SUBSECTION 2.5.0 TABLE OF CONTENTS

2.5 GEOLOGY, SEISMOLOGY, AND GEOTECHNICAL ENGINEERING

This section of the referenced DCD is incorporated by reference with the following departures and/or supplements.

STD DEP 1.1-1 This section is numbered to follow Regulatory Guide 1.206. The COL information items in DCD Subsections 2.5.1 through 2.5.6 are addressed in Subsection 2.5.6.

PTN SUP 2.5-1 This section of the Final Safety Analysis Report (FSAR) presents information on the geology, seismology, and geotechnical engineering characteristics of the region (200-mile radius), site vicinity (25-mile radius), site area (5-mile radius), and site (0.6 mile radius) of Units 6 & 7. The data and analyses in this section document the evaluation of the suitability of the site. Section 2.5 provides sufficient information to support evaluations of the site-specific ground motion response spectra (GMRS) and provides information to permit adequate engineering solutions to geologic conditions and seismic effects at the site.

Section 2.5 is divided into seven subsections that generally follow the organization of RG 1.206 and NUREG-0800.

- Subsection 2.5.0 Summary
- Subsection 2.5.1 Basic Geologic and Seismic Information
- Subsection 2.5.2 Vibratory Ground Motion
- Subsection 2.5.3 Surface Faulting
- Subsection 2.5.4 Stability of Subsurface Materials and Foundations
- Subsection 2.5.5 Stability of Slopes
- Subsection 2.5.6 Combined License Information

Units 6 & 7 are located within Miami-Dade County, Florida, approximately 25 miles south of Miami, 8 miles east of Florida City, and 9 miles southeast of Homestead, Florida (Figure 2.1-201). The original site is at or near sea level with an existing elevation of –2.4 to 0.8 feet (NAVD 88) and generally flat throughout with the exception of a few isolated vegetated depressions. The local terrain was covered with a thin (2 to 6 feet) veneer of organic muck that overlaid the Pleistocene Miami Limestone.

The vertical datum used for the Units 6 & 7 subsurface investigation is the North American Vertical Datum 1988 (NAVD 88). The vertical datum for references cited in this FSAR is per the cited reference, which include, mean sea level (MSL), NAVD 88, or National Geodetic Vertical Datum 1929 (NGVD 29).

The geological and seismological information presented in this section was developed from a review of published geologic literature, personal communication with experts in the geology and seismotectonics of the site region, aerial photo analysis, and geologic fieldwork performed as part of the COL Application (including a site subsurface investigation, a geologic field reconnaissance, and a geophysical survey). A list of the references used to compile the geological, seismological and geotechnical information presented in the following sections is provided at the end of each major subsection within Section 2.5.

The review of regional and site geologic, seismic, and geophysical information and an evaluation of the updated earthquake catalog confirm the use of the appropriate seismic sources in the probabilistic seismic hazard analysis (PSHA). Borings at the site provide the geologic and geotechnical data needed to characterize the material properties of the soil and rock.

2.5.0 SUMMARY

This section provides a summary of information presented in detail in FSAR Subsections 2.5.1, 2.5.2, 2.5.3, 2.5.4, and 2.5.5. References are provided in their respective subsections.

2.5.0.1 Basic Geologic and Seismic Information

The geological and seismological information in Subsection 2.5.1 was developed in accordance with the guidance presented in RG 1.206, Subsection 2.5.1, *Basic Geologic and Seismic Information*, NUREG-0800, and RG 1.208, *A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion*, and is intended to satisfy the requirements of 10 CFR 100.23(c). The geologic and seismotectonic information presented in this subsection is used as a basis for evaluating the detailed geologic, seismic, and man-made hazards at Units 6 & 7.

2.5.0.1.1 Regional Geology

Units 6 & 7 are located within the Atlantic Coastal Plains physiographic region. The ground surface in the region ranges from about 3 feet below sea level to 345 feet above. The geologic and tectonic setting of the region is the product of a complex history of continental collisions and rifting followed by deposition of sediments upon the newly formed Florida platform. Site regional stratigraphy consists of Paleozoic and Mesozoic igneous, metamorphic, and sedimentary basement rock overlain by up to 15,000 feet of additional Mesozoic carbonate and evaporite sedimentary rock units that are in turn overlain by up to 5,000 to 6,000 feet of Cenozoic carbonate and siliciclastic sediments.

