Progress Energy

Serial: NPD-NRC-2009-134 10 CFR 52.79
July 1, 2009

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-0001

LEVY COUNTY NUCLEAR POWER PLANT, UNITS 1 AND 2
DOCKET NOS. 52-029 AND 52-030
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 034 RELATED TO BASIC GEOLOGIC AND SEISMIC INFORMATION

Reference: Letter from Brian C. Anderson (NRC) to Garry Miller (PEF), dated May 8, 2009, "Request for Additional Information Letter No. 034 Related to SRP Section 2.5.1 for the Levy County Nuclear Plant Units 1 and 2 Combined License Application"

Ladies and Gentlemen:

Progress Energy Florida, Inc. (PEF) hereby submits our response to the Nuclear Regulatory Commission's (NRC) request for additional information provided in the referenced letter.

A partial response to the NRC request is addressed in the enclosure. The enclosure also identifies changes that will be made in a future revision of the Levy County Nuclear Power Plant Units 1 and 2 application.

If you have any further questions, or need additional information, please contact Bob Kitchen at (919) 546-6992, or me at (919) 546-6107.

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

Executed on July 1, 2009.

Sincerely,

Garry D. Miller
General Manager
Nuclear Plant Development

Enclosure

cc: U.S. NRC Region II, Regional Administrator
Mr. Brian Anderson, U.S. NRC Project Manager

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D094
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**Levy Nuclear Power Plant Units 1 and 2
Response to NRC Request for Additional Information Letter No. 034 Related to SRP Section 2.5.1 for the Combined License Application, dated May 8, 2009**

NRC RAI #	Progress Energy RAI #	Progress Energy Response
02.05.01-8	L-0292	Future Response
02.05.01-9	L-0293	Response enclosed – see following pages
02.05.01-10	L-0294	Future Response
02.05.01-11	L-0295	Response enclosed – see following pages
02.05.01-12	L-0296	Future Response
02.05.01-13	L-0297	NPD-NRC-2009-105, dated June 9, 2009
02.05.01-14	L-0298	Response enclosed – see following pages
02.05.01-15	L-0299	NPD-NRC-2009-105, dated June 9, 2009
02.05.01-16	L-0300	Response enclosed – see following pages
02.05.01-17	L-0301	Future Response
02.05.01-18	L-0302	Response enclosed – see following pages
02.05.01-19	L-0303	Future Response
02.05.01-20	L-0304	NPD-NRC-2009-105, dated June 9, 2009
02.05.01-21	L-0305	Future Response
02.05.01-22	L-0306	Future Response
02.05.01-23	L-0307	Future Response
02.05.01-24	L-0308	Future Response
02.05.01-25	L-0309	NPD-NRC-2009-105, dated June 9, 2009
02.05.01-26	L-0310	NPD-NRC-2009-105, dated June 9, 2009
02.05.01-27	L-0311	NPD-NRC-2009-105, dated June 9, 2009
02.05.01-28	L-0312	NPD-NRC-2009-105, dated June 9, 2009
02.05.01-29	L-0313	Response enclosed – see following pages
02.05.01-30	L-0314	Response enclosed – see following pages
02.05.01-31	L-0315	Future Response
02.05.01-32	L-0316	NPD-NRC-2009-122, dated June 23, 2009
02.05.01-33	L-0317	Future Response

NRC RAI #	Progress Energy RAI #	Progress Energy Response
02.05.01-34	L-0318	Response enclosed – see following pages
02.05.01-35	L-0319	Future Response
02.05.01-36	L-0320	Response enclosed – see following pages
02.05.01-37	L-0321	NPD-NRC-2009-122, dated June 23, 2009
02.05.01-38	L-0322	Future Response
02.05.01-39	L-0323	Future Response
02.05.01-40	L-0324	Future Response
02.05.01-41	L-0325	Future Response
02.05.01-42	L-0326	Future Response
02.05.01-43	L-0327	Future Response
02.05.01-44	L-0328	Future Response
02.05.01-45	L-0330	Future Response

Attachments/Enclosures	Associated NRC RAI #	Pages Included
02.05.01-11A, Electronic communication from Dr. Tom Scott, May 30, 2009	L-0295	2
02.05.01-11B, Electronic communication from Dr. Sam Upchurch, May 28, 2009	L-0295	1
02.05.01-11C, Electronic communication from Harley Means, May 28, 2009	L-0295	1
02.05.01-14A, Electronic communication from Dr. Tom Scott, June 1, 2009	L-0298	1
02.05.01-14B, Electronic communication from Dr. Tom Scott, June 9, 2009	L-0298	1
02.05.01-14C, RAI 02.05.01-14 Figure 1	L-0298	1
02.05.01-14D, RAI 02.05.01-14 Figure 2	L-0298	1
02.05.01-25A, Revised Figure 2.5.1-201	L-0298	1
02.05.01-16A, RAI 02.05.01-16 Figure 1	L-0300	1
02.05.01-16B, RAI 02.05.01-16 Figure 2	L-0300	1
02.05.01-16C1, Revised Figure 2.5.1-219 (Sheet 1)	L-0300	1

