., 2000; Ramsey, 2005; Stanford, 2006; Stanford and Sugarman, 2006).

Regarding the fault of Pazzaglia (1993), the applicant indicated that he proposed this feature to explain the apparent difference in elevations of the lower contact of the Pleistocene (2.6 to 0.01 Ma) Turkey Point Beds in Maryland on opposite sides of the fault (i.e., on the eastern and western sides of Chesapeake Bay). The applicant stated that aerial reconnaissance along the trace of the hypothesized fault where it would extend onshore within the site vicinity, also conducted for characterizing the PSEG Site, confirmed a lack of observable deformation associated with this feature. The applicant noted that topographic relief on the lower contact of the Turkey Point Beds could also produce the elevation differences of this contact on opposite sides of the Chesapeake Bay. The applicant concluded there is no geologic evidence that either of these hypothesized faults, if they exist, deform any rock units within the site vicinity, and that neither of these two features pose a surface faulting hazard at the site location.

2.5.3.2.3 Correlation of Earthquakes with Capable Tectonic Sources

SSAR Section 2.5.3.3 evaluates the correlation of earthquakes with capable tectonic sources. As previously explained in Section 2.5.3.1 of this report, the applicant equated a capable tectonic source, or capable fault, with a structure that could generate both tectonic surface deformation and vibratory ground motion based on the definition RG 1.208, Appendix A. The applicant stated that none of the earthquakes that occurred in or near the site vicinity, located in Figure 2.5.3-1 of this report, have been correlated with any known fault or capable tectonic source, including the instrumentally-recorded E[**M**] 3.77 event of February 28, 1973, discussed by Sbar et al. (1975). Therefore, the applicant concluded no data suggest there are capable tectonic sources that could generate tectonic surface deformation and vibratory ground motion within the site vicinity.

2.5.3.2.4 Ages of Most Recent Deformations

SSAR Section 2.5.3.4 evaluates ages of most recent deformations within the site area. The applicant stated that there is no evidence for surface tectonic deformation related to faulting or folding in the site area based on investigations performed for characterization of the site. In addition, based on results of subsurface investigations for both the SGS (PSEG, 2007) and HCGS (PSEG, 2008), the applicant reported that bedding in stratigraphic units of Cretaceous age and younger (i.e., < 145.5 Ma) beneath the site is planar and does not exhibit any deformation related to faulting.

2.5.3.2.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

SSAR Section 2.5.3.5 addresses the relationship of tectonic structures in the site area to regional tectonic structures. The applicant cross-referenced the discussion of geologic evidence for tectonic surface deformation in SSAR Section 2.5.3.2, summarized in Section 2.5.3.2.2 of this report, and stated that no tectonic faults exist within the site area. Therefore, the applicant concluded that there is no correlation of tectonic structures in the site area with any regional tectonic structures.

2.5.3.2.6 Characterization of Capable Tectonic Sources

SSAR Section 2.5.3.6 addresses the need for characterization of capable tectonic sources that could generate both tectonic surface deformation and vibratory ground motion within the site area. Based on information provided in detailed discussions in SSAR Sections 2.5.1.1.4.2, “Principal Tectonic Structures”; 2.5.1.2.2.4, “Structural Geology”; 2.5.2.2, “Geologic and

Tectonic Characteristics of the Site and Region"; 2.5.2.3, "Correlation of Earthquake Activity with Seismic Sources"; 2.5.2.4.2.2, "New Seismic Source Characterizations"; and 2.5.3.3, "Correlation of Earthquakes with Capable Tectonic Sources"; the applicant concluded there are no capable tectonic sources within the site area that require characterization.

2.5.3.2.7 Designation of Zones of Quaternary Deformation in the Site Region

SSAR Section 2.5.3.7 addresses designated zones of Quaternary deformation in the site region that may require detailed investigations. The applicant cross-referenced information presented in SSAR Section 2.5.1.1.4.2.5, "Potential Quaternary Tectonic Features within the Site Region," and stated that the site region does not contain any zones of Quaternary deformation that would require additional detailed investigations. The applicant also reiterated that review of aerial photographs and geotechnical boring logs and aerial and field reconnaissance investigations conducted to characterize the site did not identify any zones of Quaternary deformation in the site area.

2.5.3.2.8 Potential for Surface Tectonic Deformation or Non-Tectonic Deformation at the Site

SSAR Section 2.5.3.8 assesses the potential for surface tectonic and non-tectonic deformation at the site location. Regarding tectonic surface deformation, including faults and folds, the applicant stated that current and previous subsurface investigations in the site area showed Miocene and younger (i.e., < 23.0 Ma) strata to be planar and nearly flat-lying without any evidence of faulting or folding. The applicant also stated that examination of aerial imagery and LIDAR data collected to characterize the site did not reveal any evidence for faulting. The applicant concluded that there is no potential for surface tectonic deformation to pose a hazard at the site location.

Regarding non-tectonic surface deformation, particularly that induced by human activities (e.g., groundwater use, oil and gas extraction, and mining) or by collapse resulting from dissolution of carbonate rocks (i.e., development of karst features), the applicant stated that no evidence exists for these types of non-tectonic deformation in the site area or at the site location. The applicant cross-referenced information presented in SSAR Section 2.5.1.2.5.5, "Effects of Human Activity," and indicated that no detrimental human-related activities are on-going at the site location. The applicant also noted that, although karst features related to dissolution of the Cockeysville Marble exist in the site vicinity associated with surface exposures of the marble, there are no karst features in the site area because the marble does not occur there. The applicant concluded that there is no potential for non-tectonic surface deformation to pose a hazard at the site location.

2.5.3.3 Regulatory Basis

The applicable regulatory requirements for tectonic and non-tectonic surface deformation that must be considered in an ESP application are as follows:

- 10 CFR 52.17(a)(1)(vi), as it relates to the requirement for an ESP applicant to prepare a SSAR that contains information on geologic and seismic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, and with sufficient margin for the limited accuracy, quantity and period of time in which the historical data have been accumulated.

- 10 CFR 100.23(c), as it relates to the requirement for 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 for estimating the Safe Shutdown Earthquake ground motion; and to permit adequate engineering solutions for actual or potential geologic and seismic effects at the proposed site.

- 10 CFR 100.23(d), as it relates to the requirement for an ESP applicant to consider geologic and seismic siting factors for determining the SSE ground motion for the site; the potential for surface tectonic and nontectonic deformations; 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 information on tectonic and non-tectonic surface deformation provided by the applicant in compliance with the above regulatory requirements should also be sufficient to allow a determination at the COL application stage regarding whether the proposed facility complies with the following requirements in 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," and 10 CFR Part 50, Appendix S.IV, "Application to Engineering Design":

- General Design Criteria (GDC 2) of 10 CFR Part 50, Appendix A requires that SSCs important to safety be designed to withstand effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiche without loss of capability to perform their safety functions.

- 10 CFR Part 50, Appendix S.IV requires that vibratory ground motion and the potential for surface deformation be taken into account in the design of the nuclear power plant.

To the extent applicable in the regulatory requirements cited above and in accordance with Review Standard-002 (RS-002), "Processing Applications for Early Site Permits," the staff applied methods and approaches specified in NUREG-0800, Section 2.5.3, "Surface Faulting," for evaluation of information characterizing tectonic and non-tectonic surface deformation at the proposed site, presented by the applicant in SSAR Section 2.5.3, as recommended in RG 1.208. The acceptance criteria for tectonic and non-tectonic surface deformation presented in SSAR Section 2.5.3, defined in NUREG-0800, Section 2.5.3, are as follows. In addition, information provided by the applicant in SSAR Section 2.5.3 should be consistent with appropriate sections from RG 1.132, Revision 2; RG 1.198; and RG 1.208.

- Geologic, Seismic, and Geophysical Investigations: Requirements of 10 CFR 100.23 are met and guidance in RG 1.132, Revision 2, RG 1.198, and RG 1.208 is followed for this area of review if discussions of Quaternary tectonics, structural geology, stratigraphy, geochronologic methods used for age dating, paleoseismology, and geologic history of the site vicinity, site area, and site location are complete, compare well with studies conducted by others in the same area, and are supported by detailed investigations performed by the applicant.

- Geologic Evidence, or Absence of Evidence, for Surface Tectonic Deformation: Requirements of 10 CFR 100.23 are met and guidance in RG 1.132, Revision 2, RG 1.198, and RG 1.208 is followed for this area of review if sufficient surface and subsurface information is provided by the applicant for the site vicinity, site area, and site location to confirm the presence or absence of surface tectonic deformation (i.e., faulting) and, if present, to demonstrate the age of most recent fault displacement and ages of previous displacements.

- Correlation of Earthquakes with Capable Tectonic Sources: Requirements of 10 CFR 100.23 are met for this area of review if all reported historical earthquakes within the site vicinity are evaluated with respect to accuracy of hypocenter location and source, and if all capable tectonic sources that could, based on fault orientation and length, extend into the site area or site location are evaluated with respect to the potential for causing surface deformation. (Note: The applicant equated a capable tectonic source, or capable fault, with a structure that could generate both tectonic surface deformation and vibratory ground motion after the definition in RG 1.208, Appendix A.)

- Ages of Most Recent Deformations: Requirements of 10 CFR 100.23 are met for this area of review if every significant surface fault and feature associated with a blind fault, any part of which lies within the site area, is investigated in sufficient detail to demonstrate, or allow relatively accurate estimates of, the age of most recent fault displacement and enable identification of geologic evidence for previous displacements (if such evidence exists).

- Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures: Requirements of 10 CFR 100.23 are met for this area of review by discussion of structural and genetic relationships between site area faulting or other tectonic deformation and the regional tectonic framework.

- Characterization of Capable Tectonic Sources: Requirements of 10 CFR 100.23 are met for this area of review when it has been demonstrated that investigative techniques employed by the applicant are sufficiently sensitive to identify all potentially capable tectonic sources, including faults or structures associated with blind faults, within the site area; and when fault geometry, length, sense of movement, amount of total displacement and displacement per faulting event, age of latest and any previous displacements, recurrence rate, and limits of the fault zone are provided for each capable tectonic source.

- Designation of Zones of Quaternary Deformation in the Site Region: Requirements of 10 CFR 100.23 regarding designation of zones of Quaternary (2.6 Ma to present) deformation in the site region are met if the zone (or zones) designated by the applicant as requiring detailed faulting investigations is of sufficient length and width to include all Quaternary deformation features potentially significant to the site as described in RG 1.208.

- Potential for Surface Tectonic Deformation at the Site Location: To meet requirements of 10 CFR 100.23 for this area of review, information must be presented by the applicant if field investigations reveal that surface or near-surface tectonic deformation along a known capable tectonic structure related to a fault or blind fault must be taken into account at the site location.

2.5.3.4 Technical Evaluation

The staff reviewed SSAR, Section 2.5.3 to ensure that the materials provided by the applicant represent the required data related to assessment of the potential for tectonic and non-tectonic surface and near-surface deformation. The staff's review confirmed that data contained in the application address the information required for this topic.

The technical information presented in SSAR Section 2.5.3 resulted from the applicant's review of onshore and offshore geologic maps published by the USGS, state geological surveys, and other research workers; literature published in journals and data included in field guidebooks; reports on previous site investigations for the SGS (PSEG, 2007) and HCGS (PSEG, 2008); and the CEUS-SSC model presented in NUREG-2115. The applicant also collected information by performing the following activities to assess the potential for tectonic and non-tectonic surface deformation within the site area: Examination and interpretation of aerial photographs and remote sensing imagery; aerial and geologic field reconnaissance; and subsurface boring investigations. Through its review of SSAR Section 2.5.3, the staff determined whether the applicant had complied with applicable regulatory requirements in 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d) and conducted the site characterization investigations at the appropriate levels of detail in accordance with guidance in RG 1.208.

RG 1.208 recommends that an applicant evaluate any significant new geologic, seismic, and geophysical data to determine whether revisions to existing seismic source models and ground motion attenuation relationships are necessary. SSAR Section 2.5.3 includes geologic and seismic information collected by the applicant to support the analysis of vibratory ground motion and development of site-specific GMRS, as discussed in SSAR Section 2.5.2. RG 1.208 also recommends that an applicant evaluate faults encountered at a site to determine whether they are seismogenic or may cause surface deformation. SSAR Section 2.5.3 specifically includes information related to assessment of the potential for future tectonic and non-tectonic surface deformation at the site location.

The staff visited the PSEG Site on January 22, 2009, to observe pre-application subsurface investigation activities (ADAMS Accession No. ML090510065). A second visit, a site audit performed over September 29-30, 2011, after PSEG had submitted the ESP application, focused on examination of samples of the Vincentown Formation and pertinent outcrops, as well as interactions with the ESP applicant and its consultants in regard to the geologic, seismic, geophysical, and geotechnical investigations being conducted for characterization of the proposed ESP site. Regarding the geologic field observations made during the September 2011 site audit, the staff examined outcrops of estuarine sediments comprising the Early Pleistocene (2.6 to 1.8 Ma) Turkey Point Beds near the boundary of the PSEG Site vicinity to the west of the site for field evidence of a fault postulated by Pazzaglia (1993) to extend into the Chesapeake Bay west of the site. Pazzaglia (1993) postulated this fault based on interpreted elevation differences between Turkey Point Beds on opposite sides of the Bay. The staff noted no field evidence for this inferred fault.

Sections 2.5.3.4.1 through 2.5.3.4.8 of this report present the staff's evaluation of information provided by the applicant in SSAR Section 2.5.3 and the applicant's responses to RAIs for that SSAR section. The RAIs posed by the staff and discussed in the following sections of this report assure the applicant's compliance with 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d) as well as conformance to NUREG 0800, Section 2.5.3. In addition to the RAIs addressing specific technical issues related to the potential for future tectonic and

non-tectonic surface deformation at the site location, discussed in detail below, the staff also prepared editorial RAIs to further clarify certain descriptive statements made by the applicant in the SSAR and to better qualify specific geologic features illustrated in figures in the SSAR. This technical evaluation does not include a discussion of these editorial RAIs.

2.5.3.4.1 Geologic, Seismic and Geophysical Investigations

The staff focused the review of SSAR Section 2.5.3.1, "Geologic, Seismic and Geophysical Investigations," on information presented by the applicant related to published geologic maps, regional geologic studies, seismicity data, previous site investigations, aerial imagery analysis, current aerial and field reconnaissance, and current site subsurface investigations. The staff particularly concentrated on the descriptions of regional geologic studies, previous site investigations, aerial imagery analysis, and current aerial and field reconnaissance for evaluating the potential for surface tectonic deformation in the site vicinity and site area and at the site location.

2.5.3.4.1.1 Regional Geologic Studies.

In SSAR Section 2.5.3.1.2, the applicant described regional geologic studies. The applicant discussed the subsurface tectonic features postulated by Benson (2006) and Spoljaric (1972, 1973, 1974, and 1979) to occur in the site vicinity. Figure 2.5.3-1 of this report locates the postulated fault offset of Benson (2006), related to a buried fault inferred from borehole data, about 24 km (15 mi) north-northwest of the site location. Figures 2.5.3-1 and 2.5.3-2 of this report locate the inferred basement structures of Spoljaric (1972 and 1973), as well as the lineaments he postulated (Spoljaric, 1974 and 1979) to be related to faulting, which he collectively referred to as the New Castle County faults and which Crone and Wheeler (2000) and Wheeler (2005) interpreted to be a Class C structure (i.e., a feature with insufficient evidence to demonstrate the existence of a tectonic fault or associated Quaternary deformation).

The staff focused the review of SSAR Section 2.5.3.1.2 on the discussions of these inferred subsurface tectonic features for evaluating the potential for faulting in the site vicinity. The applicant reported that the inferred subsurface fault of Benson (2006) deforms the Lower Cretaceous (145.5 to 99.6 Ma) Potomac Formation but does not disrupt overlying Quaternary age (2.6 Ma to present) strata. However, the applicant did not indicate whether the interpretation that no deformation occurs in the Quaternary units overlying this buried offset came from Benson (2006), from interpretations by other researchers, or from investigations conducted for characterization of the PSEG ESP site. Therefore, in RAI 44, Question 02.05.03-1, the staff requested that the applicant clarify the source of data used to conclude that the fault offset proposed by Benson (2006) does not affect stratigraphic units of Quaternary age in the site vicinity. In a January 25, 2012, response to RAI 44, Question 02.05.03-1, the applicant stated that a cross section constructed by Benson (2006) based on the borehole data indicated the proposed fault offset does not deform overlying Quaternary units.

Based on its review of SSAR Section 2.5.3.1.2 and the January 25, 2012, response to RAI 44, Question 02.05.03-1, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes that the postulated fault of Benson (2006), while it likely exists in the subsurface, does not deform overlying Quaternary units and does not exhibit any surface expression in the site vicinity. The staff makes this conclusion because the

subsurface data provided by Benson (2006) strongly support it. Accordingly, the staff considers RAI 44, Question 02.05.03-1 resolved.

Regarding the New Castle County faults postulated by Spoljaric (1972, 1973, 1974, and 1979), the applicant stated that no published geologic studies reviewed for the PSEG Site indicated the presence of these features or any other possible Quaternary structures capable of producing tectonic surface deformation in the site vicinity. However, the applicant did not provide the specific published information sources used to conclude that no geologic studies indicate the presence of tectonic structures of Quaternary age, including the New Castle County faults, in the site vicinity. Therefore, in RAI 44, Question 02.05.03-2, the staff requested that the applicant clarify the published data sources used to make the conclusion and to summarize the relevant data supporting it. In a January 25, 2012, response to RAI 44, Question 02.05.03-2, the applicant cited multiple references presenting results of geologic mapping and data from borings and other subsurface investigation methods that document a lack of faulting of the Quaternary strata in the site vicinity (e.g., Stanford, 2004 and 2006; Benson and Pickett, 1986; Woodruff and Thompson, 1972; Pickett, 1970).

Based on its review of SSAR Section 2.5.3.1.2 and the January 25, 2012, response to RAI 44, Question 02.05.03-2, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes that the inferred basement faults of Spoljaric (1972 and 1973) and his postulated faults related to lineaments (Spoljaric, 1974 and 1979), which comprise the New Castle County faults, if they exist, do not deform Quaternary deposits in the site vicinity or site area. The staff makes this conclusion because field data, including that documented by geologic mapping and borehole logs, strongly support it. Accordingly, the staff considers RAI 44, Question 02.05.03-2 resolved.

2.5.3.4.1.2 Previous Site Investigations.

In SSAR Section 2.5.3.1.4, the applicant discussed previous site investigations and summarized information derived from the updated FSARs for the SGS (PSEG, 2007) and HCGS (PSEG, 2008). Since the proposed PSEG Site lies immediately north of these two operating plants, information in the two updated FSARs is important for qualifying geologic characteristics of the proposed site.

The staff focused the review of SSAR Section 2.5.3.1.4 on statements made by the applicant that investigations performed for the two operating plants did not reveal any evidence for surficial folding or faulting or prior earthquakes in the site area, and that near-surface stratigraphic units exhibit planar bedding without any indication of disruption by faulting beneath the PSEG Site location. Although the applicant made these important conclusions, SSAR Section 2.5.3.1.4 does not summarize the relevant information from the two updated FSARs used to support them. Therefore, in RAI 44, Question 02.05.03-3, the staff requested that the applicant summarize the relevant information from the two updated FSARs that support the conclusions presented in SSAR Section 2.5.3.1.4.

In a January 25, 2012, response to RAI 44, Question 02.05.03-3, the applicant provided additional information supporting each of the conclusions. In regard to a lack of evidence for folding or faulting in the site area, the applicant reported that HCGS site characterization investigations supplied supporting data based on literature reviews, 100 subsurface borings, seismic refraction surveys, and examination and geologic mapping of site excavations. The applicant also reported that SGS site characterization investigations provided supporting data from literature reviews, geologic reconnaissance of the site and surrounding area,

35 subsurface borings, and geophysical tests. Regarding the lack of evidence for prior earthquakes, the applicant explained that examination of excavation walls and borehole data at the HCGS site revealed no evidence of earthquake-induced liquefaction on foundation soils. The applicant also explained that there was no indication of earthquake-induced liquefaction of surficial soil materials at the SGS site. Regarding the planar characteristics of bedding in stratigraphic units underlying the PSEG Site area, the applicant stated that borehole data, seismic reflection data, and geologic mapping of the plant excavation discussed in the HCGS updated FSAR documented that contacts between stratigraphic units were planar and did not show any abrupt changes in elevations due to faulting. In addition, the applicant noted that borehole data from SGS site investigations indicated the base of the Quaternary was uniform across the site at a depth of approximately 10.7 m (35 ft) and Cretaceous strata were planar with gentle dips to the southeast beneath the site.

Based on its review of SSAR Section 2.5.3.1.4 and the January 25, 2012, response to RAI 44, Question 02.05.03-3, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes that no tectonic surface faulting or folding exists in the site area; surficial materials in the site area exhibit no evidence for prior earthquakes as could be indicated by liquefaction; and planar stratigraphic units show no disruption due to tectonic faulting or folding at the site location. The staff makes this conclusion because field data derived from site characterization investigations for the SGS and HCGS strongly support it, as do field observations made by staff during the September 2011 field audit. Accordingly, the staff considers RAI 44, Question 02.05.03-3 resolved.

2.5.3.4.1.3 Aerial Imagery Analysis.

In SSAR Section 2.5.3.1.5, the applicant described aerial imagery analysis and discussed lineaments identified on aerial imagery by Spoljaric (1974 and 1979) that trend into the site vicinity, two of which also extend into the site area. Figure 2.5.3-1 of this report shows the locations of these surficial linear features, which the applicant analyzed because they could possibly indicate the presence of near-surface tectonic structures such as folds or faults.

The staff focused the review of SSAR Section 2.5.3.1.5 on understanding the process used by the applicant to document the conclusion that none of the lineaments identified by Spoljaric (1974 and 1979) in the site vicinity or site area exhibited any evidence of surface faulting or folding, particularly since certain of these lineaments were not accessible for direct field examination due to the low-relief marshy landscape that characterizes much of the site area. The applicant indicated that further evaluation of the inaccessible lineaments relied on aerial reconnaissance and ground observations from nearby vantage points. Therefore, in RAI 44, Question 02.05.03-4, the staff requested that the applicant explain the process used for documenting that none of the lineaments in the site vicinity or site area showed features indicative of surface or near-surface tectonic deformation (i.e., faulting or folding); to identify the lineaments evaluated directly in the field; and to more clearly describe the approach applied to evaluate those features determined to be inaccessible.

In a January 25, 2012, response to RAI 44, Question 02.05.03-4, the applicant described ground reconnaissance traverses performed in the site vicinity and site area in March, May, and July 2009 and an aerial reconnaissance study conducted in connection with the July 2009 ground reconnaissance. The applicant provided figures illustrating locations of lineaments relative to the track logs for the March, May, and July 2009 ground reconnaissance traverses and the July 2009 aerial reconnaissance investigations, as well as points marking the positions

of stops made to directly examine specific features during the May and July 2009 ground reconnaissance traverses. The applicant evaluated the lineaments in relation to their possible association with alignment of vegetation, cultural features, and tectonic surface deformation, and stated that the only observation of inaccessible lineaments was from the air. The applicant also provided figures that showed there was little to no surface expression of many of the lineaments, and certainly no evidence of tectonic deformation features in the site vicinity or site area. The applicant reiterated that the ground and aerial reconnaissance investigations did not reveal any association of lineaments with tectonic surface deformation.

Based on its review of SSAR Section 2.5.3.1.5 and the January 25, 2012, response to RAI 44, Question 02.05.03-4, including examination of figures provided in the RAI response illustrating locations of lineaments relative to track logs for ground and aerial reconnaissance of the lineaments and points marking positions of stops made to directly examine specific features during foot traverses, the staff concludes there is no indication that any of the lineaments identified by Spoljaric (1974 and 1979) show features indicative of tectonic surface or near-surface folding or faulting. The staff makes this conclusion because the ground and aerial reconnaissance investigations of the lineaments performed by the applicant strongly support it. Accordingly, the staff considers RAI 44, Question 02.05.03-4 resolved.

2.5.3.4.1.4 Current Aerial and Field Reconnaissance.

In SSAR Section 2.5.3.1.6, the applicant discussed current aerial and field reconnaissance investigations implemented for evaluating the faults postulated by Pazzaglia (1993) and Marple (2004) to extend into the site vicinity and the possible presence of paleoliquefaction features in the site vicinity. Figure 2.5.3-1 of this report shows the locations of the postulated faults of Pazzaglia (1993) and Marple (2004).

In the January 13, 2012, and December 28, 2011, responses to RAI 42, Question 02.05.01-4 and RAI 42, Question 02.05.01-5, respectively, the applicant provided a detailed discussion of the postulated faults of Pazzaglia (1993) and Marple (2004) and the rationale for concluding that none of these features exhibits any evidence for tectonic deformation in the site vicinity. Section 2.5.1.4.1.3.1 of this report presents the staff's evaluation of these two RAI responses. Therefore, the staff focused the review of SSAR Section 2.5.3.1.6 on understanding the approach implemented to document the apparent lack of earthquake-induced paleoliquefaction features in the site vicinity as reported by the applicant. SSAR Section 2.5.3.1.6 did not include a description of the investigative approach. Therefore, in RAI 44, Question 02.05.03-5, the staff requested that the applicant describe the approach used to search for paleoliquefaction features in the site vicinity, and also to discuss the susceptibility of materials examined to assess the presence of paleoliquefaction features.

In a January 11, 2012, response to RAI 44, Question 02.05.03-5, the applicant stated that the approach to documenting the presence of paleoliquefaction features and possible associated faults in the site vicinity involved examination of historical and recent aerial photographs and aerial and ground reconnaissance. Regarding properties of the materials examined for assessing the presence of paleoliquefaction features in the site vicinity, the applicant indicated that the greatest likelihood for formation and preservation of liquefaction features would occur in association with the youngest (i.e., at the lowest elevation) fluvial terraces along the Delaware Bay and its tributaries and the Delaware River. The applicant explained that a sedimentary sequence with appropriate material properties (i.e., fine-grained sands capped by non-porous silty and clay-rich layers to provide a hydrologic confining unit) and a shallow water table were

most likely to exist for the youngest terraces, rendering them more susceptible to earthquake-induced liquefaction. The applicant referred to a figure provided in the January 13, 2012, response to RAI 42, Question 02.05.01-4, which showed extensive coverage of areas containing the materials most appropriate for forming and preserving liquefaction features by ground and aerial reconnaissance investigations conducted for characterization of the proposed PSEG Site, none of which revealed any evidence for earthquake-induced paleoliquefaction features or possible associated faults. The applicant acknowledged that large portions of the site vicinity are tidal salt marshes and any liquefaction features developed in that environment would be relatively quickly degraded and not easily recognized during aerial or ground reconnaissance investigations.

