most current interpretations by FGS geologists, the recognized area experts, who interpret the Ocala arch as non-tectonic in origin and state that regional and local fracture patterns are not unique to the platform. Consequently, the staff considers RAI 2.5.1-11 to be resolved.

2.5.1.4.2.4.3 Postulated Faults and Identification Criteria

In RAI 2.5.1-38, the staff asked the applicant to summarize the information leading to the conclusion that no faults occur within the site vicinity, and to discuss the criteria applied to distinguish faults from fractures. In response to RAI 2.5.1-38, the applicant summarized pertinent data collected by FGS geologists, including geologic maps, cross sections, and structure contour maps, used to determine that no faults occur in the site vicinity (e.g., a statewide 1:750,000-scale geologic map and cross sections from Scott and others, 2001; a 1:126,720-scale geologic map of Levy County from Campbell, 1992; a 1:500,000-scale geologic map of the Floridian aquifer system from Knapp, 1979; and structure contour maps developed by Arthur and others, 2008). None of these data sources developed by area experts from the FGS showed discontinuities or anomalies resulting in the interpretation of surface or subsurface faults in the site vicinity. However, the applicant noted that Arthur et al. (2008) postulated two short segments of a northwest-trending subsurface fault just outside the site vicinity, located about 42 km (26 mi) southeast of the LNP site at its nearest point, based on abrupt changes in thickness in the Suwannee Limestone, as suggested by their structure contour maps. The applicant indicated that there is no surface expression of this postulated fault documented in the current literature cited by the applicant and, if it exists, it is pre-Quaternary (> 2.6 Ma) in age since there is no disruption of Quaternary sediments overlying the inferred fault. Finally, the applicant defined several standard criteria used to distinguish faults from fractures in the site vicinity and site area, all of which depend on finding geologic evidence of displacement along the fault surface as indicated by the presence of sheared materials; visible fault offset or offset inferred from geologic map data; anomalies that suggest truncation or offset of geologic materials; or deposits and geomorphic surfaces disrupted by folding or tilting. By applying these criteria and considering the data collected by FGS geologists, the applicant concluded that no faults occur within the site vicinity.

Based on review of the applicant's response to RAI 2.5.1-38, as well as independent review of pertinent published literature provided by the applicant and data related to structural geology of the site vicinity and site area, including borehole information, the staff concludes that no current data support the existence of faults in the LNP site vicinity or site area. The staff makes this conclusion because the information provided by the applicant, and reviewed by the staff, documented the geologic map data used to assess the presence of faulting. In addition, the staff concludes that the criteria the applicant used to assess the presence of faulting in the site area and site vicinity are the standard criteria for recognition of faults based on field data. Consequently, the staff considers RAI 2.5.1-38 to be resolved.

Based on review of LNP COL FSAR Section 2.5.1.2.4, the applicant's responses to RAIs 2.5.1-2, 2.5.1-10, 2.5.1-11, 2.5.1-38, and 2.5.1-39 and associated changes implemented in FSAR Section 2.5.1.2.4, as well as independent review of pertinent literature cited by the applicant and data and direct field observation of fractures in the Avon Park Formation, the staff finds that the applicant provided a complete and accurate description of structural geology of the site vicinity and site area in support of the LNP COL application.

2.5.1.4.2.5 Site Location Geology

In FSAR Section 2.5.1.2.5, the applicant discussed geology of the site location, including geomorphology, stratigraphy, and karst development. The staff focused the review of FSAR Section 2.5.1.2.5 on the applicant's discussion of factors governing karst development and possible size of subsurface dissolution cavities at the site location.

2.5.1.4.2.5.1 Potential for Rapid Groundwater Flow Conduits

In RAI 2.5.1-31, the staff asked the applicant to discuss available information related to the existence of underground conduits capable of accommodating rapid groundwater flow at or near the LNP site. In RAI 2.5.1-47, the staff asked the applicant to provide a reference for a statement included in the response to RAI 2.5.1-31 that no springs of any noticeable magnitude exist within the LNP site vicinity. In responses to RAIs 2.5.1-31 and 2.5.1-47, the applicant stated that the LNP site lies in a zone of very low recharge, and cited Upchurch (personal communication, 2009) to document the absence of significant springs within the outcrop area of the Avon Park Formation, including the site vicinity. The applicant presented a map modified from Maddox (1993), which shows that no known caves occur within the outcrop area of the Avon Park Formation in Levy and Citrus Counties. Scott and others (2004) reported only two small springs near the LNP site, namely Big King and Little King Springs, which lie to the north-northwest and within 8 km (5 mi) of the site. The applicant concluded that few voids, and no large ones, occurred in the LNP site characterization borings, and reiterated that the upper 150 m (50 ft) of the Avon Park Formation consists primarily of dolomitized limestone (i.e., dolostone), which is less susceptible to dissolution than pure limestone.