Attachments/Enclosures	Associated NRC RAI #	Pages Included
02.05.01-16C2, Revised Figure 2.5.1-219 (Sheet 2)	L-0300	1
02.05.01-16D1, Revised Figure 2.5.1-220 (Sheet 1)	L-0300	1
02.05.01-16D2, Revised Figure 2.5.1-220 (Sheet 2)	L-0300	1
02.05.01-18A, Revised Figure 2.5.1-222	L-0302	1
02.05.01-18B, Revised Figure 2.5.1-209	L-0302	1
02.05.01-18C, RAI 02.05.01-18 Figure 1	L-0302	1
02.05.01-29A, Revised Figure 2.5.1-235	L-0313	1
02.05.01-29B, RAI 02.05.01-29 Figure 01	L-0313	1
02.05.01-30A, Revised Figure 2.5.1-237	L-0314	1
02.05.01-30B, Email communication from Upchurch, June 3, 2009	L-0314	2
02.05.01-28A, Revised Figure 2.5.1-244	L-0318	1
02.05.01-34A, Revised Figure 2.5.1-245	L-0318	1

NRC Letter No.: LNP-RAI-LTR-034

NRC Letter Date: May 8, 2009

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.05.01-09

Text of NRC RAI:

Details related to classification of the unconsolidated Quaternary deposits making up soil layer S-1 by USCS terminology, shown in Figure 2.5.4.2-203A, indicates that these deposits comprise interlayered poorly-graded sand (SP), silty sand (SM), clay (CL), and fat clay (CH). Layers S-2 and S-3, labeled as calcareous silts developed from weathered Avon Park Limestone in FSAR Figure 2.5.1-250, show similar unconsolidated materials in Figure 2.5.4.2-203A which indicates these two layers comprise interlayered clayey sand (SC), silt (ML), silty sand (SM), clay (CL), and fat clay (CH). FSAR Section 2.5.1.2.5.2.1 (pg 2.5-82) states that Quaternary sediments of layer S-1 are differentiated from the top of underlying calcareous silts (layer S-2) by a lack of reaction to hydrochloric acid for the Quaternary sediments. It is not clear why Quaternary sediments could not contain some calcareous material since, as stated in FSAR Section 2.5.1.2.5.2.1 (pg 2.5-81), some of the materials were likely deposited in a near-shore beach environment and such a depositional environment could contain calcareous shell fragments.

In order for the staff to understand the stratigraphic sequence which exists at the site location and to assess the thickness of Quaternary sands as a potential indicator of paleochannels or paleosinkholes, please discuss whether the acid test alone is sufficient to distinguish unconsolidated Quaternary deposits from weathered Avon Park Limestone in boreholes drilled for LNP Unit 1 and LNP Unit 2, or whether other criteria have also been used to make this distinction.

PGN RAI ID #: L-0293

PGN Response to NRC RAI:

During the geotechnical drilling program, sample reaction to dilute hydrochloric acid (HCl) was used as an indicator of carbonate content, but was not the sole indicator used to determine sediment associations. A review of Vernon (1951) indicated that the siliciclastic (quartz and/or other silicates) sediments present at the LNP site are probably of Quaternary origin, directly overlying Eocene Avon Park Formation, which was confirmed during field inspections of LNP soil and rock core samples in 2007 by Thomas Scott, PhD., Assistant State Geologist.

The S1 sediments at LNP are comprised of siliciclastic materials, mainly well-sorted fine quartz sands and silty sands, with clay interbeds, none of which displayed much reaction to HCl. Fossils were not observed in the samples of the S1 materials during the LNP geotechnical program. This observation is consistent with the experience of Tom Scott, FGS Assistant State Geologist, who indicates that typically there are no fossils found in these sediments, so determining their precise age is not possible, and even shell fragments within these quartz sands are rare. It is agreed that the Quaternary sediments at the site could have non-fossil carbonate precipitates as a component. During the investigation program, when inspecting the sediment samples with a hand lens, the presence or absence of quartz grains before and after application of HCl was noted. Also, the presence or absence of fossils and trace minerals was also noted.