Based on its review of SSAR Section 2.5.3.1.6 and the January 11, 2012, response to RAI 44, Question 02.05.03-5, including the figure provided in the January 13, 2012, response to RAI 42, Question 02.05.01-4, the staff concludes that the applicant implemented the proper approach for assessing the presence of earthquake-induced paleoliquefaction features without finding any evidence for earthquake-induced paleoliquefaction features or possible associated faults. The staff makes this conclusion because the applicant applied the appropriate ground and aerial reconnaissance investigations without revealing any evidence for such features or associated faults. Accordingly, the staff considers RAI 44, Question 02.05.03-5 resolved.

In addition, the applicant identified elliptical to round, light-colored patches in the field near the proposed PSEG Site and on aerial photographs of the Delaware Bay area as a result of the reconnaissance studies performed to determine whether earthquake-induced paleoliquefaction features occurred in the site vicinity. The applicant stated that these features formed as a result of periglacial processes, but did not address the possibility that they may have formed in response to earthquake-induced paleoliquefaction. Therefore, in RAI 44, Question 02.05.03-6, the staff specifically requested that the applicant discuss the approach used to evaluate the patches described in SSAR Section 2.5.3.1.6 leading to the conclusion that the features formed as a result of periglacial processes rather than earthquake-induced paleoliquefaction. In a January 11, 2012, response to RAI 44, Question 02.05.03-6, the applicant indicated that direct field examination of one water-filled, light-colored patch did not reveal any definitive evidence of a liquefaction origin for the patch. The applicant explained that these patches occur over a broad area on both the Delmarva Peninsula, which includes most of Delaware and portions of Maryland and Virginia, and in the Coastal Plain of New Jersey, and cited references (e.g., Newell, 2005; Losco et al., 2010) indicating these features are most likely the result of periglacial processes based on their characteristically broad distribution.

Based on its review of SSAR Section 2.5.3.1.6 and the January 11, 2012, response to RAI 44, Question 02.05.03-6, and independent examination of literature cited by the applicant in the SSAR and the RAI response, the staff concludes that the elliptical to round, light-colored patches that occur in the site vicinity most likely formed as a result of periglacial processes. The staff makes this conclusion because these features show a broad distribution within an area characterized by periglacial affects, and there is no evidence for the presence of earthquake-induced paleoliquefaction features or associated faulting in the site vicinity. Accordingly, the staff considers RAI 44, Question 02.05.03-6 resolved.

Based on its review of SSAR Section 2.5.3.1 and the January 11, 2012, responses to RAI 44, Questions 02.05.03-5 and 02.05.03-6, January 25, 2012, response to RAI 44, Questions 02.05.03-1 through 02.05.03-4, and independent review of references cited in the SSAR and the RAI responses, the staff finds that the applicant provided a thorough and

accurate description of geologic, seismic, and geophysical investigations in support of the PSEG ESP application.

2.5.3.4.2 Geologic Evidence, or Absence of Evidence, for Tectonic Surface Deformation

The staff focused the review of SSAR Section 2.5.3.2, "Geologic Evidence, or Absence of Evidence for Tectonic Surface Deformation," on the discussions of Paleozoic structures exposed in the Piedmont; faults buried by Coastal Plain sediments; and hypothesized tectonic features provided by the applicant. The staff particularly concentrated on developing a better understanding of the degree of resolution of data used to confirm a lack of displacement of Quaternary strata overlying postulated buried faults in the site vicinity to clarify what amount of displacement would not be detectable, and of the locations of trenches placed to investigate lineaments defined by Spoljaric (1979) in the site vicinity.

2.5.3.4.2.1 Paleozoic Structures Exposed in the Piedmont.

In SSAR Section 2.5.3.2.1, the applicant discussed Paleozoic structures exposed in the Piedmont and described the Rosemont shear zone and thrust faults bordering exposures of the Baltimore gneiss, which are the two primary Paleozoic tectonic structures mapped within the site vicinity. Figure 2.5.3-1 of this report shows the locations of these features.

The staff focused the review of SSAR Section 2.5.3.2.1 on the applicant's discussion of published information documenting a Paleozoic age for these structures (Valentino et al., 1995; Woodruff and Thompson, 1975; Krol et al., 1999; Alcock, 1994; Faill, 1998; Wagner and Srogi, 1987). Based on data from these information sources, the applicant reported that timing of displacement along the Rosemont shear zone was Devonian to Carboniferous (> 299 Ma), and that for the bordering thrust faults was greater than 251 Ma.

Based on its review of SSAR Section 2.5.3.2.1 and independent examination of references cited therein, the staff concludes that the Rosemont shear zone and thrust faults bordering exposures of the Baltimore gneiss are Paleozoic in age. The staff makes this conclusion because radiometric age dates and field relationships strongly support it.

2.5.3.4.2.2 Faults Buried by Coastal Plain Sediments.

In SSAR Section 2.5.3.2.2, the applicant described faults buried by Coastal Plain sediments. The applicant discussed subsurface faults and possible faults and surficial lineaments interpreted by Spoljaric (1972, 1973, 1974 and 1979) to occur in the site vicinity and site area, known collectively as the New Castle County faults. The applicant also discussed the buried faults proposed by Benson (1992 and 2006) to occur in the site vicinity, including Mesozoic basin-bounding faults (Benson, 1992) and one basement offset (Benson, 2006).
Figures 2.5.3-1 and 2.5.3-2 of this report show the locations of the postulated basement faults and fault-related lineaments, which comprise the New Castle County faults of Spoljaric (1972, 1973, 1974 and 1979). Figure 2.5.3-1 of this report also shows the locations of the buried structures proposed by Benson (1992 and 2006).

The staff focused the review of SSAR Section 2.5.3.2.2 on the applicant's discussion of the subsurface investigative methods used by Benson (1992 and 2006) to determine that the buried faults he described are pre-Quaternary in age and that locations of the faults are accurate. The staff also focused its review on the applicant's statement that McLaughlin et al. (2002) implemented trenching, borehole, and seismic investigations to assess a lineament identified by

Spoljaric (1979) based on satellite imagery for evidence of Quaternary deformation. Figure 2.5.3-2 of this report illustrates the location of the area investigated by McLaughlin et al. (2002) relative to the lineaments identified by Spoljaric (1974 and 1979), which, along with his inferred basement faults (Spoljaric, 1972 and 1973), comprise the postulated pre-Cretaceous New Castle County faults.

In RAI 44, Question 02.05.03-8, the staff requested that the applicant clarify the degree of resolution in the data (i.e., gravity and magnetic anomaly maps, boreholes, and seismic lines) used by Benson (1992) to determine that there was no evidence for displacement of Quaternary stratigraphic units in the site vicinity related to faults bounding three buried Mesozoic basins, and whether adequate data existed to eliminate concern about a subsurface Mesozoic basin and an associated basin-bounding fault underlying the site area. In a February 10, 2012, response to RAI 44, Question 02.05.03-8, the applicant reported that seismic reflection data derived from Sheridan et al. (1991), used to image Mesozoic basin-bounding faults and conclude that no rock units younger than Cretaceous (145.5 to 65.5 Ma) reveal any disruption by faulting, have a vertical resolution of about 9 m (30 ft). This resolution is relatively close to the maximum reported offset of 13.7 m (45 ft) in the Cretaceous stratigraphic section. The applicant pointed out that resolution from field and aerial reconnaissance is not easily quantified, and is strongly dependent on vegetation density. The applicant also stated that LIDAR data for the site area give elevation ranges for topographic expression of surficial features (particularly terraces along the Delaware estuary) on the order of 6 to 9 m (20 to 30 ft), which makes correlation of individual topographic surfaces problematic and limits the use of the terrace surfaces for detecting tectonic deformation. In addition, resolution limits for detecting faults in borings is dependent on spacing of boreholes and regional dip and orientation of geologic strata as well as assumptions on strata variability. Finally, the applicant noted that identification of Mesozoic basins from magnetic and gravity data alone is uncertain because anomalies result from multiple geologic conditions other than the presence of a basin. The applicant concluded that the map produced by Benson (1992) continues to provide the best available representation of Mesozoic basins and basin-bounding faults for the site vicinity, and the data from Benson (1992) do not show conclusive evidence for the presence of a basin within the site area.

Based on its review of SSAR Section 2.5.3.2.2 and the February 10, 2012, response to RAI 44, Question 02.05.03-8, and independent examination of references cited in the SSAR and the RAI response, the staff concludes that data resolution is adequate to detect fault displacements of around 6 to 9 m (20 to 30 ft) and no evidence currently exists to indicate the presence of a Mesozoic basin or basin-bounding fault in the site area. The staff makes this conclusion because the subsurface investigative methods have well-documented resolutions and no investigations have indicated the presence of a Mesozoic basin in the site area. Accordingly, the staff considers RAI 44, Question 02.05.03-8 resolved.

In RAI 44, Question 02.05-03-9, the staff requested that the applicant clarify the degree of resolution in the geophysical well log data used by Benson (2006) to determine that the subsurface offset in basement rock units, located about 24 to 32 km (15 to 20 mi) north-northwest of the site, does not disrupt stratigraphic units of Quaternary age. In a February 10, 2012, response to RAI 44, Question 02.05.03-9, the applicant reported that Benson (2006) interpreted the apparent fault offset, discovered in a geophysical well log study based on two boreholes on opposite sides of the inferred fault, based on different elevations of marker stratigraphic units in the Cretaceous Potomac Group. The applicant stated that continuous logging occurred, suggesting a high degree of vertical resolution in the logs for

registering vertical offset on the inferred structure. The applicant also reported that borings near a location having a surface exposure of the base of the Quaternary did not reveal any disruption of that surface due to faulting.

Based on its review of SSAR Section 2.5.3.2.2 and the February 10, 2012, response to RAI 44, Question 02.05.03-9, and independent examination of references cited in the SSAR and the RAI response, the staff concludes that, within the resolution limits of the methods applied, Quaternary units do not show any deformation related to the inferred basement fault of Benson (2006). The staff makes this conclusion because subsurface data strongly support it. Accordingly, the staff considers RAI 44, Question 02.05.03-9 resolved.

In RAI 44, Question 02.05.03-10, the staff requested that the applicant specify the locations of the seismic reflection line, trenches, and boreholes placed by McLaughlin et al. (2002) to investigate surficial conditions across one of the northeast-trending lineaments defined by Spoljaric (1979) and used to support the conclusion that the lineaments do not represent Quaternary faults. The staff also requested that the applicant provide details about the information derived from the trenches, borehole logs, and seismic line. Figure 2.5.3-2 of this report shows the location of the seismic line relative to the lineaments that comprise the New Castle County faults. In a February 10, 2012, response to RAI 44, Question 02.05.03-10, the applicant stated that the information reported by McLaughlin et al. (2002) included a seismic reflection line designed to image the top 457 m (1500 ft) of subsurface stratigraphy, three borings 107 to 158 m (350 to 550 ft) in depth designed to intersect postulate faults, and five 1.5 to 2.4 m (5 to 8 ft) deep trenches for examining surficial strata. The applicant stated that location of the borings and trenches along the seismic line was within a mile of the northeast-trending lineament, and that the PSEG Site was about 19.3 km (12 mi) south of the study area of McLaughlin et al. (2002) as shown in Figure 2.5.3-2 of this report. The applicant reported that the field investigations conducted by McLaughlin and others (2002) did not reveal any evidence of shallow tectonic deformation due to folding or faulting associated with the lineament along the seismic transect.

Based on its review of SSAR Section 2.5.3.2.2 and the February 10, 2012, response to RAI 44, Question 02.05.03-10, and independent examination of references cited in the SSAR and the RAI response, the staff concludes that no geologic evidence exists for faulting associated with the lineaments defined by Spoljaric (1974 and 1979). The staff makes this conclusion because the field evidence strongly supports it. Accordingly, the staff considers RAI 44, Question 02.05.03-10 resolved.

2.5.3.4.2.3 <u>Hypothesized Features</u>.

In SSAR Section 2.5.3.2.3, the applicant discussed potential tectonic features hypothesized to occur in the site vicinity and site area, specifically the faults of Pazzaglia (1993) and Marple (2004).

The staff focused the review of SSAR Section 2.5.3.2.3 on the applicant's descriptions of the hypothesized faults of Pazzaglia (1993) and Marple (2004). As indicated in Section 2.5.3.4.1.4 of this report, the applicant provided a detailed discussion of these two postulated faults and the rationale for concluding that neither of these features exhibit any evidence for tectonic deformation in the site vicinity in the responses to RAI 42, Questions 02.05.01-4 and 02.05.01-5. Section 2.5.1.4.1.3.1 of this report presents the staff's technical evaluation of these two RAI responses.

Based on its review of SSAR Section 2.5.3.2.3 and information provided by the applicant in the January 13, 2012, and December 28, 2011, responses to RAI 42, Question 02.05.01-4, and RAI 42, Question 02.05.01-5, respectively, discussed in Section 2.5.1.4.1.3.1 of this report, and independent examination of references cited in the SSAR and RAI responses, the staff concludes no evidence exits that either of these two hypothesized features, it they exist, are faults in the site vicinity. The staff makes this conclusion because field data strongly support it. In addition, during the site audit conducted in September 2011, the staff examined Pleistocene (2.6 to 0.01 Ma) estuarine sediments comprising the Turkey Point Beds in the vicinity of the Turkey Point Lighthouse, located on the eastern side of Chesapeake Bay and west of the PSEG Site near the boundary of the site vicinity, and found no field evidence for Quaternary faulting associated with the hypothesized fault of Pazzaglia (1993).

Based on its review of SSAR Section 2.5.3.2 and the February 10, 2012, response to RAI 44, Questions 02.05.03-8 through 02.05.03-10, independent examination of references cited in the SSAR and RAI responses, and field observations made during the September 2011 site audit, the staff finds that the applicant provided a thorough and accurate description of geologic evidence, or absence of evidence, for tectonic surface deformation in support of the PSEG ESP application.

2.5.3.4.3 Correlation of Earthquakes with Capable Tectonic Sources

In SSAR Section 2.5.3.3, the applicant addressed the correlation of earthquakes with capable tectonic sources that could generate tectonic surface deformation and vibratory ground motion. Based on information derived for the HCGS site (PSEG, 2008) and assessment of the instrumentally-recorded February 28, 1973, event by Sbar and others (1975), the applicant concluded no earthquakes that occurred in or near the site vicinity have been correlated with a known capable tectonic source.

The staff focused the review of SSAR Section 2.5.3.3 on the applicant’s statement that no earthquakes that occurred in or near the site vicinity have been correlated with a known capable tectonic source. Based on its review of SSAR Section 2.5.3.3 and independent examination of references cited in that SSAR section, the staff concludes that no earthquakes within the site vicinity can be correlated with tectonic sources capable of generating tectonic surface deformation and vibratory ground motion. The staff makes this conclusion because geologic and seismic data strongly support it.

Based on its review of SSAR Section 2.5.3.3 and independent examination of references cited in the SSAR, the staff finds that the applicant provided a thorough and accurate description of the correlation of earthquakes with capable tectonic sources in support of the PSEG ESP application.

2.5.3.4.4 Ages of Most Recent Deformations

In SSAR Section 2.5.3.4, the applicant addressed ages of most recent deformations. The applicant concluded no evidence exists for surficial tectonic deformation related to faulting or folding within the site area based on investigations performed for characterization of the PSEG Site, as well as data presented in the updated FSARs for both the SGS (PSEG, 2007) and HCGS (PSEG, 2008).

The staff focused the review of SSAR Section 2.5.3.4 on the applicant’s statement that no evidence exists for surficial tectonic deformation within the site area. Based on its review of

SSAR Section 2.5.3.4 and independent examination of references cited in the SSAR, the staff concludes that there are no surficial deformation features requiring an age assessment. The staff makes this conclusion because field data strongly support it.

Based on its review of SSAR Section 2.5.3.4 and independent examination of references cited in the SSAR, the staff finds that the applicant provided a thorough and accurate description of ages of most recent deformation in support of the PSEG ESP application.

2.5.3.4.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

In SSAR Section 2.5.3.5, the applicant addressed the relationship of tectonic structures in the site area to regional tectonic structures. The applicant concluded that, since no evidence exists for tectonic deformation in the site vicinity or site area as reported in SSAR Section 2.5.3.2, "Geologic Evidence, or Absence of Evidence, for Tectonic Surface Deformation," and summarized in Section 2.5.3.2.2 of this report, there is no relationship of tectonic structures in the site area to any regional tectonic features.

The staff focused the review of SSAR Section 2.5.3.5 on the applicant's statement that there is no relationship of tectonic structures in the site area to any regional tectonic features. Based on its review of SSAR Section 2.5.3.5 and independent examination of references cited in SSAR Section 2.5.3.2, which provided the rationale for stating that there is no evidence for tectonic deformation in the site vicinity or site area, the staff concludes that no relationship exists between tectonic structures in the site area and regional tectonic features. The staff makes this conclusion because field data document a lack of tectonic deformation features in the site area.

Based on its review of SSAR Section 2.5.3.5 and independent examination of references cited in SSAR Section 2.5.3.2, the staff finds that the applicant provided a thorough and accurate description of the relationship of tectonic structures in the site area to regional tectonic structures in support of the PSEG ESP application.

2.5.3.4.6 Characterization of Capable Tectonic Sources

In SSAR Section 2.5.3.6, the applicant addressed the characterization of capable tectonic sources that could generate tectonic surface deformation and vibratory ground motion within the site area. The applicant concluded no capable tectonic sources exist within the site area that would require characterization.

The staff focused the review of SSAR Section 2.5.3.6 on the applicant's statement that no capable tectonic sources exist within the site area which would require characterization. Based on its review of SSAR Section 2.5.3.6, as well as detailed discussions in SSAR Sections 2.5.1.1.4.2, "Principal Tectonic Structures"; 2.5.1.2.2.4, "Structural Geology"; 2.5.2.2, "Geologic and Tectonic Characteristics of the Site and Region"; 2.5.2.3, "Correlation of Earthquake Activity with Seismic Sources"; 2.5.2.4.2.2, "New Seismic Source Characterizations"; and 2.5.3.3, "Correlation of Earthquakes with Capable Tectonic Sources"; and independent examination of references cited in the SSAR sections, the staff concludes that there are no capable tectonic sources within the site area that require characterization. The staff makes this conclusion because there is a preponderance of geologic and seismic data that strongly support it, including direct field observations made by staff during the September 2011 site audit.

Based on its review of SSAR Section 2.5.3.6 and other multiple SSAR sections as specified in the above paragraph, independent examination of references cited in the SSAR sections, and field observations made during the September 2011 site audit, the staff finds that the applicant provided a thorough and accurate description of the characterization of capable tectonic sources in support of the PSEG ESP application.

2.5.3.4.7 Designation of Zones of Quaternary Deformation in the Site Region

In SSAR Section 2.5.3.7, the applicant addressed the designation of zones of Quaternary deformation in the site region. The applicant cross-referenced SSAR Section 2.5.1.1.4.2.5, "Potential Quaternary Tectonic Features within the Site Region," which documents a lack of Quaternary tectonic deformation features or zones in the site region, and concluded the site region does not contain any zones of Quaternary deformation that require additional detailed investigations.

The staff focused the review of SSAR Section 2.5.3.7 on the applicant's statement that no zones of Quaternary deformation occur in the site region. Based on its review of SSAR Section 2.5.3.7 and SSAR Section 2.5.1.1.4.2.5 and independent examination of references cited in the SSAR sections, the staff concludes that no evidence exists for zones of Quaternary deformation in the site region. The staff makes this conclusion because there is a considerable geologic data to support it, including direct field observations made by staff during the September 2011 site audit.

Based on its review of SSAR Sections 2.5.3.7 and 2.5.1.1.4.2.5, independent examination of references cited in the SSAR sections, and field observations made during the September 2011 site audit, the staff finds that the applicant provided a thorough and accurate description of the designation of zones of Quaternary deformation in the site region in support of the PSEG ESP application.

2.5.3.4.8 Potential for Surface Tectonic Deformation and Non-Tectonic Deformation at the Site

In SSAR Section 2.5.3.8, the applicant addressed the potential for tectonic and non-tectonic surface deformation at the site location. The applicant cross-referenced SSAR Section 2.5.3.1.6, "Current Aerial and Field Reconnaissance," which documents that examination of aerial imagery and LIDAR data collected to characterize the PSEG Site did not reveal any evidence for surface tectonic deformation at the site location, and concluded that no potential exists for surface tectonic deformation at the site location. Regarding non-tectonic surface deformation, the applicant cross-referenced SSAR Section 2.5.1.2.5, "Site Engineering Geology Evaluation," which documents the absence of human-induced activities and ground collapse due to dissolution of carbonate rocks, and concluded that no potential exists for non-tectonic surface deformation at the site location.

The staff focused the review of SSAR Section 2.5.3.8 on the applicant's statement that no potential exists for tectonic or non-tectonic surface deformation at the site location. Based on its review of SSAR Sections 2.5.3.8, 2.5.3.1.6, and 2.5.1.2.5, as well as independent examination of references cited in those SSAR sections, the staff concludes that there is no potential for tectonic or non-tectonic surface deformation at the site location. The staff makes this conclusion because current and previous subsurface investigations in the site area indicate strata younger than 23 Ma are planar without any evidence of tectonic deformation; aerial imagery and LIDAR data collected to characterize the site did not reveal any evidence for faulting; karst features related to dissolution of the Cockeysville Marble, which do exist in the

site vicinity, do not occur in the site area since that unit is not present there; and no potentially detrimental human-related activities are on-going at the site location. Direct field observations made by the staff during the September 2011 site audit also support the staff's conclusion.

Based on its review of SSAR Sections 2.5.3.8, 2.5.3.1.6, and 2.5.1.2.5, independent examination of references cited in those SSAR sections, and field observations made during the September 2011 site, the staff finds that the applicant provided a thorough and accurate description of the potential for both tectonic and non-tectonic surface deformation at the site location in support of the PSEG ESP application.

2.5.3.5 Geologic Mapping Permit Condition

For evaluation of suitability of a proposed site, requirements in 10 CFR 100.23, "Geologic and Seismic Siting Criteria," specifically 10 CFR 100.23(c), indicate that geologic data on tectonic and non-tectonic surface deformation must be obtained through review of pertinent literature and field investigations. 10 CFR 100.23(d) explicitly states that geologic and seismic siting factors considered for design must include determination of the potential for tectonic and non-tectonic surface deformation at the proposed site. In addition, guidance in RG 1.132 indicates that excavations for safety-related structures and other excavations important for verifying subsurface conditions at the site should be mapped in detail by geologists. RG 1.208 specifically states that faults exposed in site excavations should be mapped and assessed in regard to rupture potential while walls and floors of the excavations are exposed, to include assessment of non-tectonic surface deformation. In SSAR Section 2.5.4.5.4.1, "Mat Foundation Evaluation," the applicant acknowledged the need to perform geologic mapping for documenting the presence or absence of faults and shear zones in plant foundation materials. Therefore, the staff considers it the responsibility of the COL or CP applicant to perform geologic mapping of future excavations for safety-related structures at the PSEG Site. This activity is Permit Condition 3, the required actions for which are as follows:

Permit Condition 3

> An applicant for a COL or CP referencing this early site permit shall perform detailed geologic mapping of excavations for safety-related structures; examine and evaluate geologic features discovered in those excavations; and notify the Director of the Office of New Reactors, or the Director's designee, once excavations for safety-related structures are open for examination by NRC staff.

2.5.3.6 Conclusion

As documented in Sections 2.5.3.1 through 2.5.3.4 of this report, the staff reviewed and evaluated information related to surface tectonic and non-tectonic deformation submitted by the applicant in SSAR Section 2.5.3 of the PSEG ESP application. The review and evaluation made it possible for the staff to confirm that this information provides an adequate basis for concluding that there is no potential for tectonic and non-tectonic surface deformation in the site vicinity and site area or at the site location that could adversely affect suitability of the PSEG Site.

The staff further concludes that the applicant identified and appropriately characterized all seismic sources significant for determining the SSE for the ESP site in accordance with regulatory requirements stated in 10 CFR 100.23(c) and 10 CFR 100.23(d) and guidance provided in RG 1.208 and NUREG-0800, Section 2.5.3. In addition, the staff finds that the

applicant properly characterized the potential for tectonic and non-tectonic surface deformation in the site vicinity and site area and at the site location. The staff also concludes there is no potential for the effects of human activity, including surface or subsurface mining, oil or gas extraction or injection, or groundwater injection or withdrawal, to compromise the safety of the site.

Finally, based on results of the review and evaluation of SSAR Section 2.5.3, and subject to Permit Condition 3, the staff concludes that the applicant provided a thorough and accurate description of the potential for tectonic and non-tectonic surface deformation in the site vicinity and site area and at the site location in full compliance with regulatory requirements in 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d) and in accordance with guidance in RG 1.208 and NUREG-0800, Section 2.5.3.

2.5.4 Stability of Subsurface Materials and Foundations

2.5.4.1 Introduction

In SSAR Section 2.5.4, the applicant presented its evaluation of the stability of subsurface materials and foundations that relate to the PSEG Site. The properties and stability of the soil and rock underlying the site are important to the safe design and siting of the plant. The information provided by the applicant in SSAR Section 2.5.4 addresses: (1) Geologic features in the site vicinity; (2) static and dynamic engineering properties of soil and rock strata underlying the site; (3) the relationship of the foundations for safety-related facilities and the engineering properties of underlying materials; (4) results of geophysical surveys, including in-hole and cross-hole explorations; (5) safety-related excavation and backfill plans and engineered earthwork analysis and criteria; (6) groundwater conditions and piezometric pressure in all critical strata as they affect the loading and stability of foundation materials; (7) responses of site soils or rocks to dynamic loading; (8) liquefaction potential and consequences of liquefaction of all subsurface soils, including the settlement of foundations; (9) earthquake design bases; (10) results of investigations and analyses conducted to determine foundation material stability, deformation, and settlement under static conditions; (11) criteria, references, and design methods used in static and seismic analyses of foundation materials; (12) techniques and specifications to improve subsurface conditions, which are to be used at the site to provide suitable foundation conditions; and any additional information deemed necessary in accordance with 10 CFR Part 52.