Based on review of the applicant's responses to RAIs 2.5.1-31 and 2.5.1-47, as well as independent examination of cores and borehole logs from the LNP site in September 2009 and February 2010 that did not reveal interconnected underground voids or extensive fractures in the subsurface, the staff concludes that no evidence exists for interconnected underground conduits capable of accommodating rapid groundwater flow at or near the LNP site. The staff draws this conclusion because no springs of significant magnitude occur at or near the LNP site, and the site characterization core samples directly examined by staff did not contain interconnected or large voids in the subsurface. Consequently, the staff considers RAIs 2.5.1-31 and 2.5.1-47 to be resolved.

2.5.1.4.2.5.2 Size of Subsurface Dissolution Cavities

The staff requested that the applicant clarify information related to the possible maximum size of subsurface dissolution cavities as provided in a supplemental discussion of the potential for karst development at the site location (Progress Energy, 2008). In RAIs 2.5.1-5 and 2.5.1-7, the staff asked the applicant to address the uncertainty in the estimate of a maximum lateral extent for dissolution cavities of 3 m (10 ft), as cited in the supplemental discussion, and to discuss the potential for coalescing dissolution cavities at depth below LNP Unit 1 or LNP Unit 2. In responses to RAIs 2.5.1-5 and 2.5.1-7, the applicant stated that conservative parameters applied in the analysis of size of subsurface karst features based on grout uptake volume accounted for uncertainties in the subsurface data used to estimate the maximum size of dissolution voids. These conservative parameters included increasing grout volumes used in the void size analysis above the grout uptake volumes calculated from borehole data, specifically by 50-percent for vertical fractures and 100-percent for horizontal bedding planes. The use of the parameters resulted in the applicant defining a dissolution cavity with a maximum lateral dimension of 3 m (10 ft), whereas the maximum void size calculated from actual borehole

data was1.6 m (5.3 ft) in lateral extent. The applicant pointed out that the size of the dissolution cavity used in the analysis is 1.9 times the size of the cavity calculated from borehole data, and thus concluded that the estimate of maximum size of subsurface dissolution cavities presented in the supplemental discussion was conservative. The applicant noted that the degree of dolomitization of the Avon Park Formation, a process, which lowers the likelihood of dissolution, decreased the potential for coalescence of subsurface dissolution cavities. The applicant provided information documenting the fact that dolomites dissolve less readily than pure limestones in response to RAI 2.5.1-1 discussed below in SER Section 2.5.1.4.2.6, "Site Area Geologic Hazard Evaluation."

Based on the review of the applicant's responses to RAIs 2.5.1-5 and 2.5.1-7, as well as independent examination of supporting field data from grout test cores in September 2009 and the six "offset" boreholes drilled using controlled boring techniques to improve core recovery and enable assessment of subsurface dissolution cavities and fractures in February 2010, the staff concludes that the estimate of a maximum void size of 3 m (10 ft) in lateral extent is conservative. The staff makes this conclusion because the preponderance of field data indicates that large subsurface dissolution cavities do not occur in the Avon Park Formation at the site location. The supporting field data examined during the September 2009 site audit specifically showed grout uptake only in a single vertical fracture intersected by one of the slanted test grouting boreholes, and no large dissolution cavities occurred in any of the boreholes. The supporting data examined in February 2010 enabled the staff to conclude these data indicate that the low recovery horizons noted in the initial site characterization boreholes for LNP Units 1 and 2 (as examined by staff during the site visit in April 2009) mark soft zones in the normal stratigraphic sequence, rather than large subsurface dissolution cavities. Consequently, the staff considers RAIs 2.5.1-5 and 2.5.1-7 to be resolved.