The current consensus among state geologists is that sediments of the Florida Platform are Quaternary when the sediments are found at elevations below 60-100 feet (18-31 meters) NAVD88. The S2-S3 transition zone of weathered Avon Park Formation carbonate deposits will typically lack siliciclastic materials. This transition zone may occur as an epikarst (eroded/weathered) or, as calcareous silts, in this case as a dolosilt. The dolosilts observed at LNP are comprised of carbonate materials with a distinctive yellow color, and many times are comprised of small angular euhedral crystals which are very easily distinguished from rounded quartz sands, silicate-derived silts and shell fragments, both visually (via 10X hand lens) and by use of HCl test. Dolosilt is a common sediment type in the Avon Park Formation, according to Dr. Scott. During the LNP geotechnical boring program this was confirmed, especially in the upper 100 feet of the Avon Park Formation cores, where it is found interbedded with more indurated limestone and dolostone layers.

Regarding the NRC staff question of site-specific stratigraphic indicators of paleochannels or paleosinks; the differentiation between paleosinks and paleochannels in the subsurface is difficult to make. This is especially true at the LNP site given the limited amount of subsurface data available in the Quaternary deposits and upper Avon Park Formation. The general lack of significant subsurface voids at the site coupled with observed thickening of the Quaternary sequence in the northern site area could indicate a possible paleochannel interpretation, based upon currently available data.

References:
None

Associated LNP COL Application Revisions:

Paragraphs 2, 3 and 4 of the FSAR text for Section 2.5.1.2.5.2.1 will be modified in a future revision from:

"Surficial geologic deposits at the site consist of undifferentiated Quaternary age fluvial and terrace sediments, primarily silty fine sands. The sands overlie the Avon Park Formation, a shallow marine carbonate rock unit of middle Eocene age.

The Quaternary deposits (designated unit S1) encountered in the LNP site borings generally consist of gray silty sands. The subrounded to rounded sand grains and sorting indicate that the sands likely were deposited in a nearshore beach or dune environment, possibly during the transgression and regression of the high sea level stand that formed the underlying marine terrace platform, which is interpreted to be middle to early Pleistocene in age (>340,000 years ago as discussed in FSAR Subsection 2.5.1.2.1.2). There may be a component of younger eolian sand deposited during subsequent sea level fluctuations and locally derived fluvial deposits. In some boreholes, thicker section of the S1 deposits consist of gray sand intermixed or interbedded with medium brown sand and grayish black clay and sandy clay layers. These deposits are interpreted to represent infills of sand and marsh deposits into paleosinks. Some of the infill material in the deeper paleosinks may be Tertiary as well as Quaternary in age.

The Quaternary sediments (unit S1) at LNP site are differentiated from the top of the underlying calcareous silts (unit S2) at the top of the Avon Park Formation by their lack of reaction to hydrochloric acid (HCL). The thickness of these Quaternary sediments varies across the LNP site from less than 3 m (10 ft.) to approximately 30 m (100 ft.), with a thickness of approximately 2 m (6 ft.) under the nuclear island. At a few boring locations, thickness of the Quaternary sediments was higher, and the maximum thickness on site was measured at 73.5 m (241 ft.) in one boring completed as part of the pre COLA siting investigations (Borehole NB 5), located beyond the perimeter of the LNP 2 site (Figure 2.5.1-251 and Figure 2.5.1-252). This may represent infilling of localized paleokarst features or paleochannels."

To read:

"Surficial geologic deposits at the site consist of undifferentiated Quaternary age fluvial and terrace sediments, primarily silty fine quartz sands. The sands overlie the Avon Park Formation, a shallow marine carbonate rock unit of middle Eocene age.

The Quaternary deposits (designated unit S1) encountered in the LNP site borings generally consist of gray silty quartz sands. The subrounded to rounded sand grains and sorting indicate that the sands likely were deposited in a nearshore beach or dune environment, possibly during the transgression and regression of the high sea level stand that formed the underlying marine terrace platform, which is interpreted to be middle to early Pleistocene in age (>340,000 years ago as discussed in FSAR Subsection 2.5.1.2.1.2). There may be a component of younger eolian quartz sand deposited during subsequent sea level fluctuations and locally derived fluvial deposits. In some boreholes, thicker section of the S1 deposits consist of gray quartz sand intermixed or interbedded with medium brown sand and grayish black clay and sandy clay layers. These deposits are interpreted to represent infills of sand and marsh deposits into paleosinks. Some of the infill material in the deeper paleosinks may be Tertiary as well as Quaternary in age.

The Quaternary sediments (unit S1) at LNP site are differentiated from the top of the underlying calcareous silts (dolosilts, unit S2) at the top of the Avon Park Formation by their observed siliciclastic (quartz sand or other silicates) lithology, their typically gray to brown color, an absence of fossils, their subrounded to rounded grain shapes, and their lack of reaction to hydrochloric acid (HCl). The thickness of these Quaternary sediments varies across the LNP site from less than 3 m (10 ft.) to approximately 30 m (100 ft.), with a thickness of approximately 2 m (6 ft.) under the nuclear island. At a few boring locations, thickness of the Quaternary sediments was higher, and the maximum thickness on site was measured at 73.5 m (241 ft.) in one boring completed as part of the pre COLA siting investigations (Borehole NB 5), located beyond the perimeter of the LNP 2 site (Figure 2.5.1-251 and Figure 2.5.1-252). Based upon available boring data at the LNP 2 site, this local thickening of Quaternary sediments may represent infilling of localized paleokarst features or paleochannels."