2.5.4.2 Summary of Application

In SSAR Section 2.5.4, the applicant provided a set of bounding parameters, as part of the applicant's plant parameter envelope (PPE). The applicant used design parameter information from the following reactor designs in development of the PPE: Single Unit U.S. Evolutionary Power Reactor (U.S. EPR), Single Unit Advanced Boiling Water Reactor (ABWR), Single Unit U.S. Advanced Pressurized-Water Reactor (US-APWR), and Dual Unit Advanced Passive 1000 (AP1000) (See Table 1.3-1, "Plant Parameter Envelope," in SSAR Section 1.3.3, "PSEG SITE PLANT PARAMETER ENVELOPE").

2.5.4.2.1 Geologic Features and Site Stratigraphy

SSAR Section 2.5.4.1 refers to SSAR Section 2.5.1.1 and 2.5.1.2 for a complete description of the regional and site geology, including, physiography and geomorphology, geologic history, stratigraphy, tectonic setting, seismicity, structural geology, and site engineering geology

evaluation. In SSAR Section 2.5.4.1.1, the applicant described the PSEG Site stratigraphy. The applicant stated that it performed 16 geotechnical borings divided into two groups: NB - represents the borings covering the northern portion of the site, and EB – represents the borings covering the eastern portion of the site. The applicant indicated in SSAR Figure 2.5.4.1-2 that the nuclear island will be located at the northern portion of the site. Based on the information collected during the site investigation, the applicant identified 14 stratigraphic layers. The geotechnical engineering strata listed from the ground surface are: Artificial Fill, Hydraulic Fill, Alluvium, Kirkwood Formation, Vincentown and Hornerstown Formations, Navesink Formation, Mount Laurel Formation, Wenonah Formation, Mashalltown Formation, Englishtown Formation, Woodbury Formation, Merchantville Formation, Magothy Formation, and Potomac Formation. Figure 2.5.4-1 of this report shows a stratigraphic cross-section oriented along the regional southeastward dip.

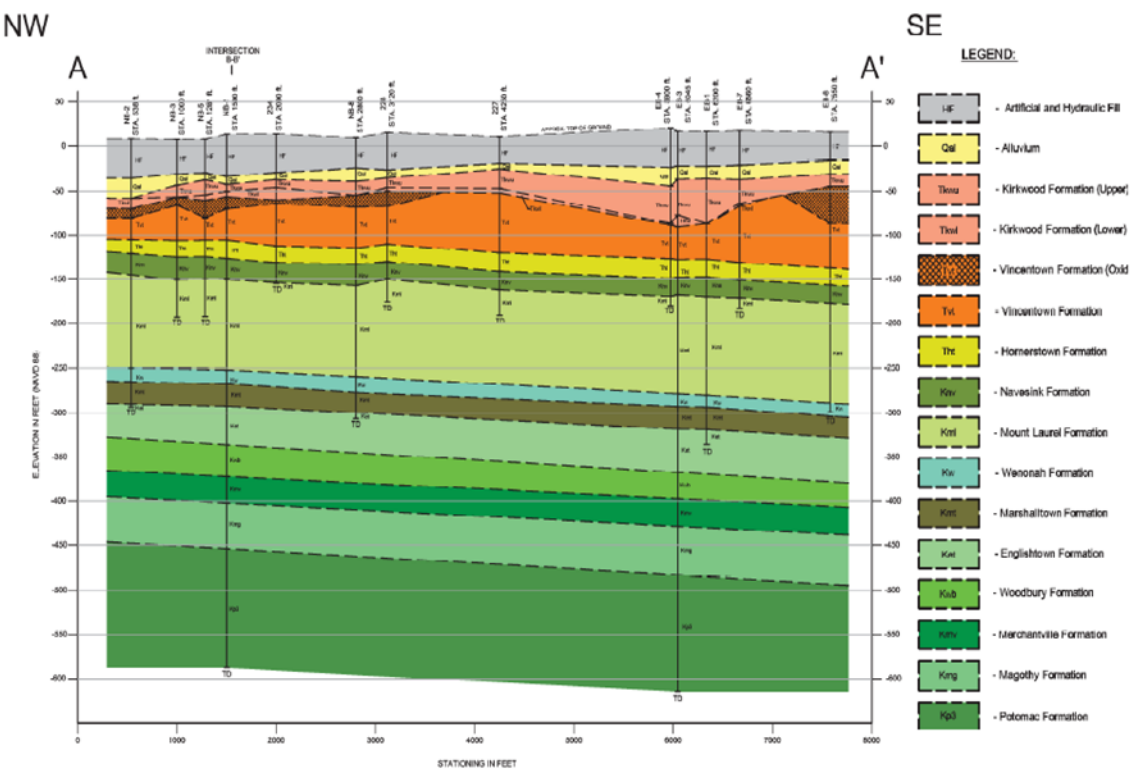

Figure 2.5.4-1 Stratigraphic Cross-Section (Reproduced from SSAR Figure 2.5.4.1-4)

SSAR Table 2.5.4.1-1 contains a summary of the PSEG Site stratigraphic data elevations at the top of formations, and SSAR Table 2.5.4.1-2 shows a comparison of the geologic stratigraphy for the ESP Site and the previous geotechnical studies performed at the HCGS. In SSAR Section 2.5.4.1.2, the applicant stated that it performed the subsurface investigation at the PSEG Site between the ground surface and 192.5 m (631.5 ft); below ground surface or elevation -187.5 m (615.0 ft) using the North American Vertical Datum (NAVD). The applicant noted that the stratigraphy at the PSEG Site is generally sub-horizontal and of a consistent thickness, with the exception of an erosional surface at the top of the Vincentown Formation. The applicant determined that the Vincentown Formation will be the foundation bearing layer and that regardless of the technology selected in the future, the vertical excavation for Seismic Category I structures will be down to elevation -20 m (-67 ft) NAVD. The applicant indicated

that the boring and the seismic velocity logging data shows that materials in the Hydraulic Fill, Alluvium and Kirkwood Formation are soft clays and exhibit shear wave velocities less than 304.8 meters per second (m/s) (1,000 feet per second (ft/s)), making these materials unsuitable as bearing layers for the technologies in consideration. The applicant plans to remove these materials in order to reach the foundation bearing layer. The Vincentown Formation is encountered at elevation -10 to -21 m (-33 to -70 ft) NAVD in the northern portion of the site. The formation overlies the Hornerstown Formation and shows significant relief in its upper portion. The applicant indicated that subaerial exposure and fluvial erosion prior to deposition of the overlying sediments, as well as groundwater movement through the formation are contributors to the weathered and oxidized nature of the formation. In addition, the applicant indicated that the oxidized and unoxidized sediments display a weak to strong reaction with 10 percent hydrochloric acid, which indicates the presence of calcareous sands.

The applicant grouped the stratigraphic layers into five categories, based on geologic ages, from youngest to oldest: Quaternary, Neogene (Upper Tertiary), Paleogene (Lower Tertiary), Upper Cretaceous, and Lower Cretaceous. Table 2.5.4-1 of this report describes the site stratigraphy and provides the average thickness in the northern portion of the site where the nuclear island will be located, and the average field standard penetration test (SPT) N values in blows per foot (bpf) for all borings across the site.

Table 2.5.4-1 PSEG Site Stratigraphy

Geologic Age	Formation	Description	Average Thickness Northft (m)	Average Field SPT N values (bpf)
Quaternary	Artificial fill	silt, clay, and sand with variable silt and clay contents, and clayey and silty gravels.	4 (1.2)	22
	Hydraulic Fill	highly plastic clay and silt with trace to organic material, locally interbedded discontinuous clay and silt layers.	33 (10)	3
	Alluvium	fine to coarse sand with gravel, silt and clay content.	13 (4)	14
Neogene	Kirkwood	clay and silt, fine to medium sand and fine to coarse gravel.	17 (5.2)	12
Paleogene	Vincentown (bearing layer)	oxidized and unoxidized glauconitic, calcareous, silty and clayey, fine to medium sand, and fine to medium sand with variable silt content; medium dense to very dense consistency; 0.1 to 1 ft discontinuous friable to indurated calcium carbonate cemented sandstone layers.	52 (16)	37
	Hornerstown	silty and clayey, fine to medium sand with trace shell segments and glauconite.	20 (6.1)	37

Geologic Age	Formation	Description	Average Thickness Northft (m)	Average Field SPT N values (bpf)
Upper Cretaceous	Navesink	silty and clayey, fine to medium grained glauconite, and quartz sand with trace to little shell fragments	24 (7.3)	72
	Mount Laurel	clayey and silty, fine to medium sand, grading with depth into fine to medium sand with variable silt and clay content, all with trace to little glauconite and shell fragments	103 (31)	91
	Wenonah	sandy clay with trace shell fragments and trace to few glauconites	15 (5)	41
	Marshalltown	of clayey and silty, fine to medium sand, and fine sandy clay of variable plasticity, all with trace to little glauconite content	25 (8)	41
	Englishtown	micaceous, sandy silt and clay to clayey sand, with trace shell fragments and trace to little glauconite	44 (13)	32
	Woodbury	highly plastic clay with trace glauconite, fine sand, mica, and shell fragments; and locally with trace indurated layers	36 (11)	32
	Merchantville	dark greenish-black glauconitic silts and clays with varying sand content.	30 (9)	50
	Magothy	carbonaceous/lignitic clay and silt, interbedded with sands at the upper portion and with variable silt and clay content at the bottom of the layer	52 (16)	85
Lower Cretaceous	Potomac	upper portion is composed of dark gray to gray clay and sand with variable silt content and the deeper portion of the formation the sediments are mottled, gray and red clay	>134 (41)	92

2.5.4.2.2 Properties of Subsurface Materials

SSAR Section 2.5.4.2 describes the static and dynamic engineering properties of the PSEG Site subsurface materials, including field investigations, laboratory tests, and engineering properties determined from the subsurface exploration and historical data. The applicant stated that the field and laboratory investigations for determining the engineering properties of soil materials follow the guidance of RG 1.132 and RG 1.138, respectively. The applicant extended its site-specific investigation to a depth of about 183 m (600 ft) in the northern portion of the site where the nuclear island will be located. Below that depth no site-specific shear wave or compressive wave velocity data were obtained; however, regional data were used.

2.5.4.2.2.1 Laboratory Testing.

SSAR Section 2.5.4.2.1 describes the applicant's laboratory testing and sample control procedures. The applicant recovered split-spoon samples and intact samples during site investigation activities and conducted static and dynamic analysis. The applicant performed the testing in accordance with American Society for Testing and Materials (ASTM) and other applicable standards. The applicant identified the type, number and industry standard for each type of laboratory test, including: testing for the Natural Moisture Content; Specific Gravity of Soils by Water Pycnometer; Particle-Size Distribution (Gradation) not including hydrometer; Particle-Size Analysis of Soils; Atterberg Limits; Unconsolidated Undrained Triaxial Strength; Consolidated Undrained Triaxial Strength; One-Dimensional Consolidation Properties of Soils using incremental loading; and Resonant Column Torsional Shear (RCTS). The applicant stated that since concrete foundations will not be in contact with in-situ material, it did not conduct testing of in-situ soils for sulfate and chloride.

The applicant also conducted dynamic laboratory testing on six intact samples using the RCTS method following the procedure of the University of Texas. The applicant indicated that a result from one test was not considered for further analysis due to high void ratios, which is inconsistent with the sampled formation.

2.5.4.2.2.1.1 *Sample Control*.

The applicant used the ASTM D 4220 standard for material storage and handling and used either a Shelby tube sampler or a rotary pitcher sampler to retrieve the undisturbed samples. The applicant obtained disturbed samples from SPT split-spoon sampling and placed the samples in glass jars and sealed the jars using moisture-tight lids. The applicant established an onsite storage facility for soil sample retention, an inventory system, and a chain of custody form to record all samples removed from the facility.

2.5.4.2.2.2 Material Engineering Properties.

2.5.4.2.2.2.1 *Static Material Properties*.

SSAR Table 2.5.4.2-8 summarizes the design values for static engineering properties of the subsurface materials based on the values determined during the ESP exploration. The applicant classified the subsurface materials in accordance with the Unified Soil Classification System (USCS). The applicant combined the Vincentown and Hornerstown formations into one engineering layer due to their similar engineering properties and reported the field and laboratory test results together. The applicant classified the Vincentown and Hornerstown formation as silty sands (SM, SP-SM) and less commonly, clayey sand (SC, SC-SM), silt (ML, MH) and clay (CL). The applicant determined the static laboratory indices for 40 SPT samples and seven intact samples of the Vincentown and Hornerstown formations collected during the ESP subsurface investigation. Laboratory testing, including sieve analysis with hydrometer, No. 200 sieve analysis wash test, Atterberg limits, specific gravity and moisture content, were performed to determine the soil index properties of the Vincentown and Hornerstown formations. The applicant performed three consolidated undrained (CU) triaxial compression tests on intact samples of the Vincentown and Hornerstown formations for the ESP application. The results of CU tests indicate average shear strength values: Cohesion (c) of 1.28 tons per square foot (tsf), and friction angle (Φ) of 20 degrees for total stress, and effective cohesion (c') of 0.40 tsf, and effective friction angle (Φ') of 37 degrees for effective stress. The applicant calculated the total unit weight from 13 intact samples of the Vincentown

and Hornerstown formations and values ranged from 17.4 to 20.5 kilonewtons per cubic meter (kN/m^3) (110.9 to 130.2 pounds per cubic foot (lb/ft^3).

The applicant encountered the Navesink and Mount Laurel formations in all the borings performed for the subsurface investigation. The applicant classified these formations as silty and clayey sands (SM, SC-SM, and SC). Underlying these formations, the Wenonah and Marshalltown formations were encountered and classified as clayey sands (SC) and, less commonly, silty sand (SM) and clay (CL). The applicant penetrated the Englishtown and Woodbury formations in two borings, NB-1 and EB-3 and classified these formations as clay (CL and CH). The applicant classified the Merchantville Formation as clay (CL), the Magothy Formation as clay and clayey sand (CH, SC), and the Potomac Formation as clay (CL).

2.5.4.2.2.2.2 *Dynamic Material Properties*.

In SSAR Section 2.5.4.2.2.2, the applicant explained that due to the presence of cemented layers, RCTS results presented in SSAR Table 2.5.4.2-9 are not representative. The applicant relied on the in situ Vs measurements to obtain the in situ Vs profile for the overall strata. SSAR Section 2.5.4.7 provides a more detailed description of the soil dynamic properties and the computational methods that the applicant used to develop the shear modulus reduction and the dynamic characteristics for the dynamic profile.

2.5.4.2.3 Foundation Interfaces

In SSAR Section 2.5.4.3, the applicant described the foundation interface conditions at the PSEG Site and geotechnical exploration and testing activities. The applicant stated that the field investigations for determining the engineering properties of soil materials follow the guidance of RG 1.132.

The applicant indicated that the site grade of the new proposed plant will be at elevation 11.2 m (36.9 ft) NAVD and that 7.6 to 9.1 m (25 to 30 ft) of fill will be required to achieve it. The range of embedment depths from the four reactor technologies considered for the site varies from 12 m (39 ft) to 25.7 m (84.3 ft) below the plant grade. Based on the selected elevation of the new plant, the bottom of the foundation will be at 6.1 to 20 m (20 to 65 ft) above the top of the competent foundation bearing material, which is in the Vincentown Formation. SSAR Figure 2.5.4.3-3 presents a cross-section illustrating the position of subsurface stratigraphy relative to the upper and lower bounds of embedment depths for safety-related structures within the PPE.

2.5.4.2.3.1 Exploratory Borehole Drilling and Sampling.

2.5.4.2.3.1.1 *SPT N-values*.

SSAR Section 2.5.4.3.1.2 states that the applicant performed a total of 16 borings. The applicant obtained the SPT soil samples at 0.8 m (2.5-foot) intervals for the first 4.6 m (15 ft) depth, at 1.5 m (5 ft) intervals from 4.6 to 61 m (15 to 200 ft) depth; and at 3 m (10 ft) (intervals from 61 to 157 m (200 ft to 450 ft) depth. The applicant extended the two deepest borings, NB-1 and EB-3, below 157 m to 183 m (450 to 600 ft) and 193 m (631 ft) depth, respectively. The applicant corrected the N-values measured in the field for overburden pressure and hammer energy.

2.5.4.2.3.1.2 *In-Situ Geophysical Testing*.

In SSAR Section 2.5.4.3.1.3, the applicant stated that the in-situ geophysical testing performed at the PSEG Site included: Downhole geophysical testing; borehole deviation; natural gamma; resistivity; caliper logging; suspension P-S velocity logging; crosshole seismic velocity testing; and downhole seismic velocity testing. Section 2.5.4.2.4 of this report describes these tests in greater detail.

2.5.4.2.3.1.3 *Observation Wells*.

The applicant installed 32 observation wells in 16 locations during exploration using rotosonic drilling methods. The applicant installed eight well pairs in each of the northern and eastern portions of the site. One well of each pair was installed in the hydraulic fill or alluvium and the other well in the pair was installed in the Vincentown Formation. The applicant used the soil lithology identified in adjacent geotechnical borings to determine the screen interval and the well completion depths.

2.5.4.2.4 Geophysical Surveys

SSAR Section 2.5.4.4 describes the geophysical survey methods that the applicant used to conduct its subsurface investigation at the PSEG Site.

2.5.4.2.4.1 Downhole Geophysical Testing and Suspension P-S Velocity Logging.

The applicant performed downhole geophysical testing in four borings (NB-1, NB-8, EB-3, EB-8G) ranging to depths of 96 to 192 m (315 to 630 ft). Figure 2.5.4-2 of this report provides a plan view of the exploration locations. The applicant conducted borehole deviation, natural gamma, resistivity, and caliper logging in each of the four boreholes. To measure in-situ compression (P) wave and horizontal shear (S) wave the applicant used the suspension P-S velocity logging method at 0.5 to 1 m (1.65 ft to 3.3 ft) intervals. The applicant used a technical procedure developed by GEOVision. The applicant indicated that the tests show similar P-wave and S-wave velocities along the four logged profiles.

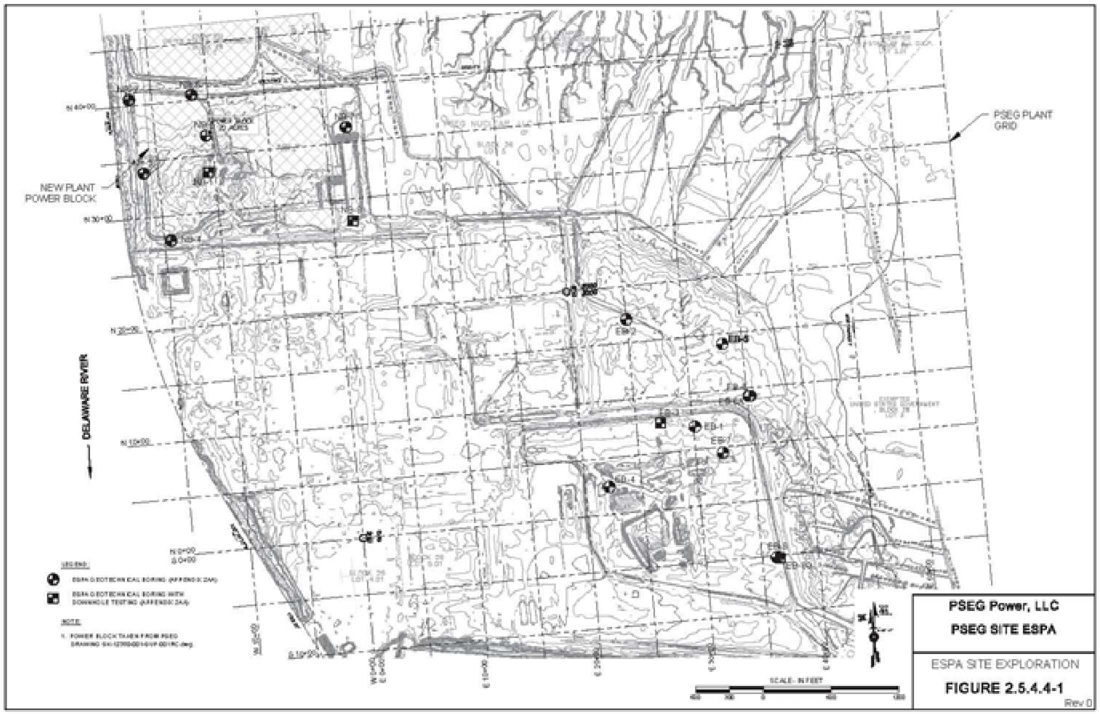

Figure 2.5.4-2 PSEG ESP Application site exploration (Reproduced from SSAR Figure 2.5.4.4-1)

2.5.4.2.4.2 Crosshole Seismic Velocity Testing.

The applicant used crosshole techniques at two locations (in the vicinity of borings NB-1 and NB-8) to complete seismic velocity measurement following the guidance in ASTM D 4428. The applicant recorded crosshole seismic velocity measurements to depths of about 61 m (200 ft). The applicant stated that the comparison of results obtained from suspension and crosshole velocity testing procedures, as presented in SSAR Figure 2.5.4.4-7, is in agreement.

2.5.4.2.4.3 Downhole Seismic Velocity Testing.

The applicant conducted downhole seismic velocity testing in borehole CH NB-1C to a depth of approximately 59 m (195 ft), following the GEOVision procedure. The applicant stated that the comparison of results obtained from downhole and suspension velocity measurements, as presented in SSAR Figure 2.5.4.4-8, is in good agreement for the foundation bearing soils and below.

2.5.4.2.5 Excavation and Backfill

SSAR Section 2.5.4.5 describes the excavation limits, sources and quantities of backfill, and dewatering and excavation methods that the applicant plans to implement at the PSEG Site.

2.5.4.2.5.1 Extent of Excavations.

SSAR Figure 2.5.4.5-1 presents a general layout of the limits of the excavation for the new plant location. The applicant stated that the lateral and vertical extent of the excavation for the

Seismic Category I structures depends on the specifications and requirements of the chosen plant technology. The PPE includes bounding conditions for the reactor building embedment depths ranging from 12 to 25.7 m (39 to 84.3 ft). Since the competent foundation layer at the PSEG Site is located at approximately elevation -20 m (-67 ft) NAVD, the vertical excavation for Seismic Category I structures will extend to approximately elevation -20 m (-67 ft) NAVD, regardless of the technology selected. The applicant will excavate approximately 23 m (75 ft) below present ground surface to reach the Vincentown Formation in the area of the safety-related structures. Figure 2.5.4-3 of this report shows a conceptual illustration for the excavation within the power block.

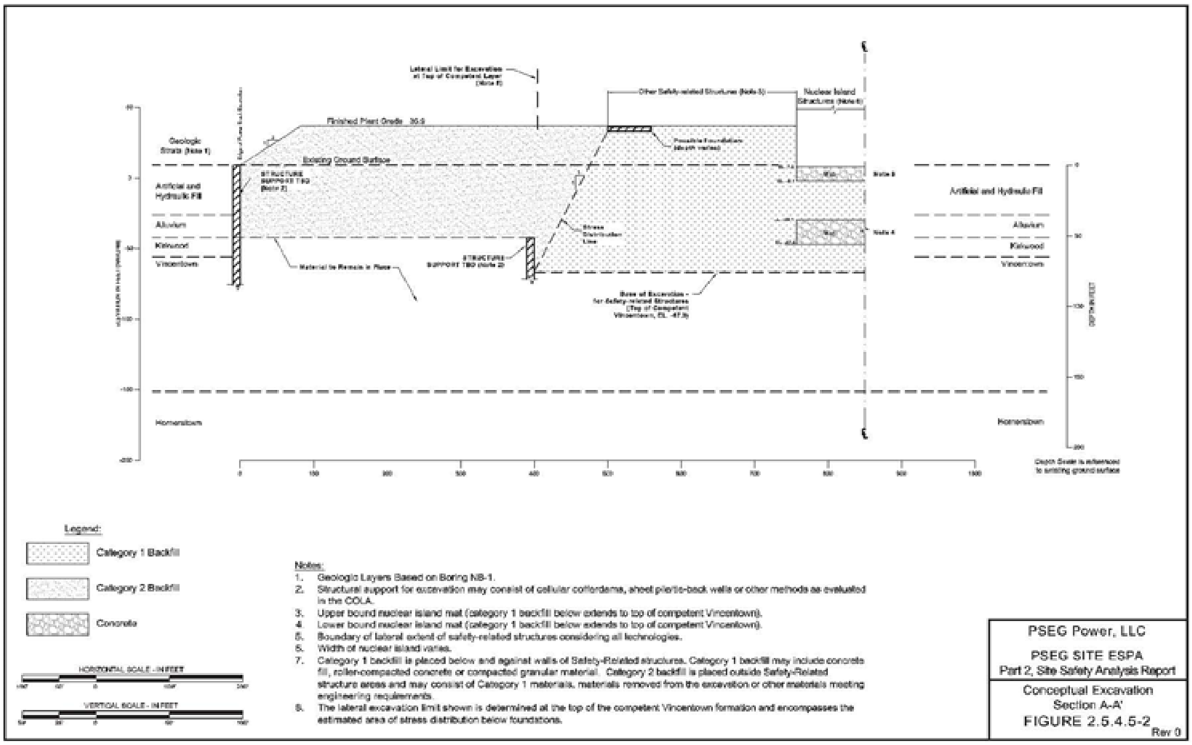

Figure 2.5.4-3 Conceptual Excavation Section A-A (Reproduced from SSAR Figure 2.5.4.5-2)

2.5.4.2.5.2 <u>Excavation and Dewatering Methods.</u>

In SSAR Section 2.5.4.5.2, the applicant stated that it will perform the site excavation in two stages. The first excavation will extend to the top of the Kirkwood Formation and the second excavation, which applies only to the area of the Seismic Category I structures, will extend to competent material within the Vincentown Formation. The applicant will decide the method of excavation support at the COL application stage. Some alternatives that the applicant is considering include: Cellular cofferdams, sheet pile walls, or other wall support systems.