The stratigraphy described in this subsection has been developed from the analysis of surface and subsurface geologic and geophysical investigations performed at the site and reported in peer-reviewed publications. The stratigraphy of southern Florida is characterized by a thick sequence of Jurassic to Holocene sediments that lie unconformably on Jurassic basement volcanic rocks. Although most of the units in the sedimentary sequence are carbonates, deposition of Appalachian derived siliciclastic sediments occurred during the Miocene and Pliocene. The oldest strata exposed at the surface in the southern Florida region is the Miocene-Pliocene Peace River Formation that outcrops in Hardee and Desoto counties.

The site region is located within the Central and Eastern United States (CEUS), a stable continental region characterized by low rates of crustal deformation and no active plate boundary conditions. There is no significant change in the understanding of the static stress in the site region since the publication of the EPRI source models in 1986, and there are no significant implications for existing characterizations of potential activity of tectonic structures. The Mid-Plate stress province is the most likely characterization of the tectonic stress at the site region.

The tectonic history of the site region begins with the late Paleozoic Alleghany orogeny, in which Gondwana (including South America and Africa) and Laurentia (ancestral North America) collided to form the supercontinent Pangaea. Pangaea was rifted apart during the Triassic and the Florida peninsula became part of North America. In the Jurassic, the southern edge of the North American plate was subducting southwestward beneath the Caribbean plate. In the Eocene Epoch, the Greater Antilles arc collided with the Bahama platform and contractional structures developed north of Cuba to accommodate this strain. After the Eocene, the crustal plate containing Cuba was transferred to the southern edge of the North American Plate, thus ending tectonic activity in the site region.

The Florida peninsula has been a stable carbonate platform since the Eocene. The dominantly carbonate strata of the subsurface Florida peninsula exhibits a series of sedimentary arches, uplifts, basins, and embayments developed in response to minor warping, regional tilting, sedimentary compaction, and sea level changes. These structures are not associated with faulting or tectonic events. No tectonic features younger than Miocene have been identified within the site region.

The Caribbean-North America plate boundary and the Charleston, South Carolina, region are more active potential seismic sources outside the site region that may contribute to site-specific seismic hazards.

2.5.0.1.2 Site Geology

Units 6 & 7 are located within the Southern Slopes subprovince of the Atlantic Coastal Plain physiographic province. The site vicinity geology was influenced by sea level fluctuations, processes of carbonate and clastic deposition, and erosion. The Paleogene (early Tertiary) is dominated by the deposition of carbonate rocks while the Neogene (late Tertiary) is more influenced by the deposition of quartzitic sands, silts, and clays. Within the site area the dominate rock types are limestones of the Arcadia Formation, Fort Thompson Formation, Key Largo Limestone, and Miami Limestone, and the sands and silts of the Peace River and Tamiami Formations. Minor units of alluvial soils, organic muck, and silt cover the surface. During the Pleistocene, worldwide glaciation and fluctuating sea levels influenced the geology in the site vicinity. The growth of continental glaciers during glacial advances resulted in the worldwide lowering of sea level. This process increased Florida's land area significantly, which led to increased erosion and clastic deposition. Warm interglacial periods resulted in a rise in sea level and an increase in nutrient-rich waters leading to a growth in carbonate material. The geology within the site area is dominated by flat, planar bedding in late Pleistocene and older units. No geologic, tectonic, or physiographic structures such as sinkholes have been identified within the site area.

Units 6 & 7 lie on the stable Florida carbonate platform, and no faults or folds are mapped within more than 25 miles. New data include geologic mapping and bedding attitudes derived from lithologic contacts in boreholes. Taken together, these data indicate generally flat, planar bedding in late Pleistocene and older units and an absence of geologic structures within the site area.

Based on the review and updating of the geological, seismological, geophysical, and geotechnical data for the site, nothing was identified that precludes the safe operation of the facilities. The only geologic hazard identified in the site area is potential surface deformation related to carbonate dissolution. Based on records kept by the Florida Geological Survey, sinkholes in the limestone of southeastern Florida are few in number, shallow, broad, and develop gradually (Figure 2.5.1-238).