Attachments/Enclosures:
None

NRC Letter No.: LNP-RAI-LTR-034

NRC Letter Date: May 8, 2009

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.05.01-11

Text of NRC RAI:

The response to RAI 2.5.1-2 indicates that Vernon (1951) attributed the regional orthogonal fracture sets to tensional stresses associated with formation of the Ocala Arch. FSAR Section 2.5.1.2.4 (pg 2.5-76) states that Vernon (1951) interpreted the arch as a plunging anticlinal fold, with the primary fracture set parallel to the axis of this structure and the secondary set perpendicular to the primary set. FSAR Section 2.5.1.2.4 (pg 2.5-76) also states that this regional fracture system is expressed at the surface by lineaments. Vernon (1951) defines the regional fracture system as two orthogonal fracture sets, spaced 30-50 km (20-30 mi) apart, which are parallel and perpendicular to the axis of the Ocala Arch and which control stream drainages and sinkhole alignments. Considering orientation of the two regional fracture sets in relation to the axis of the arch as defined by Vernon (1951), these features could be release (i.e., parallel to the axis of the Arch) and extension (perpendicular to the axis) fractures developed across the uplift. The FSAR does not clearly define orientations of these two orthogonal fracture sets (e.g., as contoured maxima on stereonet plots), but a relationship to the Ocala arch as interpreted by Vernon (1951) suggests an origin related to bending of rock units across the arch.

The response to RAI 2.5.1-2 points out that Lafrenz (2003) suggested two episodes of uplift occurred to create the Ocala Arch, the first during Late Oligocene-Early Miocene time (i.e., mid-Tertiary) and the second in Early Pliocene-Early Pleistocene time (i.e., post-Miocene neotectonic uplift during Late Tertiary-Early Quaternary). In addition, FSAR Section 2.5.1.2.1.3.1 (pg 2.5-62) states that Early Miocene "structural adjustments" of the crust associated with formation of the Ocala feature continued, with regional fracturing significantly affecting karst activity. Consequently, information presented in the FSAR suggests that tectonic uplift may have produced the Ocala Arch and the associated regional joint patterns, with deformation extending into Quaternary time. FSAR Section 2.5.1.1.4.3.5 (pg 2.5-43) discusses Quaternary tectonic structures, but does not address the interpretation of Lafrenz (2003) which suggests that Quaternary tectonic deformation was involved in development of the arch.

In contrast to the interpretation stated above for a tectonic genesis of the Ocala Arch, FSAR Section 2.5.1.1.4.3.4 (pg 2.5-39) refers to the Ocala Arch as the "Ocala platform" to avoid any connotation of a structural feature generated by uplift. This FSAR section states that the platform does not warp sedimentary units older than Middle Miocene and appears to have been produced by sedimentation processes (i.e., specifically, anomalous buildup of Middle Eocene carbonates or differential compaction of carbonates of that age shortly after deposition). The interpretation that the Ocala arch, or platform, is related to sedimentation processes is quite different from the suggestion that this feature developed as a result of two episodes of uplift and the regional orthogonal fracture sets are release and extension fractures associated with the uplift. Because fractures provide potential pathways for dissolution of limestone in the site region and at the site location, a suggestion of Quaternary deformation which could further enhance development of fractures is of potential concern.

FSAR Section 2.5.1.2.4 (pg 2.5-76) also states that the Ocala platform was produced by sedimentary processes rather than uplift as Vernon (1951) suggested. However, this section further indicates that bedding in Tertiary units dips southwest and northeast along the flanks of the feature and northwest and southeast along its plunge, suggesting uplift with deformation of bedding. It is not clear why, if development of the feature is related strictly to sedimentary processes, dips of bedding on the limbs and along the hinge line of the feature show variations which suggest at least a gentle uplift (i.e., a broad doming) of the sedimentary units.

In order for the staff to understand origin of the Ocala Arch (or platform) and the regional fracture sets which occur at and near the site location and control stream drainages and locations of sinkholes, please address the following comments:

(a) Define orientations of the two orthogonal fracture sets which comprise the regional fracture system on stereonet plots, if a sufficient number of orientations have been measured.

(b) Discuss the mechanism(s) for generation of regional and local fractures sets, including a possible association with development of the Ocala Arch and the relationship between regional and local fracture sets.