Since the average groundwater level is at an approximate elevation of 0.2 m (0.8 ft) NAVD, dewatering is required during construction. The applicant plans to install wells around the outer and inner perimeters of the structural support system to accomplish dewatering and to maintain

the water level below the excavation bottom. The applicant does not expect that degradation or instability due to upward water seepage or piping will occur.

In SSAR Section 2.5.4.5.3.4, the applicant stated that after reaching the base of the excavation for Seismic Category I structures, it will inspect, map, and check for fill placement suitability in the subgrade. The applicant will inspect the subgrade using probing, cone penetrometer soundings, borings or heavy drivable equipment to look for conditions that need repair. The applicant plans to install geotechnical instrumentation prior to the excavation to monitor heave of the excavation bottom due to unloading from excavation.

2.5.4.2.5.3 Backfill Properties and Compaction Specifications.

In SSAR Section 2.5.4.5.3, the applicant stated that backfill is required from the base of the excavation to the bearing grade of the Seismic Category I structures, and between the walls of the nuclear island structures and the adjacent excavation support system. The applicant designated the backfill below the Seismic Category I structures that support safety-related structures as Category 1 fill. Otherwise, it will be designated as Category 2 fill. The applicant will discuss the details of the backfill quantities, types, sources, and compaction requirements during the COL application stage.

The applicant identified the following Category 1 backfill materials as possible: lean concrete, roller-compacted concrete, or structural granular material. The applicant plans to obtain granular materials locally and may consider using excavated material as Category 2 backfill. The material below the nuclear island or other safety-related structures must exhibit a V_s greater than 304.8 m/s (1,000 ft/s).

In SSAR Section 2.5.4.5.3.3, the applicant stated that it will apply the requirements of the American Concrete Institute (ACI) and the test methods described by ASTM to properly test during fill placement. The applicant will develop specifications for placement and compaction of backfill at the COL application stage. These specifications will include information regarding compaction density, moisture content, testing, and lift thickness. In the COL application, the applicant plans to include an inspection, test, analyses, and acceptance criteria (ITAAC) for the backfill to ensure a V_s of 304.8 m/s (1,000 ft/s), or higher.

2.5.4.2.5.4 Foundation Excavation Monitoring.

In SSAR Section 2.5.4.5.4, the applicant stated that it will observe and monitor foundation excavations during construction. The applicant will install geotechnical instrumentation for the nuclear island structures to monitor the heave of the excavation due to unloading from excavation. The applicant will include an instrumentation plan and monitoring schedule in the COL application. The applicant will document the initial mat foundation excavation to the top of the competent layer to confirm that the soils conform to those used in the design. The applicant plans to include the geologic mapping of the exposed soils, weathered zones, shear zones or fault zones.

2.5.4.2.6 Groundwater Conditions

SSAR Section 2.5.4.6 summarizes the groundwater conditions at the PSEG ESP Site. Additional details can be found in SSAR Section 2.4.12.

2.5.4.2.6.1 Site-Specific Groundwater Occurrence.

SSAR Section 2.5.4.6.1 notes that the applicant installed 16 well pairs (32 groundwater observation wells) as part of the ESP application investigation, located at or near the geotechnical boring locations. The applicant installed the deeper well in each well pair within the Vincentown or lower Kirkwood aquifer. SSAR Section 2.4.12 presents the complete data obtained from the monitoring wells.

The upper water-bearing zone, located above the upper unit of the Kirkwood Formation, consists of hydraulic fill and alluvium. The hydraulic fill acts as an aquitard, an impervious layer that prevents water penetration. The lower water-bearing zone consists of sands and gravel of the lower Kirkwood and Vincentown Formations. The average groundwater elevations observed in the upper and lower water-bearing zones at the ESP site are 0.25 and 0.24 m (0.82 and 0.80 ft) NAVD, respectively. The applicant also stated that groundwater flow modeling (discussed in SSAR Section 2.4.12.4) provides an estimate of the post-construction groundwater elevation ranging from 1.8 to 3.1 m (6 to 10 ft) NAVD. The applicant concluded that because the depth to groundwater at the new plant location after construction is more than 7.6 m (25 ft) below plant grade, there is no requirement for post-construction dewatering.

In SSAR Section 2.5.4.6.2, the applicant described the field testing conducted for hydraulic conductivity following the procedures described in ASTM D 4044, for the 16 observation wells installed at the new plant location. SSAR Table 2.5.4.6-2 summarizes the results of this testing. Additionally, the applicant conducted a tidal study, which is presented in SSAR Section 2.4.12.1.3.6. The applicant indicated that the water levels in the upper and lower water-bearing zones could have been tidally affected by up to 0.017 and 0.12 m (0.057 and 0.39 ft), during the slug tests. The applicant concluded that these potential tidal effects are negligible.

2.5.4.2.6.2 Dewatering Effects on Adjacent Structures.

In SSAR Section 2.5.4.6.3.1, the applicant stated that SSAR Figures 2.5.4.6-3 and 2.5.4.6-4 present the piezometric heads within the hydraulic fill and the Vincentown Formation of the site-specific groundwater model, after 1 year of dewatering. To consider dewatering effects, the applicant used the groundwater surface within the hydraulic fill to estimate the effects of groundwater table lowering for the layers above the Vincentown Formation, and used the piezometric drop within the Vincentown Formation for the Vincentown Formation and layers below. As a result, the applicant listed the structures that are within the projected zone of dewatering influence as follows:

- Independent Spent Fuel Storage Installation	- Fuel Oil Tank
- Hope Creek Generating Station (HCGS) Cooling Tower	- Water Treatment Plant
- Auxiliary Boiler Building	- Material Center
- HCGS Switchyard	- Low Level Radioactive Waste Building
- HCGS Intake Structure	- Salem Generating Station (SGS) Nuclear Island
- Learning and Development Center	- SGS intake Structure
- HCGS Nuclear Island	

The applicant explained that drawdown of the groundwater level at the centers of the structures listed above will cause an increase in vertical effective pressure and consequently can cause settlement of soils. In SSAR Sections 2.5.4.6.3.1.1 through 2.5.4.6.3.1.4, the applicant discussed the potential settlement due to dewatering drawdown and reported the following:

- HCGS and SGS Nuclear Islands – 0.76 and 0.254cm (0.3 and 0.1 in.), respectively
- HCGS Plant Area Buildings – 0.8 to 1.5 cm (0.3 to 0.6 in.)
- Independent Spent Fuel Storage Installation - 2.54 to 3.8 cm (1 to 1.5 in.)
- Buildings on Shallow Foundations – 3.30 to 4.8 cm (1.3 to 1.9 in.)

Since most structures outside of the nuclear island in the HCGS plant area are supported on piles, the applicant indicated that the settlements beneath HCGS plant area buildings will move the entire soil structure and overlying soil down as a unit and will result in minimal impacts. For buildings on shallow foundations, the applicant defined settlement as area settlement including pipes, roads, parking areas and other surrounding items. The applicant stated that, for buildings on shallow foundations, differential settlement is not expected between a building and adjacent areas. The applicant plans to further evaluate dewatering and potential impacts during the COL application stage.

2.5.4.2.7 Response of Soil and Rock to Dynamic Loading

SSAR Section 2.5.4.7 addresses the subsurface properties at the PSEG Site applicable to the evaluation of the ground motion site response. The applicant referred to SSAR Section 2.5.2.6 for a detailed description of the development of the GMRS. The applicant obtained the dynamic properties from field measurements (suspension P-S seismic velocity loggings, crosshole seismic velocity tests and down-hole seismic velocity tests) and laboratory testing (RCTS). Since the samples used for RCTS testing were susceptible to disturbance due to the presence of dense soils with cemented layers, the applicant developed the site velocity profile using the P-S suspension logging results. The applicant stated that the results of the crosshole and down-hole velocity tests are in agreement with the P-S suspension logging results.

2.5.4.2.7.1 Calculation of Dynamic Soil Property Profiles.

The applicant divided the dynamic profile into two portions: The shallow profile and the deep profile. The applicant used an elevation of -20 m (-67 ft) NAVD with an expected variation of plus or minus 1.2 m (4 ft) as the top of the competent layer (Vincentown Formation) in its

analysis. The applicant calculated the Poisson's ratio using the compression wave velocities (V_p) and shear wave velocities (V_s) obtained from the P-S suspension logging tests. The applicant applied a coefficient of variation of 0.25 to measurements of layers above a depth of 51 m (300 ft) and a coefficient of variation of 0.3 for measurements below 51 m (300 ft).

In SSAR Section 2.5.4.7.4.2, the applicant stated that the deep portion of the dynamic profile begins at the top of the Potomac Formation, and extends to the crystalline basement rock. The applicant defined the crystalline basement rock as material with a V_s greater than 2,804 m/s (9,200 ft/s) based on seismic refraction measurements reported by the Delmarva Power Summit site. SSAR Figure 2.5.4.7-10 presents the Delmarva Summit site location map in reference to the PSEG Site location. The applicant estimated the top of basement rock directly beneath the PSEG Site at elevation -533 m (-1,750 ft) NAVD. The applicant's estimate is based on the PSEG well information (PSEG-6) and on the interpolation among the nearest contour lines shown in three basement surface contour maps that extend from Delaware across New Jersey (SSAR Figure 2.5.4.7-9). The applicant correlated information from two seismic refraction survey lines reported in the Preliminary Safety Analysis Report for the Delmarva Power Summit site and used the velocity layering to develop a representative velocity profile. Figure 2.5.4-4 of this report (SSAR Figure 2.5.4.7-8(a)) presents the shallow and deep layered V_s profile.

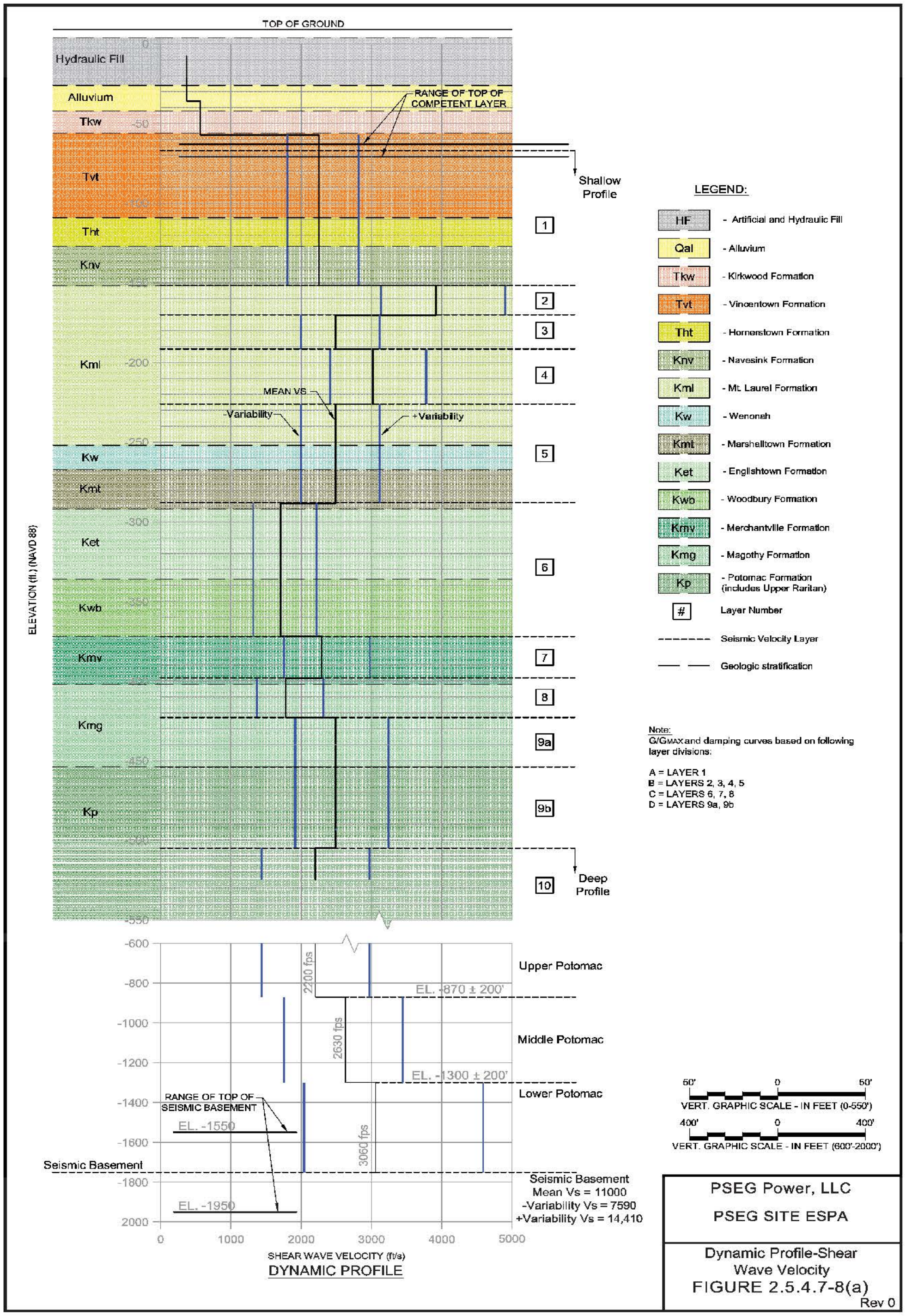

Figure 2.5.4-4 Dynamic Profile - Shear Wave Velocity (Reproduced from SSAR Figure 2.5.4.7-8(a))

Modulus Reduction and Damping Values. The applicant conducted RCTS testing in six intact samples that included the Vincentown, Hornerstown and Navesink formations. The applicant

did not consider one of the tests due to a high void ratio that was considered inconsistent with the character of the formation sampled.

The applicant did not use the RCTS test results to predict the modulus reduction and damping variation with shear strain because the RCTS test results are inconsistent with the EPRI generic curves. The applicant indicated that this inconsistency was due to the presence of the cemented layers within the formations which resulted in sample disturbance. The applicant determined that such results are not representative of the formation's behavior. Instead, the applicant used computational techniques for modeling modulus reduction and damping variation with shear strain based on results of RCTS test analyses developed at the University of Texas. The equation used to determine the modulus reduction and damping variation was developed by Darandeli (2001) and uses the confining pressure, plasticity index and overconsolidation ratio as inputs. The applicant divided the soils below the Vincentown and above the Potomac Formation into four layers, as summarized in SSAR Table 2.5.4.7-5. The resulting curves were used to develop the GMRS for the ESP site as discussed in SSAR Section 2.5.2.5.

2.5.4.2.8 Liquefaction Potential

SSAR Section 2.5.4.8 describes the liquefaction potential for the soils at the PSEG Site. The applicant performed geologically-based screening and also SPT-based liquefaction analyses in accordance with RG 1.198. Based on these analyses, the applicant stated that the soils below elevation -20 m (-67 ft) NAVD, or approximately 23 m (75 ft) below the present ground surface, are not susceptible to liquefaction. The applicant stated in SSAR Section 2.5.4.7.3 that the site has no evidence of liquefaction features based on aerial photographs and that no earthquakes larger than estimated body wave magnitude (Em_b) of 4.45 were recorded within the site vicinity.

2.5.4.2.8.1 <u>Geologically-based Liquefaction Assessment</u>.

In SSAR Section 2.5.4.8.2, the applicant performed a geologically-based liquefaction screening evaluation based on the composition of each formation, on the age of the formations and on the average corrected field SPT N value. The applicant stated that based on the granular composition (more than 50 percent sand) and the position below the water table; the Vincentown, Hornerstown, Navesink, Mount Laurel, Wenonah, Marshalltown, Englishtown, Magothy and Potomac Formations are potentially liquefiable. The applicant indicated that resistance of soils to liquefaction increases with age and that based on their ages, the formations below the top of the Vincentown Formation are not likely to liquefy. For the assessment based on the average corrected field SPT N value, the applicant indicated that because formations with an average corrected field SPT N value of less than 30 blows per foot are considered liquefiable, the Hornerstown, Wenonah and Englishtown formations are potentially liquefiable.

2.5.4.2.8.2 <u>SPT- based Liquefaction Assessment</u>.

In SSAR Section 2.5.4.8.3, the applicant described the SPT-based liquefaction assessment performed for the PSEG Site. The applicant calculated a factor of safety as the ratio of the cyclic resistance ratio (CRR) to the cyclic stress ratio (CSR). The CRR is based on SPT N-values corrected for sampling methods, overburden pressure, and fines content of the soil ($(N_1)_{60}$ values). The applicant computed this ratio based on an earthquake of magnitude 6. The CSR is a function of the maximum acceleration at the foundation level, total and effective

overburden pressures at the sample depth, and a stress reduction factor. The applicant used a maximum acceleration of 0.225g based on the GMRS calculation.

The applicant analyzed 257 SPT N-values from soil samples obtained from borings NB-1 through NB-8. Seventeen liquefaction factors of safety are less than 1.1, 15 factors of safety are between 1.1 and 1.4, and 225 are greater than 1.4. Based on the results of the calculation of factors of safety, the applicant stated that the potentially liquefiable soils are isolated pockets surrounded by dense material and not a continuous layer. The applicant stated that liquefaction below the top of the competent layer is not likely to occur.

The applicant stated that the nuclear island structures and other safety-related structures would not be impacted by liquefaction effects on soils outside of the excavation support structures. The applicant also stated that it will evaluate non-seismic liquefaction (erosion, floods, wind loads, etc.) during the COL application stage.

2.5.4.2.9 Earthquake Site Characteristics

SSAR Section 2.5.4.9 summarizes the derivation of the site-specific GMRS and SSE. The applicant developed the site-specific GMRS in accordance with the performance-based methodology provided in RG 1.208. The PSEG Site is located in the CEUS, which is a stable continental region. The applicant referred to SSAR Section 2.5.2.6 for detailed information on the development of the site-specific GMRS.

2.5.4.2.10 Static Stability

SSAR Section 2.5.4.10 describes the analysis of the stability of safety-related facilities (nuclear island) for static loading conditions. The applicant considered the following four technologies in its analysis: ABWR, AP1000, U.S. EPR, and US-APWR. SSAR Table 2.5.4.5-1 presents the plan dimensions and embedment depths for each plant technology. The applicant used the following design parameters in its stability analysis, based on the Design Control Document technologies cited above: foundation plan dimensions, upper and lower bound embedment depths of the foundation, and a static bearing pressure of 716 kN/m^2 (15,000 psf).

2.5.4.2.10.1 Bearing Capacity.

In SSAR Section 2.5.4.10.2, the applicant stated that it used three methodologies for the bearing capacity evaluation: Meyerhof, Terzaghi, and Vesic described by Bowles (1988). In the evaluation, the applicant assumed a granular structural backfill with properties similar to the fill used in the Hope Creek UFSAR: Compacted maximum dry unit weight of 20.1 kN/m^3 (128 lb/ft^3) and an angle of friction of 35 degrees. The applicant stated that the layers contributing to the bearing capacity are the Vincentown, Hornerstown, Navesink, and Mount Laurel Formations. The applicant used an average in-situ wet unit weight of 19.6 kN/m^3 (125 lb/ft^3) and an average angle of internal friction of 37 degrees to represent these layers. The applicant selected this angle of internal friction based on sample tests from the Vincentown Formation, in conjunction with calculation checks that are based on standard penetration resistance tests ($(N_1)_{60}$ values) for deeper formations. The applicant used a groundwater level at the existing ground surface, which is elevation 3 m (10 ft) NAVD in its analysis. The applicant calculated the ultimate bearing capacity as 20,100 kN/m^2 (420,000 psf).

2.5.4.2.10.2 Settlement Evaluation

In SSAR Section 2.5.4.10.3, the applicant stated that it has not established the criteria for total and differential settlement at the ESP application stage. The applicant calculated an example of possible settlement at the site using the technology with the largest mat foundation (U.S. EPR) combined with a representative static bearing pressure of 716 kN/m^2 (15,000 psf). The applicant indicated that the soils in the Vincentown and below are over-consolidated and that these soils will deform elastically because of the sandy composition of the soil and the over-consolidation of the hard clay zones. The applicant used two methods to calculate the settlement for the reactor building: Timoshenko and Goodier method, and the Janbu method described by Bowles (1988). The Timoshenko and Goodier method uses a single layer of material subject to compression (assumed to be twice the mat width in the ESP analysis) and a weighted average modulus of elasticity over this thickness. The Janbu method uses a layered subsurface model with the average vertical stress at the midpoint of each layer computed by stress distribution methods. SSAR Table 2.5.4.10-1 summarizes the layers, top elevations, unit weights, average shear wave velocities, shear modulus, Poisson's ratio, and elastic modulus used in the settlement analysis.

The applicant stated that the Janbu analysis method resulted in slightly greater estimated settlement than the Timoshenko and Goodier analysis method. The estimated settlement from the Janbu analysis, described above, was 4.1 cm (1.6 in.) for the center of the mat, and 2.54 cm (1 in.) for a side of the mat.

The applicant indicated that the subsurface layers are subhorizontal and have similar thicknesses and properties across the site. The applicant also indicated that the difference in applied stress conditions under the mat corner and the center is the only contributor to differential settlement.

2.5.4.2.11 Design Criteria

SSAR Section 2.5.4.11 summarizes the geotechnical design criteria discussed in the previous sections of the SSAR.

The applicant will provide additional settlement and construction groundwater control information at the COL application stage. SSAR Section 2.5.4.5 presents information regarding backfill material requirements. In SSAR Section 2.5.4.11, the applicant stated that the COL application will include an ITAAC for Operational Programs report to include the inspection, testing and acceptance criteria for backfill. However, in SSAR Section 2.5.4.5.3.3.2, the applicant stated that the backfill ITAAC will be part of a COL application. The staff notes that ITAAC for Operational Programs that do not relate to emergency planning are normally against Commission policy. The staff communicated this inconsistency to the applicant via a telephone call on June 17, 2014. In order to correct this inconsistency, on June 24, 2014, the applicant submitted supplemental information with SSAR markup for Section 2.5.4.11. The staff reviewed the applicant's information and determined that the applicant has appropriately corrected the inconsistency. The applicant committed to incorporate the SSAR changes in the next revision of the ESP application. The staff identified this as Confirmatory Item 2.5.4-1. The staff verified that in Revision 4 to the PSEG Site ESP application (June 5, 2015), the applicant incorporated the committed changes. Therefore, the staff considers Confirmatory Item 2.5.4-1 closed.

2.5.4.2.12 Techniques to Improve Subsurface Conditions

SSAR Section 2.5.4.12 discusses the soil improvement techniques in the foundation areas of the safety-related structures. As described in SSAR Section 2.5.4.5, the plant grade elevation is 11.2 m (36.9 ft). The materials above the stated base mat elevation are soft clays (hydraulic fill), loose sands (alluvium) and firm to soft clays (Kirkwood Formation). These materials are not adequate as bearing layers and the applicant described its plans to remove and replace them with backfill down to the competent material within the Vincentown Formation. To prepare the foundation-bearing soil, improvement techniques including over-excavation and replacement with backfill, and bearing surface compaction, will be necessary. The applicant stated that there is no need for deep soil improvement based on its preliminary static stability analysis.

2.5.4.3 Regulatory Basis

The applicable regulatory requirements for the stability of subsurface materials and foundations are as follows:

- 10 CFR Part 52, Subpart A, "Early Site Permit," as it relates to the requirements and procedures applicable to issuance of an early site permit for approval of a site for one or more power facilities.

- 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," as it relates to the design of nuclear power plant structures, systems, and components important to safety to withstand the effects of earthquakes.

- 10 CFR 100.23, "Geologic and Seismic Siting Criteria," as it relates to the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

- 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plant," as it relates to the requirements of the quality assurance program to be applied to the design, fabrication, construction, and testing of the structures, systems, and components of the facility.

The related acceptance criteria from NUREG-0800, Section 2.5.4 are as follows. Many of these acceptance criteria are not evaluated for an Early Site Permit, and are deferred to the COL stage. These are indicated within the Technical Evaluation section of this report:

- Geologic Features: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, the section defining geologic features is acceptable if the discussions, maps, and profiles of the site stratigraphy, lithology, structural geology, geologic history, and engineering geology are complete and are supported by site investigations that are sufficiently detailed to obtain an unambiguous representation of the geology.

- Properties of Subsurface Materials: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, the description of properties of underlying materials is considered acceptable if state-of-the-art methods are used to determine the static and dynamic engineering properties of all foundation soils and rocks in the site area.

- Foundation Interfaces: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, the discussion of the relationship of foundations and underlying materials is acceptable if it includes: (1) A plot plan or plans showing the locations of all site explorations, such as borings, trenches, seismic lines, piezometers, geologic profiles, and excavations with the locations of the safety-related facilities superimposed thereon; (2) profiles illustrating the detailed relationship of the foundations of all Seismic Category I and other safety-related facilities to the subsurface materials; (3) logs of core borings and test pits; and (4) logs and maps of exploratory trenches.

- Geophysical Surveys: To meet the requirements of 10 CFR 100.23, the presentation of the dynamic characteristics of soil or rock is acceptable if geophysical investigations have been performed at the site and the results obtained are presented in detail.

- Excavation and Backfill: To meet the requirements of 10 CFR Part 50 and 10 CFR Part 52, the presentation of the data concerning excavation, backfill, and earthwork analyses is acceptable if: (1) The sources and quantities of backfill and borrow are identified and are shown to have been adequately investigated by borings, pits, and laboratory property and strength testing (dynamic and static) and these data are included, interpreted, and summarized; (2) the extent (horizontally and vertically) of all Seismic Category I excavations, fills, and slopes are clearly shown on plot plans and profiles; (3) compaction specifications and embankment and foundation designs are justified by field and laboratory tests and analyses to ensure stability and reliable performance; (4) the impact of compaction methods are incorporated into the structural design of the plant facilities; (5) quality control methods are discussed and the quality assurance (QA) program described and referenced; (6) control of groundwater during excavation to preclude degradation of foundation materials and properties is described and referenced.