2.5.0.2 Vibratory Ground Motion

This subsection provides a detailed description of the vibratory ground motion assessment for the site. This assessment uses the guidance in RG 1.208. RG 1.208 incorporates developments in ground motion estimation models; updated models for seismic sources; methods for determining site response; and new methods for defining a site-specific, performance-based earthquake ground motion that satisfy the requirements of 10 CFR 100.23. Identification and characterization of seismic sources lead to the determination of safe shutdown earthquake (SSE) ground motion. This subsection develops the site-specific ground motion response spectrum (GMRS) characterized by horizontal and vertical response spectra determined as free-field motions on the ground surface using performance-based procedures.

The GMRS represents the first part in development of a SSE for a site as a characterization of the regional and local seismic hazard. The GMRS is used to determine the adequacy of the certified seismic design response spectra (CSDRS) for the DCD (RG 1.208). The CSDRS is the SSE ground motion for the site, the vibratory ground motion for which certain structures, systems, and components are designed to remain functional, pursuant to Appendix S to 10 CFR Part 50.

The starting point for the GMRS assessment is the probabilistic seismic hazard analysis (PSHA) conducted by the Electric Power Research Institute (EPRI) for the seismicity owners group (SOG). The EPRI-SOG seismic hazard study is based on the evaluation of seismicity, seismic source models, and ground motion attenuation relationships (Subsection 2.5.2, Reference 201).

Subsections 2.5.2.1 through 2.5.2.4 document the review and update of the available EPRI earthquake catalog, seismic source models, and ground motion characterizations. Subsection 2.5.2.5 summarizes information about the seismic wave transmission characteristics of the site with reference to more detailed description of all engineering aspects of the subsurface in Subsection 2.5.4.

Subsection 2.5.2.6 describes development of the horizontal GMRS ground motion for the site. Following RG 1.208, the selected ground motion is based on the risk-consistent/performance-based approach. Site-specific horizontal ground motion amplification factors are developed using site-specific estimates of subsurface soil and rock properties. These amplification factors are then used to scale the hard rock spectra to develop uniform hazard response spectra (UHRS) accounting for site-specific conditions using Approach 2A of NUREG/CR-6728 (Subsection 2.5.2, Reference 202).

Subsection 2.5.2.6 also describes vertical GMRS, developed by scaling the horizontal GMRS by a frequency-dependent vertical-to-horizontal (V:H) factor.

2.5.0.3 Surface Faulting

Subsection 2.5.3 documents an evaluation of the potential for tectonic and non-tectonic surface deformation within the site vicinity of Units 6 & 7. Information contained in Subsection 2.5.3 was developed in accordance with RG 1.208, *Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion*, and is intended to demonstrate compliance with 10 CFR 100.23, *Geologic and Seismic Siting Criteria*. RG 1.208 contains guidance on characterizing seismic sources, and it defines a “capable tectonic source” as a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation, such as faulting or folding at or near the earth’s surface, in the present seismotectonic regime.

Subsection 2.5.3 contains information on potential surface deformation associated with capable tectonic sources (Quaternary faults) and potential surface deformation associated with non-tectonic processes, such as collapse structures (karst collapse), subsurface salt migration (salt domes), volcanism, and man-induced deformation (e.g., mining collapse and subsidence due to fluid withdrawal).

The evaluation of this information indicated that there are no capable tectonic sources and there is no potential for tectonic fault rupture within the 25-mile radius site vicinity. A compilation of existing data and literature review did not indicate any tectonic or non-tectonic surface deformation hazards at the site or any faults at the surface on the Florida peninsula within the 200-mile radius site region. Interpretation of aerial photographs did not identify any lineaments within the site area. A review of seismicity data did not indicate that any earthquakes with estimated body wave magnitude (Emb) ≥ 3.0 have occurred within 30 miles of the site. A field and aerial reconnaissance did not locate any evidence of faulting or seismic activity (such as paleoliquefaction features) within the site area. However, this reconnaissance did identify non-tectonic deformation features within the site area. These features appear to be small, localized depressions caused by surface dissolution of carbonate strata.

The data contained in Subsection 2.5.3 were developed as a result of literature and data reviews, interpretations of aerial and satellite imagery, field and aerial reconnaissance, discussions with current researchers, and an analysis of seismicity with respect to geologic structures. These data indicate that there are no Quaternary faults or capable tectonic sources within the site vicinity.

2.5.0.4 Stability of Subsurface Materials and Foundations

The locations of the Units 6 & 7 nuclear islands are shown in Figure 2.5.4-201. A combination of drilling, geophysics and laboratory testing was used to characterize the subsurface. The results of the subsurface investigations and testing are presented in Reference 201.