(c) Discuss the two apparently contradictory interpretations of the genesis of the Ocala arch/platform (i.e., a possible tectonic versus a non-tectonic origin).

(d) Discuss the logic for concluding that origin of the Ocala arch/platform is the result of sedimentary processes when reported dips of bedding in the sedimentary units suggest that a broad uplift has affected these units.

(e) In light of the interpretation of Lafrenz (2003) that the Ocala Arch was created during two episodes of uplift, one of which was proposed to be early Quaternary in age, justify the conclusion that Quaternary uplift is not occurring to enhance development of fractures at the site location.

PGN RAI ID #: L-0295

PGN Response to NRC RAI:

a) As presented in FSAR Subsection 2.5.1.2.4, the regional primary-orthogonal fracture set described by Vernon trended in NW SE (North 45 degrees West) and NE SW directions. (Reference 2.5.1 261) Others have observed a second ENE WSW and WNW ESE fracture set, as described in FSAR Subsection 2.5.3.2.1. A subset of these regional fractures has been identified during subsequent LNP field investigations, with primary and orthogonal fracture spacing observed to be on the order of 5.8 to 7.2 m (19 to 23.5 ft.). The directions of these more local fracture patterns do coincide with the regional fracture trends in direction. As discussed in FSAR Subsection 2.5.4.1.2.1.1, this local fracture set has been observed in local outcrops near the LNP site during field reconnaissance at the Gulf Hammock quarry (located approximately 19 km [11.8 mi.] NNW from the LNP site), and along the banks of the Waccasassa River (located approximately 25 km [15.7 mi.] NNW from the LNP site). Stereonet plots showing the relationship between fracture sets measured at these locations compared to the orientations of fracture sets observed in excavations for the Crystal River Unit No. 3 Nuclear Station and regional fracture trends inferred from lineament analyses at regional to LNP site location scales are provided in the Response to RAI 02.05.01-39.

b) A detailed discussion of the characteristics of fracture systems at the regional to LNP site-specific scale is provided in the Response to RAI 02.05.01-39. Lineaments mapped on a regional scale (Figure 2.5.3-203) suggest that prominent regional fracture systems are statewide and not uniquely associated with the Ocala platform. Structural implications of inferred fracture trends relative to the Ocala platform and possible nontectonic mechanisms (i.e., isostatic response to carbonate dissolution and sediment loading) that may explain the systematic joint systems observed in the site region also are discussed in the Response to RAI 02.05.01-39.

c) FSAR Section 2.5.1.1.4.3.4 (pg 2.5-39) refers to the Ocala Arch as the "Ocala platform" to avoid any connotation of a structural feature generated by uplift (Reference 2.5.1-261 and Reference 2.5.1-240) and refers to the Ocala platform as being of sedimentary origin, not a tectonic-induced structural feature. Miller (Reference 2.5.1-240) cites Winston's (1976) (Reference RAI 02.05.01-11 01) research that indicated an anomalous thickening in the Middle Eocene Lake City Limestone (now part of the Middle Eocene Avon Park Formation as per Miller [1986] Reference 2.5.1-240) in the vicinity of the Ocala platform. Winston (Reference RAI 02.05.01-11 01) notes that the Ocala feature is a structure that shows closure on shallow beds, but is underlain by beds that do not reflect the structure. Winston suggested that draping of younger carbonate sediments across this feature created the appearance of an "arch or uplift" without any true structural origin . The current view held by Florida Geological Survey geologists is that the Ocala platform and associated dip patterns was formed via differential subsidence, sedimentation and erosion, not via tectonic uplift. (Reference RAI 02.05.01-11 02; Reference RAI 02.05.01-11 03; Reference RAI 02.05.01-11 04)

d) The information presented in Lafrenz et al. (Reference RAI 02.05.01-14 02) references Williams et al.(1977) (Reference RAI 02.05.01-14 03) as the source for the statement concerning two episodes of uplift forming the Ocala platform. Williams et al. (Reference RAI 02.05.01-14 03) state that the evidence for the first episode of uplift in the Late Oligocene through Early Miocene is based on the occurrence of land vertebrate faunas from this time frame, and the absence of the Suwannee Limestone and the Tampa Formation (now Tampa Member of the Arcadia Formation, Hawthorn Group). Williams et al. cite as evidence for the second episode of uplift the existence of Pliocene and Pleistocene land vertebrate faunas.

   Their assumption was that the presence of land during these times indicated uplift. The work by Williams et al. (Reference RAI 02.05.01-14 03) was done prior to the publication of significant sea level curves for the Cenozoic, and did not take sea level fluctuation into account as a cause of erosion. The Lafrenz et al. (and Williams et al.) arguments/assumptions for tectonic uplift based only on indirect (fossil) evidence without considering erosion caused by sea level change are not considered to be well supported.