- Groundwater Conditions: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, the analysis of groundwater conditions is acceptable if the following are included in this subsection or cross-referenced to the appropriate subsections in Section 2.4: (1) Discussion of critical cases of groundwater conditions relative to the foundation settlement and stability of the safety-related facilities of the nuclear power plant; (2) plans for dewatering during construction and the impact of the dewatering on temporary and permanent structures; (3) analysis and interpretation of seepage and potential piping conditions during construction; (4) records of field and laboratory permeability tests as well as dewatering induced settlements; (5) history of groundwater fluctuations as determined by periodic monitoring of 16 local wells and piezometers.

- Response of Soil and Rock to Dynamic Loading: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, descriptions of the response of soil and rock to dynamic loading are acceptable if: (1) An investigation has been conducted and discussed to determine the effects of prior earthquakes on the soils and rocks in the vicinity of the site; (2) field seismic surveys (surface refraction and reflection and in-hole and cross-hole seismic explorations) have been accomplished and the data presented and interpreted to develop bounding P and S wave velocity profiles; (3) dynamic tests have been performed in the laboratory on undisturbed samples of the foundation soil and rock sufficient to develop strain-dependent modulus reduction and hysteretic damping properties of the soils and the results included.

- Liquefaction Potential: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, if the foundation materials at the site adjacent to and under Seismic Category I structures and facilities are saturated soils and the water table is above bedrock, then an analysis of the liquefaction potential at the site is required.

- Earthquake Design Basis: To meet the requirements of 10 CFR Part 50, the earthquake design basis analysis is acceptable if a brief summary of the derivation of the site-specific Ground Motion Response Spectrum is presented and references are included to Subsection 2.5.2.6. The staff's evaluation of the amplification characteristics of specific soils and rocks beneath the site as determined by procedures discussed in that section and in Subsections 2.5.4.2, 2.5.4.4, and 2.5.4.7 are summarized and cross-referenced herein. The review of Subsection 2.5.4.9 concentrates on determining its consistency or inconsistency with other subsections. Cross-referencing with other sections is expected.

- Static Stability: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, the discussions of static analyses are acceptable if the stability of all safety-related facilities has been analyzed from a static stability standpoint including bearing capacity, rebound, settlement, and differential settlements under deadloads of fills and plant facilities, and lateral loading conditions.

- Design Criteria: To meet the requirements of 10 CFR Part 50, and 10 CFR Part 52, the discussion of criteria and design methods is acceptable if the criteria used for the design, the design methods employed, and the factors of safety obtained in the design analyses are described and a list of references presented.

- Techniques to Improve Subsurface Conditions: To meet the requirements of 10 CFR Part 50, and 10 CFR Part 52, the discussion of techniques to improve subsurface conditions is acceptable if plans, summaries of specifications, and methods of quality control are described for all techniques to be used to improve foundation conditions (such as grouting, vibroflotation, dental work, rock bolting, or anchors).

In addition, the geologic characteristics should be consistent with appropriate sections from: RG 1.28, “Quality Assurance Program Requirements (Design and Construction)”; RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants”; RG 1.132, “Site Investigations for Foundations of Nuclear Power Plants”; RG 1.138, “Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants”; and RG 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites.”

2.5.4.4 Technical Evaluation

The staff reviewed SSAR Section 2.5.4 and verified that the information contained in the ESP application addresses the required information relating to the stability of subsurface materials and foundations. This section provides the staff's evaluation of the geophysical and geotechnical investigations conducted by the applicant to determine the static and dynamic engineering properties of the materials that underlie the PSEG Site. The applicant presented technical information in SSAR Section 2.5.4 resulting from field and laboratory investigations. The applicant used the subsurface material properties from its field and laboratory investigations to evaluate the site geotechnical conditions including liquefaction potential. The applicant performed a preliminary static stability assessment and deferred the final determination of static stability to the COL stage.

Through its review of SSAR Section 2.5.4, the staff determined whether the applicant adequately sampled the subsurface materials underlying the ESP site in order to characterize the engineering properties as well as the response of the site to dynamic and static loading. The staff also determined if the applicant complied with the applicable regulations and conducted its investigations at an appropriate level of detail. The staff reviewed the applicant's field and laboratory investigation data and associated assumptions and calculations used to determine the geotechnical properties of the soil underlying the ESP site. The staff reviewed the responses to the RAIs, calculation packages supplementing these responses and the information provided in the SSAR.

On September 29 and 30, 2011, the staff conducted a site audit to observe some of the applicant's onsite borings logs and field explorations, conduct visual inspections of soil samples and review the geology, seismology and geotechnical modeling and calculations, as well as analyses and results of selected soil samples. This audit allowed the staff to better understand the modeling results in order to make accurate safety conclusions concerning the site characteristics. Further, the audit assisted the staff in identifying additional information that the staff needs for its further review of the PSEG ESP application.

2.5.4.4.1 Description of Site Geologic Features

SSAR Section 2.5.4.1 refers to SSAR Section 2.5.1.1 and 2.5.1.2 for a description of the regional and site geology. Section 2.5.1.4 of this report presents the staff evaluation regarding the regional and site geology. The staff reviewed the summary of the description and characterization of the site geology provided in SSAR Section 2.5.4.1 including the site-specific stratigraphy, and foundation stability conditions such as: (1) Zones of weathering; (2) subsurface structural weakness; (3) and groundwater conditions.

The staff focused its review particularly on the stability of the Vincentown and Hornerstown formations, which will be the foundation bearing layers for the safety-related structures for the PSEG Site. The staff examined boring logs taken from these locations and noticed considerable low SPT field N values measured from the upper portion of the Vincentown formation. In RAI 41, Question 02.05.04-4, the staff requested that the applicant describe the extent of the weathered zones, the possible impact on Seismic Category I foundations and what measures will be taken to ensure foundation bearing quality as described in the SSAR Section 2.5.4.10.

In a January 6, 2012, response to RAI 41, Question 02.05.04-4, the applicant confirmed that weathering has affected the top of the Vincentown formation. The applicant referred to SSAR Figures 2.5.4.3-3 and 2.5.4.3-4 to justify that oxidized zones, caused by weathering, in the upper part of the Vincentown Formation were not indicative of low V_s or SPT N-values and stated that oxidation may not necessarily influence geotechnical engineering properties. The applicant also stated that the Vincentown formation conditions encountered as part of the ESP investigation were very similar to the ones described in the Hope Creek FSAR. The applicant indicated that only four field SPT N-values were found to be less than 10 bpf in the Vincentown Formation and those occurred within the top 3 m (10 ft) of the formation. The applicant indicated that regardless of the technology selected, the vertical excavation for Seismic Category I structures will extend approximately to elevation -20 m (-67 ft) NAVD, where the Vincentown Formation is located. The applicant committed to perform additional investigations during the COL phase in order to provide additional information on the extent, thickness and nature of the oxidized material in the Vincentown Formation beneath the area of

Seismic Category I structures for the selected technology. The applicant also committed to remove softer soils with considerably lower SPT N-values during construction. Consistent with the applicant's stated commitment, the staff identified the following COL action item:

COL Action Item 2.5-1

> An applicant for a COL or CP referencing this early site permit should perform additional investigations in order to provide additional information on the extent, thickness, and nature of the oxidized material in the Vincentown Formation beneath the area of Seismic Category I structures for the selected reactor technology. The applicant should also remove less dense soils with considerably lower SPT N-values in order to meet the soil condition requirements.

The staff reviewed SSAR Figures 2.5.4.1-11A through 2.5.4.1-14B, which correlates V_s values with SPT N-values. These figures correlated P-S velocities, SPT field N values and geophysical logging information for NB-1, NB-8, EB-3 and EB-8/EB-8G. The staff also reviewed the location of oxidized zones in the Vincentown Formation shown in SSAR Figures 2.5.4.3-3 and 2.5.4.3-4. The staff noticed small variations in SPT field N or V_s values. V_s increased with depth despite areas with lower than average SPT values. Accordingly, the staff concurs with the applicant in that the oxidized zones are not indicative of low V_s or SPT field N-values. To confirm the applicant's assessment that only four SPT measurements were lower than 10 bpf (SSAR Figure 2.5.4.1-10), the staff reviewed most of the boring logs provided as part of SSAR Appendix 2AA. The staff confirmed that these low values occur in samples above approximately elevation -20 m (-67 ft) NAVD, which will be removed during construction. In addition, the staff noted that most field SPT N-values encountered at the site were within the range of 11 to 30 bpf for the Vincentown Formation. According to Table G-1, "Soil Density or Consistency from Standard Penetration Test Data," in the U.S. Army Corps of Engineers Geotechnical Investigation Manual (EM 1110-1-1804), these values represent medium dense soils.

The staff also verified the HCGS subsurface investigation (PSEG, 2008) to validate the applicant's assessment that subsurface conditions were similar to the PSEG Site. Based on Hope Creek's 230s series boring logs (SSAR Figure 2.5.4.1-2), which were closer to the PSEG Site, the staff noted similarities in the subsurface stratigraphy for both sites. For example, the field SPT N-values followed very similar patterns in both sites.

After reviewing foundation soil V_s measurements, field SPT N-values and boring logs, the staff agrees with the applicant that low field SPT N-values in the upper portion of the Vincentown Formation will be removed during construction and oxidized zones were not indicative of low V_s. The staff confirmed that the SSAR was revised to reflect graphical errors on figures that present boring logs with geophysical information. Accordingly, the staff finds that the applicant adequately addressed this issue and, therefore, the staff considers RAI 41, Question 02.05.04 4, resolved.

2.5.4.4.2 Properties of Subsurface Materials

The staff focused its review of SSAR Section 2.5.4.2 on the applicant's description of the static and dynamic engineering properties of the soil strata underlying the PSEG Site, and the methods used to determine the site static and dynamic soil engineering properties. The staff reviewed the applicant's field investigation methods and laboratory testing program as well as the assumptions used to determine the properties of the subsurface materials. The review was

carried out with respect to the guidance of RG 1.132, RG 1.138, RG 1.208, and NUREG-0800, Section 2.5.4.

Description of Subsurface Materials

The staff reviewed the subsurface profile and materials, which described the underlying strata, categorized into 14 different soil strata. The staff focused its review of the subsurface in the Vincentown Formation, which would be the foundation bearing layer and will support the Seismic Category I structures for the PSEG Site. The Vincentown Formation is mostly composed of silty sands with some zones of clayey sands including various cemented zones. Based on the subsurface exploratory investigations and as indicated in SSAR Table 2.5.4.2-8, the applicant estimated that the top of the Vincentown Formation beneath the PSEG Site ranges from elevation -10 to -21 m (-33 to -70 ft) NAVD. The foundation bearing layer at the PSEG Site will be elevation -20 m (-67 ft) NAVD with an expected variation of plus or minus 1.2 m (4 ft). For its seismic analyses, the applicant selected approximately elevation -20 m (-67 ft) NAVD as the top of the competent Vincentown Formation. The applicant has not decided if Seismic Category I foundation basemat will be placed either on structural fill or on concrete fill placed directly on top of the bearing layer within the Vincentown Formation.

Field Investigations

The applicant performed its subsurface investigations during field operations in accordance with RG 1.132. The applicant employed the following exploration activities to collect data: Exploratory borehole drilling and sampling, in-situ geophysical testing and observation well installation and testing. The applicant stated that it performed all fieldwork under an audited and approved quality assurance program and work procedures. The scope of the work included 16 borings, 32 observation wells, 2 cross-hole, 4 suspension P-S velocity logging seismic tests and 1 downhole seismic velocity measurement. In addition, borehole deviation, natural gamma, resistivity, and caliper logging was performed in four boreholes.

The staff reviewed the power block and adjacent boring location plans and logs, the site subsurface profiles, and the results of the applicant's site exploration tests. SPT data was widely used by the applicant to derive the soils' engineering properties which include the determination of shear strength properties which were used as part of the foundation stability analysis. SSAR Table 2.5.4.2-8 states that the N_{60} values were determined by correcting the field SPT-N values for field conditions, including hammer energy. Typically, $(N_1)_{60,}$ values, which also include correction for overburden pressures, are used to determine site-specific soil properties. To ensure the adequacy of SPT data, in RAI 41, Question 02.05.04-10, the staff requested that the applicant indicate if it applied overburden corrections to sandy layers, and thus, if $(N_1)_{60}$ values were calculated. In addition, the staff requested that the applicant clarify if N_{60} instead of $(N_1)_{60}$ were used in the calculation checks to determine the internal friction angle. If $(N_1)_{60}$ values were used, the staff requested that the applicant make the appropriate corrections in SSAR Table 2.5.4.2-8.

In a January 6, 2012, response to RAI 41, Question 02.05.04-10, the applicant stated that $(N_1)_{60}$ values were calculated for non-cohesive soils for both NB and EB series borings, and that $(N_1)_{60}$ values were used to evaluate the foundation's stability described in SSAR Section 2.5.4.10.2. In addition, the applicant agreed to update SSAR Table 2.5.4.2-8 showing design (average) $(N_1)_{60}$ values for each formation.

The staff reviewed the applicant's January 6, 2012, response to RAI 41, Question 02.05.04-10. The staff also reviewed the latest revision of the calculation package (ESP 798, Calculation 2251-ESP-GT-001, Revision 4, "Correction of field SPT N values for field variables and effective overburden pressures") to verify the corrections made to field SPT N-values account for effective overburden pressures. The staff determined that these $(N_1)_{60}$ better represent the in-situ conditions and were used as input into foundation stability analyses (e.g., bearing capacity and liquefaction assessments). Since the calculation package was corrected, and the design $(N_1)_{60}$ values were included in SSAR Table 2.5.4.2-8, the staff concludes that the applicant adequately addressed this issue and, therefore, the staff considers RAI 41, Question 02.05.04-10, resolved.

Laboratory Testing

The applicant conducted the laboratory testing program in accordance with an approved quality assurance program following the guidance presented in RG 1.138. The staff reviewed the types and number of tests performed by the applicant, the locations from where the samples were taken, and the results of the tests. SSAR Section 2.5.4.2.1.1 states that RCTS tests were performed on six soil samples, and the results for one of these tests were disregarded due to the high void ratio in the sample. To confirm if these samples were considered representative of the soils sampled, in RAI 41, Question 02.05.04-6, the staff requested that the applicant explain the origin of this high void ratio and to indicate if this was a localized condition or if it was encountered in other locations at the site.

In a January 6, 2012, response to RAI 41, Question 02.05.04-6, the applicant referenced EB-3UD-UD-31 as the specific sample that was disregarded due to high void ratio. The applicant obtained this sample from the Mount Laurel Formation at depths from 63.4 m to 64.2 m (208 to 210.5 ft) below grade. The applicant indicated that this high void ratio was inconsistent with the character of the formation. To justify this statement, the applicant referred to the field SPT N-values and V_s obtained from the EB-3 boring, located adjacent and at similar depths to the boring where the referenced sample was obtained. Based on the consistently high field SPT N-values and V_s measurements obtained throughout the formation, the Mount Laurel Formation was characterized as "very dense" therefore, the applicant concluded that the sample might have been disturbed during sampling, and therefore, was not determined to represent the entire formation.

To evaluate if it was a localized condition, the staff verified the adjacent boring EB-3, for samples above, within, and below the interval sample EB-3UD-31. The staff noted that the field SPT N values evaluated in the adjacent boring were greater than 50 bpf, and that the V_s ranged around 790 m/s (2,600 ft/s). In addition, the staff reviewed field SPT N values from EB-1 to verify uniformity between adjacent borings and noted field SPT N values over 100 bpf within the Mount Laurel Formation. In-situ P-S velocity logging was not perform for EB-1, therefore actual V_s measurements from EB-8G, within the depth range discussed above, were reviewed and values over 730 m/s (2,400 ft/s) were encountered. Since high field SPT N values and V_s were encountered consistently throughout these borings at depths from 63.4 m to 64.2 m (208 to 210.5 ft), the staff concurs with the applicant that the Mount Laurel Formation could be considered very dense and the high void ratio sample was inconsistent with the character of the Mount Laurel formation. Accordingly, the staff considers RAI 41, Question 02.05.04-6, resolved.

SSAR Section 2.5.4.2.1.3.4 states that a ratio of vertical to horizontal stress (K_o) of 0.5 was used to calculate horizontal effective stresses on samples for RCTS testing. The applicant

stated that K_o of 0.5 is a typical value for normally consolidated soils. In RAI 41, Question 02.05.04-7, the staff requested that the applicant provide additional details to justify selecting this value, especially when SSAR Section 2.5.4.10.3 states that the soils in the Vincentown Formation and below are considered to be over-consolidated.

In a January 20, 2012, response to RAI 41, Question 02.05.04-7, the applicant stated that it initially calculated the mean confining pressure (σ_m) using a K_o of 0.5 and considering isotropic conditions. Since consolidation tests were not performed and the K_o value may not be known for a particular sample, the applicant decided to estimate confining pressure values based on 0.25, 0.5, 1, 2, and 4 times the calculated mean confining pressure. The applicant stated that the purpose of doing this was to allow for variations in the estimated K_o value in order for the RCTS tests to represent soil behavior at a wide range of possible consolidation conditions.

The staff evaluated the applicant's response to RAI 41, Question 02.05.04-7, but was not convinced that the applicant's method to calculate horizontal effective stresses on samples for RCTS testing produced accurate results. Specifically, the staff was concerned with how the applicant estimated K_o and used it to calculate σ_m without laboratory data to confirm results. In SSAR Section 2.5.4.7.5, the applicant stated that because of the existence of cemented layers and the dense consistency of in-situ soils, the intact samples obtained were disturbed and the RCTS test results were not representative of the formation. The applicant encountered inconsistent RCTS test results when compared to EPRI generic curves. The applicant decided to use Darandeli (2001) equations to develop degradation curves used to calculate the GMRS. The applicant indicated that Darandeli equations were results of research work at the University of Texas under the direction of Dr. Ken Stokoe and that the validity of these equations is supported by comparison with data from the Savannah River Site (Stokoe 2005).

The staff reviewed calculation package ESP811_PSEG_CALC_2251_ESP_GT_006_REV_2, "Dynamic Soil Profile," and reviewed how the applicant derived Darendeli curves. Darandeli equations use the confining pressure, plasticity index and overconsolidation ratio as inputs. The staff reviewed how the applicant estimated K_o and confining pressures and used them in the Darendeli equations. The staff found no information about the assumptions taken to obtain K_o used to estimate confining pressures. As a follow-up to RAI 41, Question 02.05.04-7, the staff issued RAI 64, Question 02.05.04-22, requesting that the applicant explain how variations in the estimated K_o were accounted for when using the Darandeli equations. The staff also requested that the applicant justify the use of K_o of 0.5 as input to the equation.

In a September 20, 2012, response RAI 64, Question 02.05.04-22, the applicant indicated that the Darandeli equations were calculated using a single value of K_o for all the layers. As part of its response, the applicant performed calculations to explore the effect of different K_o values on the calculated modulus of reduction (G/G_{max}) and damping variation with shear strain. K_o is an input that affects the mean effective pressure parameter that is an input to the Darandeli equations. Since a K_o of 0.5 is commonly used for normally consolidated soils, and the degree of overconsolidation in the subsurface soils is unknown, the applicant assumed three values of overconsolidation ratio (OCR) equal to 2, 4 and 6 to compute G/G_{max} and damping variation with shear strain for comparison with the original values that used a K_o of 0.5. The staff reviewed RAI Figures 64-22-1 through 64-22-8, which show the results of the calculations by comparing plots of the G/G_{max} and damping variation with shear strain for each of the three OCR cases against the original values. The staff noted that these plots showed a slight increase in the G/G_{max} and damping values for the same shear strain. Accordingly, the staff concurs with the applicant that the degradation curves developed using different OCRs are similar. The staff

considers RAI 64, Question 02.05.04-22 resolved. Additional details regarding the staff's review of Darandeli's equations and how they were used to estimate settlement is provided as part of the evaluation of the response to RAI 64, Question 02.05.04-25 (which is a follow-up of RAI 41, Question 02.05.04-13) in Section 2.5.4.4.7 of this report.

SSAR Table 2.5.4.2-4 illustrates several consolidated undrained triaxial test results for several samples from the Vincentown and Hornerstown Formations. The applicant stated that these soils have the presence of cemented zones and thus, samples from such materials are susceptible to disturbance. In RAI 41, Question 02.05.04-8, the staff requested that the applicant explain how two tests located on the northern part of the site are considered reliable to assess the soil's shear strength properties for the entire PSEG Site.

In a January 6, 2012, response to RAI 41, Question 02.05.04-8, the applicant used the Unified Soil Classification System (USCS) designation, V_s and field SPT N values to demonstrate that soils of the Vincentown and Hornerstown Formations are similar laterally across the site. To further justify the limited lateral variability in these two formations, the applicant developed two tables summarizing the field SPT N-values from the NB and EB borings. The applicant stated that based on average field SPT N-values of 37 and 57 bpf for the NB and EB respectively, site foundation soils could be classified as dense to very dense soils. The applicant referred to SSAR Table 2.5.4.7-3, which shows the lateral variation in V_s within the same geologic formations. Specifically, the applicant mentioned that V_s in the Vincentown and Hornerstown ranged from approximately 610 to 790 m/s (2,000 to 2,600 ft/s). Based on similar V_s and field SPT N values, the applicant concluded that the Vincentown and Hornerstown Formations are consistent laterally across the site and, therefore, soil engineering properties are likely to be similar. Based on this comparison, the applicant considered the soil shear strength values, determined from CU tests from NB- and EB-series borings, reliable to assess soil shear strength of the Vincentown and Hornerstown Formations.

The staff evaluated the applicant's January 6, 2012, response to RAI 41, Question 02.05.04-8. Specifically, the staff verified V_s and SPT data from samples recovered from the NB and EB borings. The staff reviewed SSAR Table 2.5.4.7-3 showing the lateral variation in V_s within the Vincentown and Hornerstown Formations obtained from P-S logging analysis from NB and EB borings. The staff noted that similar V_s values were encountered throughout the site. The staff reviewed the summary tables provided showing the field SPT N values and noted that the average field SPT N values for EB borings was 57 bpf ,while for the NB borings (borings located within the footprint of safety-related NPP foundations) was 37 bpf. As a follow-up to RAI 41, Question 02.05.04-8, the staff issued RAI 64, Question 02.05.04-23, requesting that the applicant explain how these formations were considered to be laterally uniform when considerable variations in average field SPT N values exist between NB and EB borings. In addition, the staff requested that the applicant explain why a design value of 47 bpf was used for the Vincentown and Hornerstown Formations and to justify how the selected single value statistically reflects the entire layer.

In a September 20, 2012, response to RAI 64, Question 02.05.04-23, the applicant clarified that the response to RAI 41, Question 02.05.04-8 describes the soils of the Vincentown and Hornerstown Formations in terms of similarities and do not present them as being laterally uniform. The applicant indicated that these soils will behave similarly because the average SPT values obtained from NB-series and EB-series borings represent dense sand. Since the field SPT N value of 47 bpf would provide higher soil shear strength properties than the average field SPT N value of 37 bpf for NB-series, the applicant decided to revise the design field

SPT N-value to 37 bpf for both formations. Consequently, the design corrected value, $(N_1)_{60}$, was revised from 35 bpf to 32 bpf. The applicant indicated that additional subsurface information will be obtained during the COLA phase to obtain more SPT data and further evaluate and fully characterize the engineering properties of the Vincentown and Hornerstown Formation, including their potential lateral and vertical variation.

The staff reviewed the September 20, 2012, response to RAI 64, Question 02.05.04-23, and along with the recommendation provided in the Federal Highway Administration FHWA (2002) regarding the estimation of the friction angle, the staff finds that field SPT N values ranging from 37 to 54 bpf are representative of dense to very dense sand. Since the design SPT $(N_1)_{60}$ is used to estimate the soil friction angle, the staff verified how the effective friction angle changes when calculated using design $(N_1)_{60}$ equal to 32 bpf. The staff noted that the effective friction angle calculated using the empirical equation with $(N_1)_{60}$ equal to 32 bpf is higher than the design effective friction angle of 37 degrees, selected by the applicant. Therefore, the staff finds that the applicant used an adequate and conservative field SPT N value and design friction angle value. Accordingly, the staff considers RAI 64, Question 02.05.04-23, resolved.

In response to RAI 64, Question 02.05.04-23, the applicant stated that it would conduct additional subsurface investigation during the COLA phase to evaluate and fully characterize the engineering properties of the Vincentown and Hornerstown Formations and their potential lateral and vertical variation. In addition, the applicant stated that it would perform additional strength tests to further evaluate the soil shear strength parameter for the Vincentown and Hornerstown Formations. Consistent with the applicant's stated intention, the staff identified the following COL action item:

COL Action Item 2.5-2

> An applicant for a COL or CP referencing this early site permit should conduct additional subsurface investigations to evaluate and fully characterize the engineering properties of the Vincentown and Hornerstown Formations and their potential lateral and vertical variation. The applicant should also perform additional strength tests to further evaluate the soil shear strength parameter for the Vincentown and Hornerstown Formations.

Engineering Properties of Soils

The staff reviewed SSAR Section 2.5.4.2.2 focusing on the static and dynamic engineering properties of each of the 14 layers derived from the applicant's field and laboratory testing programs.

<u>Static Engineering Properties for the Artificial Fill, Hydraulic Fill, Alluvium and Kirkwood Formation</u>

SSAR Sections 2.5.4.2.2.1.1 through 2.5.4.2.2.1.4 summarize the engineering properties for the top four soil layers encountered at the PSEG Site. The applicant provided the engineering properties of these for completeness, even though these layers will be removed beneath the nuclear island. The staff reviewed the information provided in the SSAR and concludes that the applicant provided sufficient information to characterize the geotechnical engineering properties of these soils and acknowledges that these units will be removed from beneath the planned PSEG safety-related foundation areas.

Static Engineering Properties for the Vincentown and Hornerstown Formations

SSAR Section 2.5.4.2.2.1.5 summarizes the engineering properties of the Vincentown and Hornerstown formations. The applicant performed 40 static laboratory index tests from 40 SPT samples and a series of shear strength tests, including CU triaxial compression tests. The applicant stated that, for engineering purposes, the Vincentown and Hornerstown Formations are combined into one engineering layer due to their similar engineering properties. The staff reviewed the assigned properties for these two layers and in RAI 41, Question 02.05.04-9, requested that the applicant provide additional details regarding properties from both layers and how overall properties were weighted. In addition, the staff requested that the applicant justify how both formations would behave similarly, especially when the Vincentown Formation is classified as mostly silty sand layer, while the Hornerstown Formation has a considerable increase in fine content.