Limestone strata extend from 3 feet below the surface to a depth of approximately 115 feet and are in turn underlain by sandy silty strata that extend to a depth of approximately 450 feet. Below this depth, evaporate-capped carbonate strata continue to basement volcanics at a depth of approximately 15,000 feet.

No zones of solutioning are observed in the site investigation. The subsurface investigation (drilling and downhole geophysics) does not indicate the presence of voids. No evidence suggests the presence of active or recent tectonic deformation within the site vicinity. No uplift due to natural forces or development is anticipated.

The engineering properties for all in situ soil and rock units were obtained from the subsurface investigation and the laboratory-testing program. The average RQD values in the Key Largo Limestone and Fort Thompson Formation range from approximately 54 to 81 percent and 16 to 91 percent, respectively. Average core recovery in these units ranges from 41 percent to 98 percent, respectively. Average unconfined compressive strength is 1500 psi in the Key Largo Limestone and 2000 psi in the Fort Thompson Formation. In general, rock quality is greatest from approximately El. –45 to El. –60 feet.

The average values obtained for corrected (standard penetration test) SPT N-values in the unconsolidated upper and lower Tamiami Formation are 40 and 32 blows per foot, respectively. There is a marked difference in fines content between the silty sand of the upper Tamiami Formation (28 percent) and the sandy silt of the lower Tamiami Formation (62 percent). The value of unit weight is taken as 120 pcf (pound per cubic feet) for both units. The average values for the effective friction angle in the upper and lower Tamiami Formation are 35 and 20 degrees, respectively. The average values for the elastic modulus (high strain) in the upper and lower Tamiami Formation are 1500 and 2500 ksf (kips per square foot), respectively, and for the shear modulus (high strain) are 550 and 900 ksf, respectively. The values for the sliding coefficient in the upper and lower Tamiami Formation are 0.4 and 0.3, respectively, and 0.7 in the rock of both the Key Largo Limestone and Fort Thompson Formation. The average shear wave velocities are 5800 fps (feet per second) in the Key Largo Limestone, 4250 fps in the Fort Thompson Formation, 1400 fps in the upper Tamiami Formation and 1600 fps in the lower Tamiami Formation.

Laboratory testing for potential harmful behavior toward buried concrete and steel showed pH values indicative of relatively noncorrosive soils but chloride content for the same soils indicate the soil is somewhat corrosive. Sulfate content ranges from 0.034 to 0.76 percent. Tests also showed that the soil strata had a relatively high (21 percent average) percent calcite equivalent.

Significant earthwork is required to establish finished grades at the site. The deepest excavation planned is to El. –35 feet within the Key Largo Limestone, with concrete placed between the base of the reactor (El. –14 feet) and the bottom of the excavation. Power block excavations are primarily open cuts and will require a dewatering system. Temporary ground support will be provided by a steel-reinforced concrete diaphragm wall surrounding each power block excavation area.

The unconsolidated deposits (Tamiami and Peace River Formations) at the site are Pliocene (at least 1.8 million years old) or older. Additionally, the overlying rock should preclude development of liquefaction-induced features, such as lateral spreading and settlement, from propagation to the ground surface. For completeness, a comprehensive liquefaction analysis for all cone penetrometer tests (CPT), and shear wave velocity (V_s) data was performed.

Using the calculated allowable bearing capacity of 43 ksf for rock and the overylying lean concrete, the bearing capacity is within threshold limits. The risk associated with settlement is considered insignificant as it is within the tolerable threshold. A Factor of Safety of 1.10 is recommended to resist sliding and overturning due to lateral loads when the seismic component is included.

Given the depths of structure foundations and the subsurface conditions that occur at those depths, special ground improvement measures are not warranted. Ground treatment is limited to localized over-excavation of unsuitable soils. Over-excavations of approximately 21 feet at the containment buildings are designed to replace soils and rock that may not be adequate to directly bear the high foundation loads of these structures. Groundwater control is required as part of this over-excavation.

2.5.0.5 Stability of Slopes

Subsection 2.5.5 considers nonsafety-related earth structures and slopes. There are no earth slopes at or in the plant area.

2.5.0.6 References

201. MACTEC Engineering and Consulting, Inc., *Final Data Report—Geotechnical Exploration and Testing: Turkey Point COL Project Florida City, Florida*, Rev. 2, October 6, 2008. Included in COLA Part 11.