   FSAR Section 2.5.1.2.1.3.1 (pg 2.5-62) states that Early Miocene "structural adjustments" of the crust associated with formation of the Ocala feature continued, with regional fracturing significantly affecting karst activity. Denizman and Randazzo (Reference 2.5.1-

316) refer to Vernon (Reference 2.5.1-262) for the timing and continuation of any uplift and do not present any new data on the reality, mechanism or timing of any uplift associated with the Ocala platform.

References:

1. RAI 02.05.01-11 01, Winston, G. O., "Florida's Ocala Uplift is Not an Uplift," Bulletin of the American Association of Petroleum Geologists, v. 60, no. 6, p. 992-994
2. RAI 02.05.01-11 02, Scott, T., personal communication, May 30, 2009
3. RAI 02.05.01-11 03, Upchurch, S., personal communication, May 28, 2009
4. RAI 02.05.01-11 04, Means, H., personal communication, May 28, 2009
5. RAI 02.05.01-11 05, Lafrenz, W. B., W. H. Bulmer, S. V. Jamilla, "Characteristics and Development of Shallow Solution Features in Thinly Mantled Karst, Alachua and Levy Counties, Florida, " in Florea, L. J., Vacher, H. L., and Oches, E. A., eds., Karst Studies in West Central Florida USF Seminar in Karst Environments 2003, Proceedings of the 2003 Seminar in Karst Environments course at the University of South Florida Department of Geology, Published in cooperation with the Southwest Florida Water Management District, December, 2003, pp. 21-38
6. RAI 02.05.01-11 06, Williams, K. E., Nicol, D., and Randazzo, A. F., "The Geology of the Western Part of Alachua County, Florida," Florida Bureau of Geology Report of Investigations No. 85, 105 pp

Associated LNP COL Application Revisions:

See Response to RAI 02.05.01-18 for Revisions to Section 2.5.1.1.4.3.4

Attachments/Enclosures:

Attachment 02.05.01-11A, Reference RAI 02.05.01-11 02

Attachment 02.05.01-11B, Reference RAI 02.05.01-11 03

Attachment 02.05.01-11C, Reference RAI 02.05.01-11 04

NRC Letter No.: LNP-RAI-LTR-034

NRC Letter Date: May 8, 2009

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.05.01-14

Text of NRC RAI:

FSAR Section 2.5.1.1.1.1.3 (pgs 2.5-16 through 2.5-18) discusses the Floridian Coastal Plain section of the Coastal Plain physiographic province. The LNP site is located in the Central Zone of the Floridian section which encompasses the entire Florida peninsula and is made up of the Northern, Central, and Southern Zones. This FSAR section states that the Floridian section is recently emergent, and that the Northern Zone of the section reaches elevations of 60-90m (200-300ft) above mean sea level (amsl), while the Central Zone lies 61m (200ft) amsl and the Southern Zone reaches elevations less than 10m (35ft) amsl. FSAR Section 2.5.1.1.1.1.3 does not provide a discussion of timing of "recent" emergence of the Floridian section. In addition, FSAR Section 2.5.1.1.1.1.1 (pg 2.5-15) indicates that the Sea Island Coastal Plain Section, which lies to the north of the Floridian section, exhibits a slightly submerged margin. It is not clear from the discussion presented in the FSAR whether differential emergence of the three zones of the Floridian section (as possibly suggested by differences in elevation between the zones) relative to the Sea Island section to the north may result from differential uplift of the Floridian section across a hinge line lying between these two sections, or from changes in sea level around relict topography. Uplift could imply neotectonic deformation (i.e., post-Miocene, or less than 5.3 mya in age) of the Florida peninsula.

In order for the staff to assess whether neotectonic deformation may be occurring in the Florida peninsula, and consequently in the region containing the LNP site, please discuss the mechanism for the apparent differential emergence of the Floridian Coastal Plain section in which the LNP site lies, relative to the Sea Island Coastal Plain section. Please discuss the timing of recent emergence of the Floridian section. If differential uplift is suggested, please also discuss whether there is any regional tectonic feature located in northern Florida that may represent a flexural hinge between the Floridian and Sea Island Coastal Plain sections of the Coastal Plain physiographic province.

PGN RAI ID #: L-0298

PGN Response to NRC RAI:

This RAI requests additional information regarding the history of emergence of the Floridian peninsula and further discussion of the neotectonic implications, if any, of the differences in the present topography and physiography of the Floridian Coastal Plain section relative to the Sea Island Coastal Plain section to the north and among the different physiographic units within the Floridian Coastal Plain section.