In a January 20, 2012, response to RAI 41, Question 02.05.04-9, to justify similarities between Vincentown and Hornerstown Formations, the applicant developed Table RAI-41-9-1, which summarizes the engineering properties of these formations including data related to the USCS classification, percent fines, field SPT N values and V_s. The applicant determined the design values presented in SSAR Table 2.5.4.2-8 by considering data from each formation with no weighting. The staff reviewed Table RAI-41-9-1 and noted similarities in the engineering characteristics for both formations. The majority of the samples taken from the two formations are classified as poorly graded sand, silty sand and clayey sand with average percent of fines of 24. In addition, average V_s between 681 and 640 m/s (2,233 and 2,101 ft/s) and average field SPT N values between 45 and 52 bpf were noted for both formations. Based on these similarities, the staff concludes that it is appropriate to group the Vincentown and Hornerstown Formations for engineering purposes. The applicant committed to modify the SSAR to correct the references of SSAR Table 2.5.4.2-2. The staff confirmed that the SSAR was revised as committed in the RAI response. Accordingly, the staff finds that the applicant adequately addressed this issue and, therefore, considers RAI 41, Question 02.05.04-9, resolved.

Static Engineering Properties for the Navesink, Mount Laurel, Wenonah and Marshalltown, Englishtown and Woodbury, Merchantville, Magothy and Potomac Formations

In SSAR Sections 2.5.4.2.2.1.6 through 2.5.4.2.2.1.12, the applicant summarized the engineering properties for the remaining formations. The applicant classified the Navesink, Mount Laurel, Wenonah and Marshalltown formations as granular material and the Englishtown Woodbury, Merchantville, Magothy and Potomac Formations as clay material.

SSAR Section 2.5.4.2.2.1.6 states that two intact soil samples were recovered from the Navesink Formation. The applicant used these samples solely to determine static laboratory indices. In RAI 41, Question 02.05.04-11, the staff requested that the applicant explain why soil strength tests or other types of evaluations using these intact soil samples were not performed for this formation given that it is located directly within the safety-related foundation zone of influence.

In a January 6, 2012, response to RAI 41, Question 02.05.01-11, the applicant stated that the Navesink Formation was classified as very dense sand with an average $(N_1)_{60}$ of 45 bpf. The applicant also stated that the friction angle for this formation was estimated from an empirical correlation based on field SPT N values from the Federal Highway Administration Geotechnical Engineering Circular No. 5 (2002). To assess deformation or settlement properties, the applicant derived elastic properties from V_s measurements. The applicant explained that

because this formation was composed mostly of sandy soils and low fine content, direct shear or triaxial tests were not considered to estimate shear strength properties.

In the applicant's January 6, 2012, response to RAI 41, Question 02.05.04-11, the staff evaluated field SPT N-values from boring logs from the Navesink Formation used in correlations to estimate the formation's frictions angle. The field SPT N values for this formation were in the range of 40 and 80 bpf, which is indicative of a dense to very dense sand. When reviewing the FHWA geotechnical engineering manual, the applicant used to estimate the friction angle, the staff noted that several correlations were provided. It was unclear to the staff exactly which correlation the applicant used to estimate the friction angle. As a follow-up RAI 41, Question 02.05.04-11, the staff issued RAI 64, Question 02.05.04-24, requesting that the applicant clarify which correlation was actually used and to explain why a friction angle design value was not included in SSAR Table 2.5.4.2-8 for this formation. In addition, the staff requested that the applicant justify the adequacy of the friction angle, given the absence of laboratory testing and the sole reliance on empirical correlations.

In a September 20, 2012, response to RAI 64, Question 02.05.04-24, the applicant referenced its January 20, 2012, response to RAI 41, Question 02.05.04-15 for the calculation and the empirical correlation used to determine the friction angle for the Navesink Formation. The applicant provided the formula used for the calculation of the friction angle. The applicant clarified that it only reported in SSAR Table 2.5.4.2-8 the strength properties determined from laboratory shear strength test; therefore, the friction angle that was determined based on empirical correlations was not included in this table. The staff reviewed the applicant's response focusing on the FHWA methodology used for calculating friction angle and Table RAI-41-15-1b, which summarizes the friction angle results for Vincentown and Hornerstown, Navesink, and Mount Laurel Formations. When reviewing the FHWA methodology for selecting the friction angle based on SPT, the staff noted that for field SPT N-values ranging between 30 to 50 bpf, the effective friction angles ranged between 40 to 45 degrees. The staff also noted in the FHWA manual that for field SPT N-values higher than 50 bpf the effective friction angle would be higher than 45 degrees. The calculated friction angle based on the FHWA empirical formula was 46.3 degrees. The staff finds that the selection of 37 degrees for the friction angle for the Navesink Formation is a reasonable value for bearing capacity calculations. In the response to RAI 64, Question 02.05.04-24, the applicant stated that it would perform additional borings during the COLA phase to provide information for further evaluation of the shear strength properties of the Navesink formation. Consistent with the applicant's stated intention, the staff identified the following COL action item:

COL Action Item 2.5-3

> An applicant for a COL or CP referencing this early site permit should perform additional borings to provide information for further evaluation of the shear strength properties of the Navesink formation.

SSAR Section 2.5.4.2.2.1.8 states that the unit weights of soils for formations below the Mount Laurel were not determined for the ESP application. In RAI 41, Question 02.05.04-12, the staff requested that the applicant explain why unit weights were not determined. The staff also requested that the applicant include these values in SSAR Table 2.5.4.2-8.

As part of the January 6, 2012, response to RAI 41, Question 02.05.04-12, the applicant stated that no undisturbed samples were recovered for soils below the Mount Laurel Formation. From published correlations of typical soils and based on USCS classification, SPT N-values and

particle size distribution, the applicant selected a unit weight of 19.6 kN/m^3 (125 lbs/ft^3) as a representative value for formations below the Mount Laurel.

The staff reviewed the work of Coduto (2001) and the FHWA Soil and Foundation publication (2006), which present typical unit weights for various soil types depending on the saturation condition. The staff concludes that, given the ranges provided in these references (for saturated CL between 12 to 20 kN/m^3 (75 to 130 lb/ft^3) and for saturated SM between 17.3 to 21.2 kN/m^3 (110 to 135 lb/ft^3), a value of 19.6 kN/m^3 (125 lbs/ft^3) is considered a typical and reasonable value for unit weights for both sandy and clay type site soils encountered below the Mount Laurel Formation.

In the response to RAI 41, Question 02.05.04-12, the applicant stated that it would perform additional borings and unit weight determinations during the COLA phase of the project, including for the materials underlying the Mount Laurel Formation. Consistent with the applicant's stated intention, the staff identified the following COL action item:

COL Action Item 2.5-4

> An applicant for a COL or CP referencing this early site permit should perform additional borings and unit weight determinations for the materials underlying the Mount Laurel Formation.

Dynamic Material Properties

In SSAR Section 2.5.4.2.2.2, the applicant described the rationale followed when evaluating dynamic material properties. The applicant stated that RCTS tests were performed on samples from the Vincentown, Hornerstown and Navesink Formations. Given the dense and cemented nature of recovered samples, the RCTS test results from such materials were susceptible to disturbance and were not used to develop design shear modulus reduction and damping curves. Instead, the applicant used Darandeli equations described in Section 2.5.4.4.7 of this report, to develop the site dynamic profiles.

The staff reviewed the applicant's explanation regarding dynamic material properties, including RCTS results provided in SSAR Table 2.5.4.2-9 and Figures 2.5.4.2-4 through 2.5.4.2-7. The staff noted that the RCTS data range of shear strain is generally limited to strain less than 10^{-2} percent and does not cover the full range of shear strain presented by EPRI curves. The staff also noted that the pattern of the plotted data followed the shape of the EPRI curve, but with a more linear pattern, indicating the presence of cemented layers and dense consistency. The staff agrees with the applicant in that given the site soil condition, RCTS were unreliable and alternative methods should be considered. The staff's evaluation of these alternative methods and the processes followed to develop the site dynamic profile is provided in Section 2.5.4.4.7 of this report.

Conclusions Regarding the Properties of Subsurface Materials

Based on its review of SSAR Section 2.5.4.2 and the applicant's responses to the RAIs discussed above, the staff concludes that the applicant adequately determined the engineering properties of the soil underlying the ESP site following state of the art methodology for its field and laboratory investigations. The staff concludes that the applicant adequately characterized most of the layers by determining the extent, thickness, density, consistency, strength, and engineering and static design properties. However, the staff also concludes that the applicant

did not performed sufficient field investigation and laboratory testing to fully characterize the overall subsurface profile as well as the material properties underlying the ESP site.
The applicant committed to conduct additional subsurface investigation during the COLA phase to obtain additional SPT data, evaluate soil shear strength, perform additional unit weight determinations, thus evaluate and fully characterize the engineering properties of subsurface materials and their potential variation laterally and vertically.

Therefore, subject to COL Action Items 2.5-1 through 2.5-4 detailed above, the staff concludes that the applicant's description of the subsurface materials and properties at the PSEG Site forms an adequate basis to satisfy the criteria of 10 CFR Part 50 and 10 CFR Part 100.

2.5.4.4.3 Foundation Interfaces

In SSAR Section 2.5.4.3, the applicant described the foundation interface conditions at the PSEG Site based on a detailed geotechnical exploration and testing activity program, which include borehole drilling and sampling, in-situ geophysical testing and observation well installation and testing.

The staff's review focused on the relationship between the planned foundations for safety-related structures and the engineering properties of underlying materials. The applicant indicated that its PPE described in SSAR Section 1.3.3 shows the bounding condition for the reactor building/nuclear island base mat embedment depth as 12 m (39 ft) at its shallowest to 25.6 m (84.3 ft) at its deepest. The staff reviewed the position and properties of the subsurface stratigraphy relative to the bounding conditions of foundation embedment depths for safety-related structures. The staff noted that for an external plant grade of elevation 11.2 m (36.9 ft) NAVD, the range of vertical limit for the technologies, by elevation, is -0.6 to -14 m (-2.1 to -47 ft) NAVD, therefore, the proposed reactor building/nuclear island base mat embedment depths are bounded by the vertical limit of excavation at approximately elevation -20 m (-67 ft) NAVD. The staff reviewed the cross sections provided in SSAR Figures 2.5.4.3-3 and 2.5.4.3-4 in detail with the results of all subsurface investigations conducted at the site to ascertain that there has been sufficient exploration. The applicant stated that it would perform additional subsurface investigations in the COLA phase in order to ensure safety-related structures will be placed on competent foundation bearing materials. While the staff's COL Action Item 2.5-1 in Section 2.5.4.4.1 of this report addresses the need to perform additional subsurface investigations at the COL application stage, the staff's following COL action item includes additional specifics regarding these investigations:

COL Action Item 2.5-5

> An applicant for a COL or CP referencing this early site permit should perform additional subsurface investigations and correlate the plot plans and profiles of each Seismic Category I structure with the subsurface profile and material properties, and ensure placement of safety-related structures on competent foundation bearing material.

Conclusions Regarding Foundation Interfaces

The staff concludes that subject to COL Action Item 2.5-5, the applicant's description of the relationship between foundations and underlying materials, based on geotechnical exploration and testing, is consistent with state-of-the-art standards and common practice and is, therefore, acceptable.

2.5.4.4.4 Geophysical Surveys

The staff focused the review of SSAR Section 2.5.4.4 on the adequacy of the applicant's geophysical investigations to determine soil dynamic properties. The applicant relied primarily on the suspension P-S velocity logging method to determine the site stratigraphy and develop the site's V_s and V_p profiles. The applicant also obtained V_s and V_p profiles from crosshole seismic and downhole seismic velocity testing and compared the profiles to those obtained using P-S velocity logging. In addition, the staff considered the downhole geophysical testing results for additional information on the site's lithology and stratigraphy, location of low density zones, presence of clay, and variations in moisture content.

The staff reviewed the results of the geophysical surveys, specifically the profiles of V_s and V_p. The staff reviewed SSAR Figures 2.5.4.4-2 through 2.5.4.4-6, which show the V_s and V_p profiles developed from the downhole geophysical testing, suspension velocity logging and crosshole seismic velocity testing. The staff noted similar results between V_s and V_p along the profiles logged. Based on the applicant's site investigation program and results, the staff concludes that the applicant performed a complete and thorough geophysical survey of the PSEG Site using a variety of geophysical testing methods.

Conclusions Regarding Geophysical Surveys

Based on its review of SSAR Section 2.5.4.4, the staff concludes that the applicant adequately determined the soil dynamic properties through its geophysical survey of the ESP site and that the geophysical tests and methods form an adequate basis for the geophysical surveys of the site and meet the requirements of 10 CFR 100.23.

2.5.4.4.5 Excavation and Backfill

The staff reviewed SSAR Section 2.5.4.5, focusing on the earthwork for the proposed placement of safety-related structures, which includes the following activities: limits of excavation, construction excavation and dewatering, foundation excavation monitoring, backfill, compaction specifications and quality control testing. The applicant plans to raise the current ground surface elevation of 1.5 to 4.6 m (5 to 15 ft) to reach the proposed external plant grade of 11.2 m (36.9 ft) NAVD. The applicant also described plans to remove unsuitable materials at the power block area and below Seismic Category I structures and replace it with suitable backfill materials.

Extent of Excavations

The applicant indicated that the lateral and vertical extent of the excavation for Seismic Category I structures will depend on the plant technology chosen. The applicant defined the bearing layer at approximately elevation -20 m (-67 ft) NAVD based on shear wave velocities of 304.8 m/s (1,000 ft/s) or higher, therefore, the vertical limits of excavation for Seismic Category I structures will extend to approximately elevation -20 m (-67 ft) NAVD to reach the Vincentown formation. The staff reviewed boring logs presented in SSAR Appendix 2AA and noted that at elevation -20 m (-67 ft) NAVD, the V_s were 304.8 m/s (1,000 ft/s) or higher. SSAR Table 2.5.4-1 shows the plant dimensions for the four technologies assessed by the applicant. In SSAR Section 2.5.4.5, the applicant committed to provide specific details regarding the lateral and vertical extent of the excavation for the plant design technology selected in the COL application stage. Consistent with the applicant's stated commitment, the staff identified the following COL action item:

COL Action Item 2.5-6

> An applicant for a COL or CP referencing this early site permit should provide specific details regarding the lateral and vertical extent of the excavation consistent with the selected reactor technology.

Construction Excavation and Dewatering Methods

The staff reviewed the applicant's description of its dewatering methodology. The applicant plans to lower the water table to facilitate excavation work.

In SSAR Section 2.5.4.5.2.1, the applicant committed to evaluate the method of excavation support and the stability of temporary excavation slopes or support in the COLA stage. Consistent with the applicant's commitment, the staff identified the following COL action item:

COL Action Item 2.5-7

> An applicant for a COL or CP referencing this early site permit should evaluate the method of excavation support and the stability of temporary excavation slopes or support.

Backfill Properties and Compaction Specifications

The applicant mentioned several potential Category 1 backfill materials including: Lean concrete; roller compacted concrete (RCC) or structural granular material. The applicant indicated that the material removed from the excavation that meets the engineering requirements may be considered for use as Category 2 fill. The applicant stated that the lean concrete or RCC for backfill beneath and around the mat foundations will meet the requirements to support Seismic Category I structures. In addition, the applicant stated that the properties of the Category 1 granular materials are expected to be similar to the backfill used for the HCGS facility; however, the applicant deferred the determination of final granular backfill material properties to the COLA stage. The applicant committed to include specifications for placement and compaction of lean concrete, RCC and soil backfill at the COLA stage. In addition, in SSAR Section 2.5.4.5.3.3.2, the applicant committed to include in the COLA stage an ITAAC for the soil backfill, with specifications to ensure a V_s of 304.8 m/s (1,000 ft/s) or higher below Seismic Category I structures. Consistent with the applicant's commitment, the staff identified the following COL action item:

COL Action Item 2.5-8

> An applicant for a COL or CP referencing this early site permit should include in the COL application, an ITAAC for the soil backfill, with specifications to ensure a V_s of 304.8 m/s (1,000 ft/s) or higher below Seismic Category I structures.

The applicant indicated that the lateral loading conditions are not included as part of the ESP because information on the type and characteristics of these backfill materials is not available and the reactor technology, and its corresponding foundation depth, has not been selected. In SSAR Section 2.5.4.5.3, the applicant committed to evaluate lateral pressure from backfill materials and to discuss the details for the backfill quantities, types and sources during the COLA stage. Consistent with the applicant's stated commitment, the staff identified the following COL action item:

COL Action Item 2.5-9

> An applicant for a COL or CP referencing this early site permit should provide, consistent with the selected reactor technology, (i) details for the backfill quantities, types and sources; (ii) lateral loading conditions; (iii) information on the type and characteristics of backfill materials; and (iv) lateral pressure evaluation from backfill materials.

Foundation Excavation Monitoring

The staff reviewed SSAR Section 2.5.4.5.4. The applicant indicated that it will install geotechnical instrumentation for the nuclear island structures to monitor possible heave caused by removing soils during the excavation. The applicant stated that it will document the initial mat foundation excavation to the top of the competent layer to confirm that the soils conform to those used in the design. In SSAR Section 2.5.4.5.4.1, the applicant recognized the need to perform geologic mapping for documenting the presence or absence of faults and shear zones in plant foundation materials. Section 2.5.3.5, "Geologic Mapping Permit Condition," of this report identifies Permit Condition 3 as the COL or CP applicant's responsibility to perform detailed geologic mapping of excavations for nuclear island structures; and examine and evaluate geologic features discovered in those excavations.

In SSAR Section 2.5.4.5.4.2, the applicant committed to include the geotechnical instrumentation plan and monitoring schedule in the COL application. Consistent with the applicant's stated commitment, the staff identified the following COL action item:

COL Action Item 2.5-10

> An applicant for a COL or CP referencing this early site permit should include the geotechnical instrumentation plan and heave monitoring schedule in the COL application.

Conclusions Regarding Excavation and Backfill

Since the applicant has not selected a reactor technology design for the ESP site, it deferred to the COLA stage the specific details regarding excavation and backfill. However, regardless of the technology selected, the applicant defined the bearing layer at approximately elevation -20 m (-67 ft) NAVD, based on shear wave velocities of 304.8 m/s (1,000 ft/s) or higher. The applicant committed to provide specific details during the COLA stage regarding the lateral and vertical extent of the excavation for the plant design technology selected; the method of excavation support and the stability of temporary excavation slopes or support; the specification for placement and compaction of Category 1 backfill; ITAAC for the soil backfill and V_s; details for the backfill quantities, types and sources; lateral loading conditions; evaluation of the lateral pressure from backfill materials; and the instrumentation plan and monitoring schedule. Therefore, the staff defers its evaluation of the applicant's excavation and backfill plans until these plans are submitted as part of a COL or CP application.

2.5.4.4.6 Groundwater Conditions

The applicant described the installation of 16 well pairs in the site to characterize groundwater conditions. Eight of the well pairs were located in the north portion of the site within the new plant location. The applicant described the groundwater model it used to characterize

dewatering during construction and presented the dewatering effects on adjacent structures. SSAR Section 2.4.12 presents the applicant's full descriptions and results of the groundwater flow models during construction and subsequent plant operations. The staff's evaluation of this model is provided in Section 2.4.12.4 of this report.

The staff reviewed SSAR Section 2.5.4.6 focusing on the groundwater conditions relative to foundation stability for the safety-related structures. The staff noted that the average groundwater elevation of 0.2 m (0.6 ft) NAVD was calculated from groundwater monitoring data collected between January 2009 and July 2009 instead of the complete data range from January to December 2009. Since the position of the water table can affect the potential for liquefaction by changing the effective vertical stresses in the soil profile, in RAI 30, Question 02.05.04-2, the staff requested that the applicant discuss why the complete data range was not selected to calculate the average groundwater elevation. The staff also requested that the applicant discuss any potential impacts to the liquefaction assessment if the complete date range of monitoring data had been used.

In a June 29, 2011, response to RAI 30, Question 02.05.04-2, the applicant indicated that the depth to the groundwater table at each boring location used in the liquefaction evaluation was selected from water level measurements made in April 2009 in the shallow-depth observation wells installed adjacent to the geotechnical borings. In Table RAI-30-1, as part of the RAI response, the applicant summarized the groundwater elevations used for the liquefaction evaluation for each boring and the groundwater elevations from January through April at the observation wells near each boring. The applicant referenced SSAR Table 2.5.4.6-1 to indicate that the largest fluctuation in the shallow water table observation wells over the period from January 2009 to December 2009 was noted at 0.8 m (2.67 ft) in observation well NOW-2U. The maximum water table elevation for the observation well NOW-2U was at elevation 0.7 m (2.19 ft), which corresponds to a depth to water from the ground surface of 2 m (6 ft). As a consequence, the applicant prepared Table RAI 30-2, as part of the RAI response, to compare the factor of safety (FS) against liquefaction assuming a depth to the water table of 2 m (6 ft) instead of the original 2.6 m (8.4 ft) that was calculated based on groundwater data between January and July 2009.

The staff reviewed the liquefaction evaluation results after it considered the complete groundwater monitoring data, including the seasonal high water table. The staff reviewed the applicant's comparisons in calculated FS based on a different depth to the water table, as provided in Table RAI 30-2. The staff noted no changes for the factors of safety that were less than 1.4 and no additional samples with factors of safety less than 1.4. In the June 29, 2011, response to RAI 30, Question 02.05.04-2, the applicant committed to modify SSAR Table 2.5.4.8-2, update liquefaction factor of safety results and include additional information regarding this RAI. The staff confirmed that the revised SSAR includes the additional information as committed to in the RAI response. Accordingly, the staff finds that the applicant adequately addressed this issue and, therefore, considers RAI 30, Question 02.05.04-2, resolved.

The applicant also discussed its groundwater investigation in SSAR Section 2.4.12. SSAR Section 2.4.12.1.2.5 discusses the groundwater conditions for the bearing layer. The applicant stated that groundwater in the Vincentown Formation beneath the PSEG Site has relatively high concentrations of chloride and is not suitable for use as a water supply. Since high concentrations of chloride content have the potential to increase the risk of corrosion of steel reinforcement in concrete foundations, in RAI 41, Question 02.05.04-5, the staff requested that

the applicant indicate any measures that will be taken to mitigate these effects and to provide chemical analyses for groundwater and soils, specifically for sulfate and chloride concentrations and pH values.

In a January 6, 2012, response to RAI 41, Question 02.05.04-5, the applicant indicated that chemical analysis of groundwater was not conducted as part of this SSAR site investigation. To provide appropriate protection against corrosion of below grade steel and concrete structures, the applicant stated in the RAI 41, Question 02.05.04-5 response, that it would evaluate and implement, during the COLA stage, design measures appropriate for the chemical characteristics of the Category 1 fill, site soils and site groundwater. Consistent with the applicant's stated intention, the staff identified the following COL action item:

COL Action Item 2.5-11

> An applicant for a COL or CP referencing this early site permit should evaluate and implement, during the COL application stage, design measures appropriate for the chemical characteristics of the Category 1 fill, site soils and site groundwater.

In SSAR Section 2.5.4.6.3.1, the applicant described construction dewatering effects on adjacent structures. The applicant plans to conduct construction dewatering to facilitate excavation and allow proper fill placement. The staff reviewed SSAR Table 2.5.4.6-3, which shows a summary of groundwater drawdowns at existing structures within the Vincentown Formation after one year of dewatering. The staff reviewed Calculation Package PSEG 2251-ESP-GT-009, Revision 2, "Evaluation of ground settlement in the area of existing structures due to temporary dewatering," and Figure 2251-ESP-GT-009, which shows contour maps depicting these drawdowns overlaid onto a general layout plan of the existing HCGS and SGS plants. The staff noted different groundwater levels across the existing HCGS's and SGS's safety-related structure foundations and, in RAI 41, Question 02.05.04-18, the staff requested that the applicant discuss possible impacts on differential settlement and the stability of these safety-related structures due to these different groundwater levels.

In a January 20, 2012, response to RAI 41, Question 02.05.04-18, the applicant estimated possible differential elastic settlement under the HCGS and SGS safety-related structures resulting from the dewatering activities described above. The applicant indicated that because the soil properties of the Vincentown Formation and underlying formations were considered to be the same under all structures, the settlement is proportional to the drawdown and varies linearly with it. The staff reviewed Table RAI 41-18-1 as part of the RAI response, which summarizes the estimated future drawdown and vertical settlement under the HCGS and SGS safety-related structures after 1 year of dewatering during the excavations for PSEG structures. U.S. Army Corps of Engineers Manual (1990) establishes that the differential settlements should not exceed 1.3 cm (0.5 in.) in buildings, otherwise cracking and structural damage may occur. Following the Army Corps of Engineers technical manual for settlement, the staff concludes that the future elastic differential settlement calculated by the applicant (0.25 cm (≤ 0.1 in.)) is not anticipated to negatively impact existing HCGS and SGS safety-related structures. Accordingly, the staff considers RAI 41, Question 02.05.04-18, resolved.

Conclusions Regarding Groundwater Conditions

The applicant described the groundwater measurements and elevations, construction dewatering plans and dewatering effects on existing safety-related structures located adjacent

to the PSEG Site. Based on the information above, the staff concludes that the applicant conducted an appropriate preliminary evaluation of the groundwater conditions. However, the applicant did not select a reactor design nor provide a final evaluation of groundwater conditions as they affect foundation stability or detailed dewatering plans. Therefore, the staff could not evaluate in detail the groundwater conditions as they affect the loading and stability of foundation materials, as well as groundwater control throughout the life of the plant. As such, the staff defers these evaluations and plans until the information is submitted as part of the COL or CP application. In SSAR Section 2.5.4.6.3.1, the applicant committed to further evaluate dewatering and potential impacts during the COLA stage. Consistent with the applicant's stated commitment, the staff identified the following COL action item:

COL Action Item 2.5-12

> An applicant for a COL or CP referencing this early site permit should perform, consistent with the selected reactor technology, evaluation of groundwater conditions as they affect the loading and stability of foundation materials, and also provide detailed dewatering and groundwater control plans.