In RAIs 2.5.1-12 and 2.5.1-46, the staff asked the applicant to discuss what the scale of surficial features may suggest in regard to a maximum lateral dimension for dissolution voids in the subsurface. In responses to RAIs 2.5.1-12 and 2.5.1-46, the applicant indicated that surface morphology of the LNP site is characterized by shallow depressions, classified as solution sinkholes, which vary in size from small, well-defined depressions less than 50 m (64 ft) in diameter and 1 to 2 m (2 to 6 ft) in depth to large, irregular, shallow depressions ranging up to 600 m (2,000 ft) wide. Based on Sinclair and Stewart (1985), the applicant reported that the diameter of these shallow, surficial solution sinkholes observed at the LNP site is not indicative of the size of expected subsurface karst features. Following Sinclair and Stewart (1985), the applicant stated that dissolution is most active at the limestone surface where dissolution features develop, commonly along fractures that allow water to easily percolate into the subsurface, dissolve the limestone, and transport insoluble residues, such that these features indicate shallow dissolution only. The applicant further indicated that deep dissolution does not commonly occur because subsidence of the soil layer occurs as the surface of the limestone dissolves and seals the bottom of the shallow depression, forming a marsh or lake in the depression. The applicant stated that this shallow dissolution process produced the undulating topography characterized by the shallow depressions, which are common over large parts of Florida and which dominate the LNP site.

Based on review of the applicant's responses to RAIs 2.5.1-12 and 2.5.1-46, as well as independent review of Sinclair and Stewart (1985) and other pertinent published literature cited by the applicant, the staff concludes that the shallow solution sinkhole depressions, which dominate the surface of the LNP site, are surficial sinkholes that do not reflect deep dissolution cavities. The staff makes this conclusion because experts in the region have documented this interpretation based on borehole data that do not reveal deep dissolution cavities beneath these

solution sinkholes. Consequently, the staff considers RAIs 2.5.1-12 and 2.5.1-46 to be resolved.

Based on review of LNP COL FSAR Section 2.5.1.2.5, the applicant's responses to RAIs 2.5.1-5, 2.5.1-7, 2.5.1-12, 2.5.1-31, 2.5.1-46, and 2.5.1-47, as well as independent review of pertinent literature cited by the applicant and data and direct observation of grout test cores in September 2009 and examination of information from the six "offset" boreholes drilled using controlled boring techniques to improve core recovery in February 2010, the staff finds that the applicant provided a complete and accurate description of site location geology in support of the LNP COL application.

2.5.1.4.2.6 Site Area Geologic Hazard Evaluation

FSAR Section 2.5.1.2.6 presents an evaluation of the geologic hazards at the LNP site. The applicant noted that the LNP site is located in an area of infrequent and low seismicity, and that no capable tectonic sources occur in the site area. The applicant did not indicate whether field reconnaissance studies or literature searches cited by the applicant were performed to determine if paleoliquefaction features (i.e., indicators of prehistoric earthquake activity) occur in the site region, vicinity, or area. The applicant concluded that the only geologic hazard identified in the LNP site area is potential surface deformation resulting from carbonate dissolution and collapse or subsidence related to karst development.

The staff focused the review of FSAR Section 2.5.1.2.6 on qualification of the dissolution rates cited for development of karst at the LNP site, and whether paleoliquefaction features may exist in the site region, site vicinity, or site area as indicators of prehistoric seismic events.

2.5.1.4.2.6.1 Proposed Dissolution Rates

In RAI 2.5.1-1, the staff asked the applicant to summarize the technical basis for the dissolution rates cited in the LNP COL FSAR, and to document the statement in the FSAR that dolomitized limestone dissolves more slowly than pure limestone. In response to RAI 2.5.1-1, the applicant indicated that a comparison of the more dolomitized Avon Park Formation with the less dolomitized Ocala Formation at the CR3 site provided the dissolution rate of less than 1E-4 percent per year proposed for the Avon Park Formation at the LNP site. The applicant stated that the dissolution rate for the Ocala Formation at the CR3 site, 1E-4 percent per year, calculated out to 6E-3 percent over the projected 60-year life of that plant. Regarding the degree of dolomitization of the Avon Park Formation at the LNP site, which converts limestone to dolomite, the applicant reported that 18 of 20 samples from the LNP site analyzed during LNP site characterization investigations exhibited a high degree of dolomitization, containing less than 50 percent calcium carbonate ($CaCO_3$). The applicant reported that Easterbrook (1999) documented that about 60 percent $CaCO_3$ is necessary to form karst, and about 90 percent may be required to fully develop karst. Also citing Easterbrook (1999), the applicant stated that dolomites, composed of calcium-magnesium carbonate [$CaMg(CO_3)_2$], have a lower permeability than non-dolomitized limestones. This characteristic diminishes dissolution and karst formation. The applicant concluded that the potential for dissolution and karst formation at the LNP site during the life of the plant is not significant, and added that a monitoring program would be established for the LNP plant to confirm this low dissolution rate as part of the groundwater monitoring program.