The Sea Island Coastal Plain section was subdivided by Clark and Zisa (1976) (Reference RAI 02.05.01-14 01) to delineate the Barrier Island Sequence District that encompasses the modern coastal areas in Georgia. In this region Pliocene – Pleistocene sea level fluctuations deposited sediments forming step-like terraces, barrier islands, and beach. The Barrier Island Sequence District, which is characterized by beach ridges, dunes, and paleo-lagoons, extends into Florida from Georgia. The surficial and shallow subsurface sediments of the district were deposited during the Pliocene-Pleistocene and lie unconformably on sediments ranging from the Middle Eocene Avon Park Formation to the Oligocene – Miocene Hawthorn Group (Reference RAI 02.05.01-14 02 and Reference RAI 02.05.01-14 03, see Attachments RAI 02.05.01-14 A and RAI 02.05.01-14 B).

The seaward margin of the Sea Island Coastal Plain is described as being slightly submerged (Reference 2.5.1-210). The margin is slowly being inundated as sea level rises. This margin is the site of active deposition and reworking of sediments.

Paleo-shoreline features near the border of northern Florida and southern Georgia have been found to contain marine fossils of possible Pleistocene age at elevations of between 42 and 49 m (138 and 160 ft.) above mean sea level (amsl), suggesting that some mechanism of epeirogenic uplift has affected the area (Reference RAI 02.05.01-14 04, Reference RAI 02.05.01-14 05, Reference 02.05.01-14 06). Pleistocene shoreline features do not maintain a constant elevation when traced from Georgia into southern Florida. From a low point along the Georgia coast, the Trail Ridge shoreline features rise to maximum elevation of about 58 m (190 ft.) in northern peninsular Florida and gradually drops to elevations of approximately 40 m (130 ft.) in south-central Florida (Reference RAI 02.05.01-14 04) (RAI 02.05.01-14 Figure 1 and RAI 02.05.01-14 Figure 2) This area straddles the boundary between the Sea Island Coastal Plain and the Floridian Coastal Plain sections (see Revised Figure 2.5.1-201 [see Attachment 02.05.01-25A]). As noted below, a possible cause of nontectonic broad uplift during the late Cenozoic in this region is mass removal from the Florida carbonate platform via karst-related groundwater dissolution and subsequent isostatic readjustment.

The Cenozoic history of the Floridian peninsula, which discusses the gradual emergence of the Florida peninsula from north to south is outlined in FSAR Section 2.5.1.1.2.3. The differences in elevation between the three zones of the Floridian section are the result of depositional and erosional processes. As sea level fluctuated through the Pliocene and Pleistocene, marine waters covered the existing topography during the highest sea levels. Reduction in sea level re-exposed the relict topography, modifying it in the process. The emergence of any portion of the Florida peninsula was controlled primarily by sea level variations. The relatively low elevations of topography in southern zone of the Floridian section are the result of marine erosion that occurred during middle and late Pleistocene sea-level highstands that inundated most of southern Florida (Reference 2.5.1-236).

Although the distribution of Miocene and younger marine sedimentary rocks at the surface demonstrates emergence of the Florida platform from a submarine environment during the Neogene, no evidence exists to suggest tectonic deformation or orogenic activity of any nature throughout the Cenozoic (Reference 2.5.1 225). Opdyke et al. (1984) (Reference RAI 02.05.01-14 04) and Willett (2006) (Reference RAI 02.05.01-14 05) postulate that isostatic readjustment driven by carbonate dissolution has caused broad epeirogenic uplift in Florida. Readjustment rates calculated by Opdyke et al. (Reference RAI 02.05.01-14 05) were 36 m (118 ft) during the Pleistocene and Holocene. This equates to one meter of limestone every approximately 38,000 years. Willett (Reference RAI 02.05.01-14 05), using a more robust data set, concluded that karst areas in Florida are losing approximately one meter (three ft.) of limestone every 160,000 years and that the impact of long-term carbonate dissolution and mass loss from the Florida platform has led to isostatic uplift of at least 9 m (30 ft.) and as much as 58 m (190 ft.) since the beginning of the Quaternary (~1.6 Ma). This process helps to explain the observed elevations of Pliocene-Pleistocene marine sediments that exceed paleosea level projections.

Means (Reference 02.05.01-14 07) suggests that lithospheric flexture due to sediment loading is another nontectonic mechanism in addition to isostatic adjustment due to carbonate dissolution that could explain the presence of marine-influenced sediments observed at elevations of over 66 m (216 ft) in the panhandle region of Florida, higher than any maximum sea-level stand of the Miocene, Pliocene, or Pleistocene.

References:

The following references were used for the RAI response; References RAI 02.05.01-14 04 and RAI 02.05.01-14 05 will be added in a future revision of the FSAR.