2.5.4.4.7 Response of Soil and Rock to Dynamic Loading

The staff reviewed SSAR Section 2.5.4.7, focusing on subsurface properties and the rationale used by the applicant when developing: seismic wave velocity profiles, modulus reduction and damping curves and Poisson's ratio, which were ultimately used as input to develop the site response analyses. The applicant provided detailed information on its site response analysis and development of the GMRS in SSAR Section 2.5.2.5.2.

The applicant indicated in SSAR Section 2.5.4.7.4.1 that the site shallow dynamic profile was based on four P-S suspension logged boreholes. The staff reviewed the V_s profiles shown in SSAR Figures 2.5.4.4-1 through 2.5.4.4-4, and noted that out of the four boreholes in which P-S suspension was used to measure V_s, two were used to record V_s measurements in deeper layers (between 90 to 180 m (300 and 600 ft)), and out of these two, just one measures V_s within the northern portion of the site or proposed location of Seismic Category I buildings. Therefore, in RAI 41, Question 02.05.04-17, the staff requested that the applicant indicate how variations in V_s were estimated based on only one P-S suspension reading over the deeper portion of the profile.

In a January 6, 2012, response to RAI 41, Question 02.05.04-17, the applicant indicated that, geologically, the materials are consistent across the entire area, and V_s values are similar between borings NB-1, located on the north and EB-3, located east of the PSEG Site. The staff reviewed geologic cross-section provided in SSAR Figure 2.5.4.1-4 and concurs with the applicant that, in the deeper portions across the site, similar V_s measurements were noted. In addition, the staff revisited SSAR Figures 2.5.4.7-1B, 2.5.4.7-1C, 2.5.4.7-3B, 2.5.4.7-3C, which show boring profiles with SPT and V_s data. The staff also noted, based on the review of SSAR Figure 2.5.4.7-7, similar V_s values in the deeper portions of the profile for borings NB-1 and EB-3. As detailed in Section 2.5.4.4.2 of this report, the applicant committed to perform additional geotechnical investigations during the COLA stage. The staff concludes that this additional geotechnical investigation will provide further insights regarding the site's potential V_s variability's in the deeper portions of the soil profile. Accordingly, the staff considers RAI 41, Question 02.05.04-17, resolved.

SSAR Section 2.5.4.7.5 states that the applicant used Darendeli equations instead of RCTS test results to characterize the degradation properties of foundation bearing soils because of sample disturbances of the cemented soil layers. In RAI 41, Question 02.05.04-13, the staff requested that the applicant justify the validity of Darandeli equations and discuss how they represent actual degradation properties of the soils at the site and whether it is a conservative approach when used in site seismic response analysis.

In a January 20, 2012, response to RAI 41, Question 02.05.04-13, the applicant stated that the validity of Darandeli equations to characterize the PSEG Site's dynamic properties was supported by a comparison with data from the U.S. Department of Energy (DOE) Savannah River Site, indicating that the subsurface conditions of the Savannah River Site were similar to PSEG Site. In addition, the applicant used the elastic modulus derived from the Darandeli equations to calculate the settlement estimates.

The staff reviewed Figures RAI-41-13-5 through RAI-41-13-8, which show the degradation curves derived using Darendeli equations and used to calculate the elastic modulus for the settlement analysis. As a follow-up to RAI 41, Question 02.05.04-13, in RAI 64, Question 02.05.04-25, the staff requested that the applicant (i) provide additional details on the similarities between the PSEG and Savannah soils and (ii) explain how the use of these curves was considered appropriate and conservative to estimate site-specific settlements and to justify using dynamic instead of static properties for this analysis.

In a September 20, 2012, response to RAI 64, Question 02.05.04-25, part (i), the applicant stated that the response to RAI 41, Question 02.05.04-13 was not intended to imply that the use of Darandeli equations was contingent upon soils at the PSEG Site being similar to those at the Savannah River site; but to show that the modulus reduction and the material damping for the Savannah River site calculated using Darandeli equations compared favorably with the results based on RCTS testing for the same site. The staff reviewed the applicant's September 20, 2012, response to RAI 64, Question 02.05.04-25, and noted that the Darandeli equations were the result of research work at the University of Texas under the direction of Dr. Ken Stokoe and the validity of Darandeli equations is supported by comparison with data from the Savannah River Site. The staff concludes that the Darandeli equations are appropriate to calculate the modulus reduction and material damping for the PSEG Site. Therefore, the staff considers RAI 64, Question 02.05.04-25, part (i), resolved. The staff also noted that the degradation curves were used for the GMRS analysis and for the calculation of the elastic modulus for the settlement preliminary analysis. Section 2.5.4.4.10 of this report provides the staff's evaluation of the applicant's response related to RAI 64, Question 02.05.04-25, part (ii), the estimation of site-specific settlements, and Section 2.5.2.4.6 of this report provides the evaluation related to the GMRS analysis.

Conclusion Regarding Response of Soil and Rock to Dynamic Loading

The staff reviewed SSAR Section 2.5.4.7, and concludes that the applicant provided adequate information on the subsurface properties and the rationale used when developing the V_s profiles and modulus reduction and damping curves used to perform the dynamic response analyses. Section 2.5.2.4.5 of this report contains the staff's evaluation of the applicant's site response analyses, and Section 2.5.4.4.2 of this report provides additional details of the staff's evaluation of the ESP site dynamic soil properties. In SSAR Sections 2.5.2 and 2.5.4.7, the applicant indicated that it developed the GMRS at the top of a competent layer as a result of the dynamic analyses and that the development of foundation input response spectra (FIRS) and the Soil

Structure Interaction (SSI) analysis will be performed during the COLA stage. Consistent with the applicant's stated intention, the staff identified the following COL action item:

COL Action Item 2.5-13

> An applicant for a COL or CP referencing this early site permit should develop the foundation input response spectra (FIRS) and the Soil Structure Interaction (SSI) analysis at the COL application stage.

2.5.4.4.8 Liquefaction Potential

In its review of SSAR Section 2.5.4.8, the staff evaluated the applicant's description of liquefaction potential, including the geological based screening and SPT based liquefaction analyses at the PSEG Site. The staff focused its review on the input parameters, assumptions and processes used in the SPT based liquefaction analysis. The staff reviewed the calculation package DCN ESP-750, calculation 2251-ESP-GT-008, Revision 5, "Potential Liquefaction Evaluation," to verify that the applicant used the method recommended by RG 1.198 for determining the FS against liquefaction. The applicant used the procedure described by Youd et al. (2001), which evaluates soil strength against liquefaction based on SPT blowcount values and the induced cyclic stresses based on earthquake PGA and magnitude values.

To conduct a confirmatory analysis, in RAI 8, Question 02.05.04-1, the staff requested that the applicant provide additional information regarding the following site-specific input parameters used for the liquefaction evaluation; SPT N_{60}, V_s, shear modulus, effective overburden pressures and total stresses values. In addition, in RAI 30, Question 02.05.04-3, the staff requested that the applicant provide the methods and equations used to calculate $(N_1)_{60,}$ Cyclic Stress Ratio ($CRR_{7.5}$), Magnitude Scaling Factor (MSF), correction factor for overburden stress (k_s) and to justify the selected values.

In a March 21, 2011, response to RAI 8, Question 02.05.04-1, and a June 29, 2011, response to RAI 30, Question 02.05.04-3, the applicant provided the requested information regarding the input parameters used for the staff's confirmatory liquefaction analysis. In the March 21, 2011, response to RAI 8, Question 02.05.04-1, the applicant committed to modify associated text in SSAR Sections 2.5.4.2 and 2.5.4.8. While preparing the response, the applicant found a discrepancy in the assignment of stratigraphy to the split spoon samples. The applicant included corrections for the samples above the competent layer and committed to incorporate changes in the next scheduled update to the SSAR. The staff confirmed that Revision 1 of the ESP application, dated May 21, 2012, contains the SSAR changes committed in the RAI response. Accordingly, the staff finds that the applicant adequately addressed this issue and, therefore, considers RAI 8, Question 02.05.04-1, resolved.

The staff was able to conduct the liquefaction confirmatory analysis using the methods described in RG 1.198. When performing the confirmatory analysis, the staff noted some variations between the FS calculated by the staff and the FS provided by the applicant. Therefore, the staff revisited the applicant submittal and noted that in the June 29, 2011, response to RAI 30, Question 02.05.04-3, the applicant indicated that the equation for relative density was developed based on Tokimatsu and Seed (1987), Figure 3 and stated that the value used for the calculation of the relative density was the field corrected value $(N_1)_{60cs}$, which includes correction for fines content. The staff reviewed Tokimatsu and Seed (1987) and noted that the equation from Figure 3 does not use SPT $(N_1)_{60cs}$ values. The relative density is used to calculate the overburden correction factor (K_σ), which was, in turn, used to adjust the calculated

liquefaction FS to account for high stresses. Therefore, as a follow-up to RAI 30, Question 02.05.04-3, in RAI 45, Questions 02.05.04-20, and 02.05.04-21, the staff requested that the applicant elaborate about how the relative density equation was derived, given the discrepancy noted above between different SPT N values used in the RAI responses and in Tokimatsu and Seed (1987).

In a December 19, 2011, response to RAI 45, Questions 02.05.04-20, and 02.05.04-21, the applicant elaborated on the development of the relative density equation. Figure RAI-45-21-1 shows a relationship curve representing the relative density equation using SPT N-values measured by Japanese standards. From this curve, the applicant derived an equation relating $(N_1)_{60}$ to the relative density as follows:

$$D_r = k\ [(N_1)_{60}]^{0.5}$$

where
D_r= relative density
k= constant
$(N_1)_{60}$= Field SPT N value corrected for overburden stress, energy, borehole diameter, rod length and sampler liner

The applicant selected D_r and $(N_1)_{60}$ values from Figure RAI-45-21-1 and calculated a value of 15 for k. Furthermore, the applicant indicated that the inclusion of $(N_1)_{60cs}$ was a typographical error as fines content is not part of the equation to determined relative density. The applicant indicated that the correct equation includes $(N_1)_{60}$, which is the field SPT N-value corrected for overburden stress, energy, borehole diameter, rod length and sample liner. The staff reviewed the derivation of the formula, including the calculation of the k value and noted that the applicant employed a reasonable approach for determining the values of relative density. In accordance with the method of Youd and others (2001) referenced in RG 1.198, the staff agrees that $(N_1)_{60}$ is the correct value to use for the K_σ value, ultimately used to adjust the calculated liquefaction factor of safety to account for high stresses. In its June 29, 2011, response to RAI 30, Question 02.05.04-3, the applicant committed to modify the SSAR to include the appropriate markups for this response. The staff confirmed that the Revision 1 of the ESP application, dated May 21, 2012, contains the SSAR changes committed in the RAI response. Accordingly, the staff finds that the applicant adequately addressed this issue and, therefore, considers RAI 30, Question 02.05.04-3, and RAI 45, Questions 02.05.04-20 and 02.05.04-21 resolved.

In addition, when reviewing PSEG calculation package DCN ESP-750, calculation 2251-ESP-GT-008, Revision 5, “Potential Liquefaction Evaluation,” the staff noted that for the calculation of the Cyclic Stress Ratio, the stress reduction factor (rd) was calculated starting at elevation -20 m (-67 ft) NAVD, and the total overburden stress and the effective overburden stress were calculated from the ground surface elevations at the boring locations at the time the borings were drilled. In RAI 41, Question 02.05.04-19, the staff requested that the applicant justify the difference in the chosen depth for the calculation of the stress reduction factor, overburden stresses and effective overburden stresses and to discuss how the difference in the chosen depth affects the factors of safety against liquefaction.

In a January 6, 2012, response to RAI 41, Question 02.05.04-19, the applicant prepared additional calculations using boring NB-1 data to illustrate the effect on FS based liquefaction of using rd computed with the ground surface as the reference point (3.9 m (12.8 ft)), instead of at

the top of the competent material, at elevation -20 m (-67 ft) NAVD. Based on this new calculation, the FS calculated using an rd referenced at elevation -20 m (-67 ft) NAVD were lower than the FS calculated using an elevation 3.9 m (12.8 ft). Therefore, the applicant concluded that rd will be calculated from elevation -20 m (-67 ft) NAVD, since it will provide more conservative results.

The staff reviewed Table RAI-41-19-1 as part of the RAI response, which compares the results from the additional calculation. The staff noted that the factors of safety when the rd is computed at the existing ground elevation, are greater than if rd is computed at -20 m (-67 ft) NAVD. The staff agrees that to compute rd at elevation -20 m (-67 ft) NAVD produces conservative FS values. This explains the variations between the FS calculated in the staff's confirmatory analysis and the FS calculated by the applicant. However, given that input parameters were calculated using different references within the soil profile, the staff issued RAI 69, Question 02.05.04-27, as a follow-up to RAI 41, Question 02.05.04-19, requesting that the applicant justify in the SSAR the deviation from the formula and explain the appropriateness of the results, or correct the liquefaction analysis and include the changes in the SSAR.

In an April 4, 2013, response to RAI 69, Question 02.05.04-27, the applicant referenced its December 20, 2012, response to RAI 61, Question 02.05.02-10, to support its conclusion. As a result of RAI 61, Question 02.05.02-10, in which the staff requested that the applicant re-evaluate the site seismicity using the CEUS-SSC model, the applicant revised its liquefaction analysis using a PGA equal to 0.225g. To support its response, the applicant selected the result of condition 1 in Table RAI-69-1 as part of the response to RAI 69, which computes liquefaction FS using rd computed at the top of the competent material at elevation -20 m (-67 ft) NAVD. In Table RAI-69-2, as part of the response to RAI 69, the applicant reported a total of 17 liquefaction safety factors less than or equal to 1.1, 15 of which are in the Vincentown Formation. The applicant characterized these specific samples as isolated pockets surrounded by denser materials, not a continuous layer. The applicant concluded that liquefaction of granular soils below the top of the Vincentown Formation is not likely to occur. The applicant committed to revise SSAR Section 2.5.4.8 and SSAR Table 2.5.4.8-2 to incorporate changes in response to RAI 69, Question 02.05.04-27. The staff confirmed that Revision 3 of the ESP application, dated March 31, 2014, contains the SSAR changes committed in the RAI response. Accordingly, the staff finds that the applicant adequately addressed this issue and, therefore, considers RAI 69, Question 02.05.04-27 resolved. However, the staff noted that results from the updated liquefaction analysis, based on a higher input PGA, indicate a considerable increase in the number of samples with FS less than or equal to 1.1. Table RAI-69-1, shows that most of the points with FS equal to or less than 1.1 are located within the Vincentown Formation and are from samples taken from borings NB-1, NB-2, NB-3 and NB-4. In the first 15 m (50 ft) evaluated by the applicant, a total of 17 values of FS were equal to or lower than 1.1. The staff notes a consistent pattern in the FSs that might indicate a potentially weak liquefiable zone. Given the considerable number of samples with FS equal to or lower than 1.1 encountered at the site, and the limited extent of field investigation performed at the site, as a follow-up to RAI 69, Question 02.05.04-27, the staff issued RAI 70, Question 02.05.04-28, requesting that the applicant justify its conclusion.

In a July 17, 2013, response to RAI 70, Question 02.05.04-28, the applicant provided site information and references regarding geologic aging, historical information from the HCGS's and SGS's licensing studies and a discussion of the evaluation of liquefaction potential using a V_s screening method proposed by Andrus, Stokoe II and Juang (2004). The applicant indicated that according to literature, the Vincentown Formation is considered generally immune to

liquefaction because of its pre-Pleistocene age. However, RG 1.198 indicates that cases of liquefaction have been observed in Pleistocene and pre-Pleistocene deposits, especially those deposits dealing with dune sands, talus and loess. The applicant stated that Vincentown Formation consists of marine sediments and does not contain dune sands, talus or loess.

The staff reviewed the references associated with the V_s screening used by the applicant to support its conclusion. Particularly, the staff focused in the reference by Andrus, Stokoe II and Juang (2004), which provides guidance to evaluate liquefaction potential based on V_s data. The paper proposes an approach to extend V_s screening to deeper depths and to older geologic formations. Andrus, Stokoe II and Juang (2004) based its calculation of the CSR on Youd et al., (2001), but proposed the calculation of the CRR based on stress correction of V_s and the application of an age correction factor to the CRR. Although the case study presented in Andrus, Stokoe II and Juang (2004) demonstrates that cyclic strengths could increase with age, it also indicates that a high degree of uncertainty is present in the results due to assumptions made and limited case history data. Furthermore, Andrus, Stokoe II and Juang (2004) acknowledge that additional work is needed to better quantify the influence of age on V_s and liquefaction resistance of soils. Since there is no professional consensus on a quantitative correction factor to account for the age of the deposit, the staff concludes that, for the use of age correction factor in the liquefaction assessment, additional investigation is needed to better quantify the influence of age on V_s and liquefaction resistance of soils.

In addition, the staff reviewed information provided by the applicant regarding borings logs performed at HCGS and SGS. Based on the review of these borings, the applicant indicated that the low values for FS against liquefaction do not indicate a continuous liquefiable layer across the PSEG Site. The staff reviewed the URS Corporation Independent Spent Fuel Storage Installation (ISFSI) Geotechnical Investigation borings report detailing borings performed directly south of the south boundary of the PSEG Site and confirmed that only two instances of lower blow count were found below elevation -20 m (-67 ft) NAVD of the 11 borings performed. Although this supports the applicant's conclusion regarding not having a continuous liquefiable layer across the PSEG Site, it is not located in the area of interest enclosed by PSEG borings NB-1, NB-2, NB-3 and NB-4. In its response, the applicant referred to 10 borings from HCGS located in the area between NB-4 and NB-8 and extending approximately 240 m (800 ft) south of these borings to indicate that PSEG borings with lower blow counts are an isolated condition. However, these 10 borings are not located within the area enclosed by borings NB-1, NB-2, NB-3 and NB-4. Moreover, the applicant provided information regarding boring 30 of the SGS site investigation, which is located in the area enclosed by borings NB-1, NB-2, NB-3 and NB-4. The staff reviewed the boring log and found five instances of low blow counts (less than 30 bpf) in the Vincentown Formation, between elevation -20 m (-67 ft) and -27 m (-90 ft) NAVD. The field investigation data presented by the applicant from past licensing studies and current field investigation data in the PSEG Site area indicates that the Vincentown Formation does have instances where looser soils are encountered which are associated with low liquefaction FSs, which might indicate a potentially weak liquefiable zone in the area enclosed by borings NB-1, NB-2, NB-3 and NB-4. Therefore, the staff notes that additional geotechnical investigation is needed for a complete seismic liquefaction assessment at the COL stage. In addition, as part of its response to RAI 70, Question 02.05.04-28, the applicant acknowledged that additional borings will be conducted during the COL stage, and analyzed to determine if zones of lower blow counts are present underneath the competent layer. If the additional borings and analyses performed during COLA development identify areas where the potential for liquefaction may be present, the applicant stated that it would remove the unsuitable material

and replace it with competent material. Consistent with the applicant's stated intention, the staff identified the following COL action item to address liquefaction potential:

COL Action Item 2.5-14

> An applicant for a COL or CP referencing this early site permit should perform additional geotechnical investigation, consistent with RG 1.132, including the performance of additional borings and a detailed liquefaction assessment to determine if zones of lower blow counts, which might indicate a potentially weak liquefiable zone, are present underneath the competent layer. If the additional borings and analyses identify areas where potential for liquefaction may be present, the applicant should remove unsuitable materials and either replace it with competent material or improve it to eliminate liquefaction potential.

NUREG-0800 suggests that non-seismic liquefaction, such as that induced by erosion, floods, wind loads on structures and wave action should be analyzed using state-of-the-art principles of soil mechanics. In SSAR Section 2.5.4.8.5, the applicant committed to evaluate non-seismic liquefaction during the COLA stage. Consistent with the applicant's stated commitment, the staff identified the following COL action item to address non-seismic liquefaction:

COL Action Item 2.5-15

> An applicant for a COL or CP referencing this early site permit should evaluate non-seismic liquefaction.

In SSAR Section 2.5.4.7.4.1, the applicant stated that the soils above the Vincentown Formation present unsuitable engineering characteristics with shear wave velocities less than 304.8 m/s (1,000 ft/s). The applicant stated that they will remove these soils from the area of safety-related structures to reach the competent material and replace it with a suitable backfill. The applicant stated that the top of the competent layer is located, in the Vincentown Formation, at approximately elevation -67 ft NAVD.

Consistent with the applicant's commitments described above, the staff identified Permit Condition 4, described in Section 2.5.4.5 of this report.

Conclusions Regarding Liquefaction Potential

The staff concludes that based on the information and findings above, the applicant used an acceptable methodology to determine the liquefaction potential of the soil underlying the ESP site. Because soils above the Vincentown Formation present unsuitable engineering characteristics, the applicant stated that it will remove and replace these soils from the area of safety-related structures. Subject to Permit Condition 4 described in Section 2.5.4.5 of this report, and COL Action Items 2.5-14 and 2.5-15, the staff concludes that the information provided in the ESP is consistent with the guidelines in NUREG-0800.

2.5.4.4.9 Earthquake Design Basis

SSAR Section 2.5.4.9 summarizes the applicant's approach to derive the site-specific GMRS and SSE. This derivation is detailed by the applicant in SSAR Section 2.5.2.6. The applicant indicated that the GMRS satisfies the requirements of 10 CFR 100.23 for the development of

the site-specific SSE ground motion. Section 2.5.2.4.6 of this report provides the staff's evaluation for the GMRS and SSE.

2.5.4.4.10 Static Stability

The staff reviewed SSAR Section 2.5.4.10 focusing on the applicant's evaluation of bearing capacity and settlement of the bearing strata at the ESP site. For its analyses, the applicant used the reactor foundation design parameters included in the reactor technology Design Control Documents (DCD) for four reactor technologies: ABWR; AP1000; U.S. EPR; and US-APWR.

Bearing Capacity

The applicant evaluated the bearing capacity under static and dynamic conditions using three methodologies that included: Meyerhof, Terzaghi and Vesic described by Bowles (1988). Based on the evaluation of bearing capacity for the technologies stated above, the applicant determined that the PPE value for the ultimate bearing capacity was 20,100 kN/m^2 (420,000 psf) under static conditions. The ultimate bearing capacity is defined as the bearing pressure required to produce a bearing capacity failure. The staff performed a confirmatory analysis using the design foundation parameters for each technology and the PSEG soil properties. The staff used 37 degrees as the effective angle of friction and a unit weight of 19.6 kN/m^3 (125 lb/ft^3), the foundation dimension and embedment depth for each design technology, and a groundwater depth of 3 m (10 ft) NAVD. The staff used the Terzaghi and Vesic methodologies and concluded that the PPE value for the ultimate bearing capacity is appropriate for the four reactor technologies considered by the applicant. The staff's confirmatory analysis for each of the technologies produced values for the ultimate bearing capacity of approximately 20,100 kN/m^2 (420,000 psf) or higher.

The applicant stated in SSAR Section 2.5.4.10.2 that for the bearing capacity calculations, a friction angle of 37 degrees was selected based on N_{60} values and a unit weight of 19.6 kN/m^3 (125 lb/ft^3) based on a weighted average of unit weights from the Vincentown, Hornerstown, Navesink and Mount Laurel Formations. In Section 2.5.4.4.2 of this report, the staff discussed RAI 41, Question 02.05.04-15, related to the selection of the internal friction angle. Also in RAI 41, Question 02.05.04-15, the staff requested that the applicant justify selecting 19.6 kN/m^3 (125 lb/ft^3) for the bearing capacity calculation, when the referenced values given in SSAR Table 2.5.4.2-9 were lower.

In a January 20, 2012, response to RAI 41, Question 02.05.04-15, the applicant indicated that it used the weighted average of the unit weight for the combined Vincentown and Hornerstown, Navesink, and Mount Laurel Formations, instead of using its design values. The applicant presented details in Table RAI-41-15-2 as part of the RAI response. The applicant indicated that the unit weight values given in SSAR Table 2.5.4.2-8 for these formations were used to calculate the average unit weight for use in the bearing capacity analysis. The staff reviewed Table RAI-41-15-2 and considers that the use of weighted unit weights is a simplification that provides a reasonable approximation of the bearing capacity. Accordingly, the staff considers RAI 41, Question 02.05.04-15, resolved. However, the staff identified the following COL action item to address recalculations of the bearing capacity:

COL Action Item 2.5-16

An applicant for a COL or CP referencing this early site permit should analyze the stability of all planned safety-related facilities, including static and dynamic bearing capacity, rebound, settlement, and differential settlements under dead loads of fills and plant facilities, as well as lateral loading conditions.

Settlement

In SSAR Section 2.5.4.10.3, the applicant stated that it has not established the criteria to estimate the site-specific total and differential settlement because the settlement is dependent on the position of the applied load relative to the subsurface layer and the size of the mat. This information has not yet been determined. The staff reviewed SSAR Section 2.5.4.10.3, which includes a preliminary evaluation of possible settlement at the site using the technology with the largest mat foundation, U.S. EPR.

As stated in Section 2.5.4.4.7, of this report, the staff reviewed Figures RAI-41-13-5 through RAI-41-13-8, as part of the response to RAI 41, which show the degradation curves derived using Darendeli (2001) equations, and which the applicant used to calculate the elastic modulus for the settlement analysis. As a follow-up to RAI 41, Question 02.05.04-13, the staff issued RAI 64, Question 02.05.04-25, part (ii), requesting that the applicant explain how the use of these curves was considered appropriate and conservative to estimate site-specific settlements and to justify them using dynamic, instead of static, properties for this analysis.