Based on review of the applicant's response to RAI 2.5.1-1, as well as an independent review of the references cited therein, the staff concludes that there is a strong technical basis for the

proposed low dissolution rate at the site location. The staff draws this conclusion because characterization of the Avon Park Formation indicates that this unit is dolomitized at depth, and there is a preponderance of published information to document that dolomites and dolomitic limestones have much lower dissolution rates than pure limestones. Consequently, the staff considers RAI 2.5.1-1 to be resolved. The staff further concludes that the only geologic hazard identified in the LNP site area is potential non-tectonic surface deformation resulting from collapse or subsidence related to karst development. The staff addresses this potential hazard in SER Section 2.5.3.4.8.

2.5.1.4.2.6.2 Paleoliquefaction Features

In RAI 2.5.1-41, the staff asked the applicant to discuss the efforts undertaken to document the presence or absence of paleoliquefaction features in the site region, site vicinity, and site area, or to explain why such efforts were not thought to be necessary. In response to RAI 2.5.1-41, the applicant stated that no published or unpublished reports reviewed during site characterization or preparation of FSAR Section 2.5 identified paleoliquefaction features in the LNP site region. In addition, based on discussions with Dr. T. Scott of the FGS (personal communications, 2009), the applicant confirmed that no paleoliquefaction features have been reported anywhere in Florida. The applicant also discussed observations made during field reconnaissance in the LNP site vicinity and site area, which resulted in the suggestion that detailed studies, would not likely provide data useful for evaluating the occurrence, location, or size of prehistoric earthquakes in the LNP site vicinity and area. The applicant indicated that a paucity of exposures and limited stratigraphy favorable for liquefaction in the site vicinity, including along major drainages, rendered it difficult to document the presence or absence of paleoliquefaction features. Therefore, based on existing information documenting that no reported paleoliquefaction features occur in the site region and that Florida currently has a low risk of earthquakes, communications with a knowledgeable expert from the FGS indicating that no paleoliquefaction features have been observed in Florida, and the existence of only sparse exposures, which lack materials favorable for liquefaction, the applicant stated that detailed paleoliquefaction studies were not performed to assess the possibility of prehistoric earthquakes in the site region, site vicinity, or site area.

Based on review of the applicant's response to RAI 2.5.1-41, the staff concludes that paleoliquefaction features are not likely to exist in the site region, site vicinity, or site area. The staff draws this conclusion because investigations by experts knowledgeable about the geology and seismicity of Florida have not demonstrated the existence of paleoliquefaction features anywhere in the State of Florida. In addition, the Florida platform on which the LNP site is located reflects regional tectonic quiescence since the Cretaceous (145.5 Ma) as discussed in FSAR Section 2.5.1.1.2, and there is no geologic or geomorphic evidence of Quaternary (2.6 Ma to present) faulting as discussed in FSAR Section 2.5.3. Consequently, the staff considers RAI 2.5.1-41 to be resolved.

Based on review of FSAR Section 2.5.1.2.6 and the applicant's responses to RAIs 2.5.1-1 and 2.5.1-41, the staff finds that the applicant provided a complete and accurate description of potential geologic hazards in the site area in support of the LNP COL application.

2.5.1.4.2.7 Site Engineering Geology Evaluation

FSAR Section 2.5.1.2.7 discusses site engineering geology, including engineering behavior of soil and rock; zones of alteration, weathering, and structural weakness; karst features; and deformation zones. The applicant indicated that FSAR Section 2.5.4 discusses engineering