In a September 20, 2012, response to RAI 64, Question 02.05.04-25**,** part (ii), the applicant indicated that it used the V_s to estimate the elastic modulus of a soil using the method described in FHWA Geotechnical Engineering Circular (2002). The applicant estimated the elastic modulus as follows:

$E/E_0 = 1 – (q/q_{ult})^{0.3}$ where

E= reduced modulus for higher shear strain

E_o= modulus at low shear strain

q= applied bearing pressure

q_{ult}= ultimate bearing pressure

The applicant stated that the ratio E/E_o is the same as G/G_{max}, because E and E_o are related to G and G_{max} by the same factor. The applicant calculated E/E_o of 0.63 using a typical bearing pressure for reactor technologies of 15,000 psf (716 kN/m^2) and q_{ult} of 20,100 kN/m^2 (420,000 psf). While reviewing the applicant's response, the staff noted that the applicant used a conservative ratio to estimate the settlement, because the G/G_{max} listed in SSAR Table 2.5.4.10-1 is lower than that calculated using its PPE parameters for bearing pressure. In addition, the applicant compared the estimated settlement using reduction values of 0.4 and 0.5 with the estimated settlement using modulus reduction curves at 10^{-3} and concluded that the results show an increase of approximately 10 percent in the estimated settlement using reduction values. The staff concludes that the reduction values of 0.4 for materials above elevation -90 m (-300 ft) and 0.5 for materials below that elevation are appropriate with respect to the FHWA methodology, and when compared with the reduction values using modulus reduction curves at 10^{-3} at the foundation level because the use of a smaller reduction factor results in a decrease in the modulus value and produces higher settlements; therefore it is a

conservative approach. Accordingly, the staff considers RAI 64, Question 02.05.04-25, part (ii), resolved.

While describing its settlement analysis, the applicant stated that the Vincentown Formation and soils below will deform elastically because of the sandy composition of soils and over-consolidated nature of clays. In RAI 41, Question 02.05.04-14, the staff requested that the applicant provide additional information to support this statement, especially when the pre-consolidation pressures were not obtained from one dimensional consolidation test for these clay type soils. In addition, the staff requested that the applicant clarify if they calculated drained elastic modulus values for clay-type soils to assess the long term conditions.

In a January 20, 2012, response to RAI 41, Question 02.05.04-14, the applicant indicated that it relied on the area's geologic history (erosion and sea level changes) to justify describing site soils as overconsolidated. The staff noted that laboratory testing was not performed to obtain consolidation data. Therefore, as a follow-up to RAI 41, Question 02.05.04-14, the staff issued RAI 64, Question 02.05.04-26, requesting that the applicant indicate if laboratory tests were planned to be performed on site subsurface soils to assess consolidation properties during the COLA phase, and explain why the liquidity indices from the Atterberg limits test on these soils are unreliable to assess consolidation properties to support the statement that foundation soils will behave as over-consolidated soils.

In a September 20, 2012, response to RAI 64, Question 02.05.04-26, the applicant indicated that the reason for not using the Atterberg limits to support its conclusion was because the results interpreted during the ESP work to further assess consolidation properties were not considered reliable. The applicant provided Table RAI-64-26-1 as part of the RAI response, which shows a comparison of liquidity index values and the estimated consolidated pressures. Based on this table, the applicant stated that the estimated existing overburden pressures are greater than the estimated preconsolidation pressures developed from the United Facilities Criteria Soil Mechanics chart (UFC-3-220-10N). The staff reviewed Table RAI-64-26-1, and the United Facilities Criteria Soil Mechanics chart (UFC-3-220-10N), which provides the relation between the liquid index and preconsolidation pressures. The staff concurs with the applicant that the effective overburden pressures were greater than the preconsolidated pressures. Since a soil is considered to be overconsolidated when the preconsolidation pressures are equal or larger than the present overburden pressures and because the applicant described the soils as overconsoildated, the staff further concurs with the applicant that the liquidity limits from the Atterberg limits test are unreliable to further assess consolidation properties.

In the response to RAI 64, Question 02.05.04-26, the applicant stated that during the COLA exploration, additional borings will be drilled, intact samples will be obtained, and laboratory testing will be conducted, including the consolidation testing for materials having a high percentage of fine-grained particles. Consistent with the applicant's stated intention, the staff identified the following COL action item:

COL Action Item 2.5-17

> An applicant for a COL or CP referencing this early site permit should conduct laboratory testing on intact samples and conduct consolidation testing for materials having a high percentage of fine-grained particles.

Lateral Earth Pressures

In SSAR Section 2.5.4.10, the applicant did not include information for lateral loading conditions as suggested in RS-002. To study the stability of all planned safety-related facilities, lateral loading conditions and their effects on Seismic Category I structures should be analyzed. Therefore, in RAI 41, Question 02.05.04-16, the staff requested that the applicant explain why lateral loading conditions were not included as part of the ESP, and indicate when the lateral earth pressure evaluation will be performed.

In a January 6, 2012, response to RAI 41, Question 02.05.04-16, the applicant indicated that lateral loading conditions were not evaluated as part of the ESP because information on the types and characteristics of the backfill were not available at this stage. In addition, the applicant indicated that it has not selected the reactor technology and its foundation depth. In SSAR Section 2.5.4.5.3, the applicant committed to evaluate lateral earth pressures as part of the COLA stage. The staff addressed this in COL Action Item 2.5-9. In its January 6, 2012, response to RAI 41, Question 02.05.04-16, the applicant also committed to modify SSAR Section 2.5.4.5.3 to describe the reason for not performing the lateral pressure evaluation as part of the ESP application, and to state its plan to perform it as part of the COLA stage. The staff confirmed that the Revision 1 of the ESP application, dated May 21, 2012, contains the SSAR changes committed in the RAI response. Accordingly, the staff finds that the applicant adequately addressed this issue and, therefore, considers RAI 41, Question 02.05.04-16, resolved.

Conclusions Regarding Static Stability

Based on its review of SSAR Section 2.5.4.10, the staff concludes that the applicant provided an adequate preliminary assessment of the static stability of the ESP site. However, for the staff to perform a complete review of site static stability, the COL or CP applicant referencing this ESP will need to analyze the stability of all planned safety-related facilities once the locations and technology of the plant structures are specified. This analysis should include bearing capacity, rebound, settlement, and differential settlements, as well as lateral loading conditions for all safety-related facilities. Therefore, the staff concludes that the applicant's description of the static stability is adequate to provide assurance of the stability of the ESP site, but the staff needs additional information to support any finding regarding detailed structure-specific stability. The staff identified COL Action Item 2.5-16 in Section 2.5.4.4.10 of this report to address the need for analyzing the stability of all planned safety-related facilities, including static and dynamic bearing capacity, rebound, settlement, and differential settlements under dead loads of fills and plant facilities, as well as lateral loading conditions.

2.5.4.4.11 Design Criteria

In SSAR Section 2.5.4.11, the applicant referenced the geotechnical characteristics discussed in the previous sections of the SSAR. The staff reviewed the general PSEG geotechnical site characteristics as described in the previous sections of this report.

In SSAR Section 2.5.4.5.3.3.2, the applicant committed to include, as part of the COLA submittal, an ITAAC to address the inspection, testing and acceptance criteria for backfill. In addition, the applicant stated that the complete settlement evaluation and construction groundwater control will be addressed at the COL application stage. The staff's COL Action Item 2.5-8 identified in Section 2.5.4.4.5 addresses the backfill ITAAC.

Since the applicant has not selected a reactor design technology and, therefore, did not describe the design criteria for the PSEG Site, the staff identified the following COL action item:

COL Action Item 2.5-18

> An applicant for a COL or CP referencing this early site permit should describe the design criteria and methods, including the factors of safety (FSs) from the design foundation stability analyses consistent with the selected reactor technology.

2.5.4.4.12 Techniques to Improve Subsurface Conditions

The staff reviewed the techniques for soil improvement for the foundation areas of the safety-related structures. Given Permit Condition 4, the COL or CP applicant may need to apply improvement techniques to eliminate any liquefaction potential found during its COL or CP investigation.

In SSAR Section 2.5.4.12, the applicant stated that removal of the unsuitable materials will extend to competent materials present in the Vincentown Formation. In the area of safety-related structures, the applicant plans to excavate down to the competent foundation layer, the Vincentown Formation. The applicant further stated that in the preparation of the foundation bearing surfaces, the applicant will use shallow depth soil improvement techniques, including over-excavation and replacement, and bearing surface compaction. The applicant plans to use dewatering systems to allow construction under dry conditions. Consistent with the applicant's stated intention, the staff identified the following COL action item:

COL Action Item 2.5-19

> An applicant for a COL or CP referencing this early site permit should improve subsurface conditions in cases where foundation soils do not provide adequate bearing capacity for safety-related structures.

2.5.4.5 Permit Conditions

In SSAR Section 2.5.4.5.4.1, the applicant acknowledged the need to perform geologic mapping for documenting the presence or absence of faults and shear zones in plant foundation materials. Therefore, in Section 2.5.3.5, "Geologic Mapping Permit Condition," of this report, the staff identified Permit Condition 3 related to detailed geologic mapping of safety-related excavations at the PSEG Site as the responsibility of the COL or CP applicant.

For evaluation of suitability of a proposed site, requirements in 10 CFR 100.23, "Geologic and Seismic Siting Criteria," specifically 10 CFR 100.23(c), indicate that the engineering characteristics of a site and its environs must be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site. Several siting factors are discussed in 10 CFR 100.23(d) that must be evaluated, including the potential for soil liquefaction, in addition to several other geologic and seismic factors. In addition, guidance in RG 1.198 indicates that if evaluations of the site investigations indicate the presence of potentially liquefiable soils, the resistance of these soils to liquefaction must be evaluated, and it must also be determined whether the potentially liquefiable soils should be removed, whether remedial action should be undertaken, whether further field and laboratory investigations are needed, or whether detailed stability and deformation analysis could demonstrate that an acceptable margin of safety is

maintained for the design structures even if liquefaction is assumed to occur. In SSAR Section 2.5.4.7.4.1, the applicant stated that the soils above the Vincentown Formation present unsuitable engineering characteristics with shear wave velocities less than 304.8 m/s (1,000 ft/s). The applicant stated that it will remove these soils from the area of safety-related structures to reach the competent material and replace it with suitable backfill. The applicant stated that the top of the competent layer is located, in the Vincentown Formation, at approximately elevation -20 m (-67 ft) NAVD. This activity is Permit Condition 4, the required actions for which are as follows:

Permit Condition 4

> An applicant for a COL or CP referencing this early site permit shall remove and replace the soils directly above the Vincentown Formation for soils under or adjacent to Seismic Category I structures to minimize any liquefaction potential.

2.5.4.6 Conclusion

Based on its review of SSAR Section 2.5.4, and the applicant's responses to the associated RAIs, the staff concludes that the applicant adequately determined the site-specific engineering properties of the soil underlying the ESP site following state-of the art methodology for its field and laboratory methods and in accordance with RG 1.132, RG 1.138, and RG 1.198. However, the staff also concludes that the applicant did not perform sufficient field investigations and laboratory testing to fully characterize the overall subsurface profile. The staff notes that the applicant committed to perform additional field investigations, once it has selected the reactor technology at the COL stage. The applicant addressed the response of the soil to dynamic loading in SSAR Section 2.5.2.

In SSAR Sections 2.5.4.5, 2.5.4.6, 2.5.4.10, 2.5.4.11, and 2.5.4.12, the applicant did not provide sufficient information for the staff to perform a complete evaluation. Each of these topics depends on specific information related to building location and design, and will be needed as part of any COL or CP application referencing this ESP.

In SSAR Table 2.0-1, the applicant identified three subsurface material properties as PSEG Site characteristic values. The first site characteristic specifies that “soils below the competent layer are not susceptible to liquefaction.” The applicant used an acceptable methodology, to determine the liquefaction potential of the soil underlying the ESP site; however, in consideration of instances of lower blow counts encountered in the widely spaced and limited numbers of ESP borings performed during the investigation, the staff identified Permit Condition 4, which addresses the need for additional geotechnical investigations and liquefaction assessments for a COL or CP. The second site characteristic value specifies a minimum ultimate bearing capacity of 20,100 kN/m^2 (420,000 psf). The staff reviewed the site characteristic value and found that the PPE value for the ultimate bearing capacity is appropriate for the four reactor technologies considered by the applicant. However, for the staff to perform a complete review of site static stability, including the bearing capacity, the staff will need a COL or CP applicant to analyze the stability of all planned safety-related facilities when the locations and technology for the plant structures are specified. Finally, the third design parameter specifies the minimum V_s through the foundation materials as 492 m/s (1,613 ft/s). The minimum V_s value is based on the applicant's field geophysical surveys. The staff reviewed the applicant's suggested site characteristics related to SSAR Section 2.5.4 for inclusion in an ESP. For the reasons discussed above, the staff concurs with the applicant that the site characteristics values are reasonable.

Subject to Permit Condition 4 and COL Action Items 2.5-1 through 2.5-19, the staff concludes that the applicant meets the requirements of 10 CFR Part 52, Subpart A, applicable to “Stability of Subsurface Materials and Foundations,” for an early site permit.

2.5.5 Stability of Slopes

2.5.5.1 Introduction

SSAR Section 2.5.5, “Stability of Slopes,” addresses the stability of both natural and manmade (cuts, fill, embankments, dams, etc.) earth slopes whose failure could affect safety-related structures. The staff evaluated this section based on the data provided by the applicant in the SSAR. In SSAR Section 2.5.5.3, the applicant indicated that boring logs for slopes were not performed because the locations of slopes are not known at the ESP stage. The applicant plans to conduct exploration for the design and analysis of slopes at the COL stage.

2.5.5.2 Summary of Application

SSAR Section 2.5.5 discusses stability of earth slopes whose failure could affect safety-related structures. SSAR Table 2.0-1, “PSEG Site Characteristics,” contains the site characteristics related to stability of slopes. The pertinent information related to stability of slopes includes: capable tectonic structures, maximum flood, maximum groundwater level, and liquefaction. The applicant deferred the specifics for slope stability design until the COL application stage with a selected reactor technology.

2.5.5.2.1 Slope Characteristics

In SSAR Section 2.5.5.1, “Slope Characteristics,” the applicant stated that it plans to perform temporary excavations to remove unsuitable soils above the competent layer and replace these soils with compacted granular fill, lean concrete, or roller-compacted concrete. The applicant stated that the edges of the new fill will be sloped at 3 (horizontal): 1 (vertical) or flatter. Figure 2.5.5-1, “Section A-A′ Slope Configuration,” in this report (Reproduced from SSAR Figure 2.5.5-2) presents the approximated slopes configuration corresponding to Section A-A′ located in the power block area.

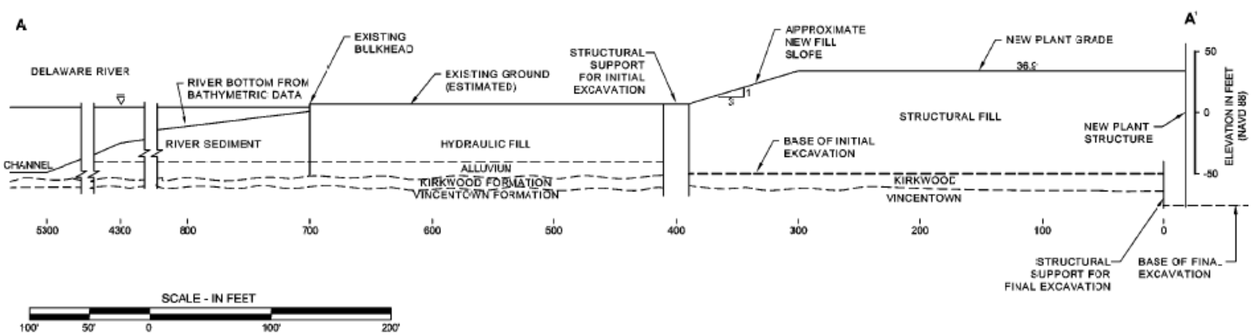

Figure 2.5.5-1 Section A-A’ Slope Configuration (Reproduced from SSAR Figure 2.5.5-2)

The applicant stated that one of the four technologies included in the PPE may require an ultimate heat sink, and that the slope stability analysis of the ultimate heat sink will be completed during the COL application stage. Slope stability for the selected technology will

include evaluation of deep slope failure surfaces that may extend into the Delaware River and will also be performed during the COL application stage.

The applicant indicated that there are no existing slopes on the site at this time, either natural or manmade, that could affect the stability of the site.

2.5.5.2.2 Design Criteria and Analysis

In SSAR Section 2.5.5.2, “Design Criteria and Analysis,” the applicant stated that the stability of slopes will be assessed during the COL application stage. The applicant will use limit equilibrium methods for their analysis, such as Bishop’s simplified method, Janbu’s simplified method, and the Spencer method. The stability analysis will evaluate the following loading conditions: end of construction, steady state, rapid drawdown, and seismic events.

2.5.5.2.3 Boring Logs

In SSAR Section 2.5.5.3, “Boring Logs,” the applicant stated that because the locations of the new slopes, resulting from the fill material to be placed to reach the new plant grade and the possible construction of an ultimate heat sink pond, are unknown at the ESP stage, the borings for slopes were not performed. In SSAR Section 2.5.5.3, the applicant indicated that it will conduct further exploration for design and analysis of slopes for the COL application, including the evaluation of the required bearing elevation for fill material placement.

2.5.5.2.4 Compacted Fill

In SSAR Section 2.5.5.4, “Compacted Fill,” the applicant stated that fill material will be from on-site and off-site sources, but specific characteristics are not identified during the ESP stage. The applicant mentioned that it will protect the exterior slopes of the fill above the existing ground level against scour and erosion using rock riprap, concrete blocks or mats. The applicant will present details of slope protection at the COL application stage.

2.5.5.3 Regulatory Basis

The applicable regulatory requirements for the stability of slopes are as follows:

- 10 CFR Part 52, Subpart A, “Early Site Permit,” as it relates to the requirements and procedures applicable to issuance of an early site permit for approval of a site for one or more power facilities.

- 10 CFR Part 50, Appendix S, “Earthquake Engineering Criteria for Nuclear Power Plants,” as it relates to the design of nuclear power plant structures, systems, and components important to safety to withstand the effects of earthquakes.

- 10 CFR 100.23, "Geologic and Seismic Criteria," as it relates to the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

The related acceptance criteria from NUREG-0800, Section 2.5 are summarized as follows:

- Slope Characteristics: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, the discussion of slope characteristics is acceptable if the subsection includes: (1) Cross sections and profiles of the slope in sufficient quantity and detail to represent the slope and foundation conditions; (2) a summary and description of static and dynamic properties of the soil and rock comprised by Seismic Category I embankment dams and their foundations, natural and cut slopes, and all soil or rock slopes whose stability would directly or indirectly affect safety-related and Seismic Category I facilities; and (3) a summary and description of groundwater, seepage, and high and low groundwater conditions.

- Design Criteria and Analyses: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, the discussion of design criteria and analyses is acceptable if the criteria for the stability and design of all Seismic Category I slopes are described and valid static and dynamic analyses have been presented to demonstrate that there is an adequate margin of safety.

- Boring Logs: To meet the requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100, the applicant should describe the borings and soil testing carried out for slope stability studies and dam and dike analyses.

- Compacted Fill: To meet the requirements of 10 CFR Part 50, and 10 CFR Part 52, the applicant should describe the excavation, backfill, and borrow material planned for any dams, dikes, and embankment slopes.

- In addition, the geologic characteristics should be consistent with appropriate sections from: RG 1.27; RG 1.28; RG 1.132; RG 1.138; and RG 1.198.

2.5.5.4 Technical Evaluation

The staff reviewed SSAR Section 2.5.5, which provides the applicant's general description of its plan for future slope stability analysis at the COL stage. The staff reviewed SSAR Figures 2.5.4.3-3 and 2.5.4.3-4, which show PSEG geologic cross sections, and has determined that there are no existing slopes at this time that could affect the stability of the site. The staff's determination is consistent with the applicant's information. While the general description was useful to the staff in performing the ESP application review, the staff identified the following COL action item to address the need for slope stability analyses:

COL Action Item 2.5-20

> An applicant for a COL or CP referencing this early site permit should perform a slope stability analysis consistent with the selected reactor technology. Slope stability analysis will include the evaluation of deep slope failure surfaces that may extend into the Delaware River and various water level considerations.

2.5.5.5 Conclusion

The applicant's information regarding the stability of slopes analysis is incomplete at this time. In SSAR Section 2.5.5, the applicant stated that during the COL application stage, it would present details of slope protection, and complete the slope stability analysis for the selected reactor technology. As such, at this time the staff is unable to reach any conclusion regarding the stability of slopes that have not been designed or constructed due to absence of a reactor

technology. The staff evaluation of slope stability will be performed as part of its review of the COL or CP application.

When referenced by a COL applicant pursuant to 10 CFR 52.73, “Relationship to Subparts A and B,” this ESP is subject to these COL action Items and permit conditions:

COL Action Items 2.5-1 through 2.5-20

2.5-1 An applicant for a COL or CP referencing this early site permit should perform additional investigations in order to provide additional information on the extent, thickness, and nature of the oxidized material in the Vincentown Formation beneath the area of Seismic Category I structures for the selected reactor technology. The applicant should also remove less dense soils with considerably lower SPT N-values in order to meet the soil condition requirements. (See Section 2.5.4.4.1 of this report.)

2.5-2 An applicant for a COL or CP referencing this early site permit should conduct additional subsurface investigations to evaluate and fully characterize the engineering properties of the Vincentown and Hornerstown Formations and their potential lateral and vertical variation. The applicant should also perform additional strength tests to further evaluate the soil shear strength parameter for the Vincentown and Hornerstown Formations. (See Section 2.5.4.4.2 of this report.)

2.5-3 An applicant for a COL or CP referencing this early site permit should perform additional borings to provide information for further evaluation of the shear strength properties of the Navesink formation. (See Section 2.5.4.4.2 of this report.)

2.5-4 An applicant for a COL or CP referencing this early site permit should perform additional borings and unit weight determinations for the materials underlying the Mount Laurel Formation. (See Section 2.5.4.4.2 of this report.)

2.5-5 An applicant for a COL or CP referencing this early site permit should perform additional subsurface investigations and correlate the plot plans and profiles of each Seismic Category I structure with the subsurface profile and material properties, and ensure placement of safety-related structures on competent foundation bearing material. (See Section 2.5.4.4.3 of this report.)

2.5-6 An applicant for a COL or CP referencing this early site permit should provide specific details regarding the lateral and vertical extent of the excavation consistent with the selected reactor technology. (See Section 2.5.4.4.5 of this report.)

2.5-7 An applicant for a COL or CP referencing this early site permit should evaluate the method of excavation support and the stability of temporary excavation slopes or support. (See Section 2.5.4.4.5 of this report.)

2.5-8 An applicant for a COL or CP referencing this early site permit should include in the COL application, an ITAAC for the soil backfill, with specifications to ensure a V_s of 304.8 m/s (1,000 ft/s) or higher below Seismic Category I structures. (See Section 2.5.4.4.5 of this report.)

2.5-9 An applicant for a COL or CP referencing this early site permit should provide, consistent with the selected reactor technology, (i) details for the backfill quantities,

types and sources; (ii) lateral loading conditions; (iii) information on the type and characteristics of backfill materials; and (iv) lateral pressure evaluation from backfill materials. (See Section 2.5.4.4.5 of this report.)

2.5-10 An applicant for a COL or CP referencing this early site permit should include the geotechnical instrumentation plan and heave monitoring schedule in the COL application. (See Section 2.5.4.4.5 of this report.)

2.5-11 An applicant for a COL or CP referencing this early site permit should evaluate and implement, during the COL application stage, design measures appropriate for the chemical characteristics of the Category 1 fill, site soils and site groundwater. (See Section 2.5.4.4.6 of this report.)

2.5-12 An applicant for a COL or CP referencing this early site permit should perform, consistent with the selected reactor technology, evaluation of groundwater conditions as they affect the loading and stability of foundation materials, and also provide detailed dewatering and groundwater control plans. (See Section 2.5.4.4.6 of this report.)

2.5-13 An applicant for a COL or CP referencing this early site permit should develop the foundation input response spectra (FIRS) and the Soil Structure Interaction (SSI) analysis at the COL application stage. (See Section 2.5.4.4.7 of this report.)

2.5-14 An applicant for a COL or CP referencing this early site permit should perform additional geotechnical investigation, consistent with RG 1.132, including the performance of additional borings and a detailed liquefaction assessment to determine if zones of lower blow counts, which might indicate a potentially weak liquefiable zone, are present underneath the competent layer. If the additional borings and analyses identify areas where potential for liquefaction may be present, the applicant should remove unsuitable materials and either replace it with competent material or improve it to eliminate liquefaction potential. (See Section 2.5.4.4.8 of this report.)

2.5-15 An applicant for a COL or CP referencing this early site permit should evaluate non-seismic liquefaction. (See Section 2.5.4.4.8 of this report.)

2.5-16 An applicant for a COL or CP referencing this early site permit should analyze the stability of all planned safety-related facilities, including static and dynamic bearing capacity, rebound, settlement, and differential settlements under dead loads of fills and plant facilities, as well as lateral loading conditions. (See Section 2.5.4.4.10 of this report.)

2.5-17 An applicant for a COL or CP referencing this early site permit should conduct laboratory testing on intact samples and conduct consolidation testing for materials having a high percentage of fine-grained particles. (See Section 2.5.4.4.10 of this report.)

2.5-18 An applicant for a COL or CP referencing this early site permit should describe the design criteria and methods, including the factors of safety (FSs) from the design foundation stability analyses consistent with the selected reactor technology. (See Section 2.5.4.4.11 of this report.)

2.5-19 An applicant for a COL or CP referencing this early site permit should improve subsurface conditions in cases where foundation soils do not provide adequate bearing capacity for safety-related structures. (See Section 2.5.4.4.12 of this report.)

2.5-20 An applicant for a COL or CP referencing this early site permit should perform a slope stability analysis consistent with the selected reactor technology. Slope stability analysis will include the evaluation of deep slope failure surfaces that may extend into the Delaware River and various water level considerations. (See Section 2.5.5.4 of this report.)

Permit Conditions 3 and 4

3. An applicant for a COL or CP referencing this early site permit shall perform detailed geologic mapping of excavations for safety-related structures; examine and evaluate geologic features discovered in those excavations; and notify the Director of the Office of New Reactors, or the Director's designee, once excavations for safety-related structures are open for examination by NRC staff. (See Section 2.5.3.5 of this report.)

4. An applicant for a COL or CP referencing this early site permit shall remove and replace the soils directly above the Vincentown Formation for soils under or adjacent to Seismic Category I structures to minimize any liquefaction potential. (See Section 2.5.4.5 of this report.)