1. RAI 02.05.01-14 01, Clark, W.Z., Jr., and A.C. Zisa, Physiographic Map of Georgia, The Geologic and Water Resources Division, Department of Natural Resources,1976, 2 pp., one map
2. RAI 02.05.01-14 02, Scott, T. Personal communication, June 1, 2009
3. RAI 02.05.01-14 03, Scott, T. Personal communication, June 9, 2009
4. RAI 02.05.01-14 04, Opdyke, N.D., D.P. Spangler, D.L. Smith, D.S. Jones, and R.C. Lindquist, "Origin of the Epeirogenic Uplift of Pliocene-Pleistocene Beach Ridges in Florida and Development of the Florida Karst," Geology, Vol. 15, 1984, pp. 900 – 903
5. RAI 02.05.01-14 05, Willett, M.A., "Effect of Dissolution of the Florida Carbonate Platform on Isostatic Uplift and Relative Sea-Level Change," M.S. thesis, Florida State University, 2006
6. RAI 02.05.01-14 06, Pirkle, F.L., and L.J. Czel, "Marine Fossils from Region of Trail Ridge, A Georgia-Florida Landform," Southeastern Geology, Vol. 24, 1983, pp. 31 – 38
7. RAI 02.05.01-14 07, Means, G. H., "A Marine-influenced Siliciclastic Unit (Citronelle Formation) in Western Panhandle Florida," M. S. thesis submitted to the Department of Geological Sciences, Florida State University, 2009,134 pp

Associated LNP COL Application Revisions:

The revisions include text modifications and the addition of references as outlined below.

Text revisions:

In addition to changes to Section 2.5.1.2.1.2 Marine Terraces as outlined in the Response to RAI 02.05.01-29, the following change will be made to the LNP FSAR Chapter 2 in a future revision:

Insert a new paragraph before the last paragraph of Section 2.5.1.1.2 and revise the following portion of FSAR Section 2.5.1.1.2, from:

"Pleistocene high sea level stands are recorded in southern Florida and in the reef record of the tectonically stable Florida Keys island chain that lies just beyond the site region boundary. (Reference 2.5.1 236) Stratigraphic studies suggest that two high sea level stands of Middle Pleistocene age are recorded there; preliminary ages are on the order of approximately 300 to 340 thousand years before present (ka) and 220 to 230 ka. Corals in reefs of two high sea level stands of the last interglacial complex, the approximately 80 ka and 120 ka stands, also are present on the Florida Keys and the approximately 120 ka high stand terrace is mapped around the perimeter of the Florida peninsula at an elevation of approximately 6 m (21 ft.) amsl. (Reference 2.5.1 237) Because the Florida platform represents long term carbonate sedimentation on a passive margin, late Quaternary deposits on the Florida Keys have not experienced significant uplift, subsidence, or tectonic deformation. (Reference 2.5.1 237)"

The revision will read:

Although the distribution of Miocene and younger marine sedimentary rocks at the surface demonstrates emergence of the Florida platform from a submarine environment during the Neogene, no evidence exists to suggest tectonic deformation or orogenic activity of any nature throughout the Cenozoic (Reference 2.5.1 225). .Epeirogenic uplift and regional elevation of Plio-Pleistocene beach ridges in northern Florida have been attributed to density changes within limestone formations experiencing Pleistocene and Holocene karstification (Reference RAI 02.05.01-14 04). Estimates of dissolved limestone based on current erosion rates suggest an isostatic uplift of at least 9 m (30 ft.) and as much as 58 m (190 ft.) since the beginning of the Quaternary. (Reference RAI 02.05.01-14 05).

Pleistocene high sea level stands are recorded in southern Florida and in the reef record of the tectonically stable Florida Keys island chain that lies just beyond the site region boundary (Reference 2.5.1 236). Stratigraphic studies suggest that two high sea level stands of Middle Pleistocene age are recorded there; preliminary ages are on the order of approximately 300 to 340 thousand years before present (ka) and 220 to 230 ka. Corals in reefs of two high sea level stands of the last interglacial complex, the approximately 80 ka and 120 ka stands, also are present on the Florida Keys, and the approximately 120 ka high stand terrace is mapped around the perimeter of the Florida peninsula at an elevation of approximately 6 m (21 ft.) amsl. (Reference 2.5.1 237) Because the Florida platform represents long term carbonate sedimentation on a passive margin, late Quaternary deposits on the Florida Keys have not experienced significant uplift, subsidence, or tectonic deformation. (Reference 2.5.1 237)

Attachments/Enclosures:

Attachment 02.05.01-14A, Reference RAI 02.05.01-14 02

Attachment 02.05.01-14B, Reference RAI 02.05.01-14 03

Attachment 02.05.01-14C, RAI 02.05.01-14 Figure 1

Attachment 02.05.01-14D, RAI 02.05.01-14 Figure 2

Attachment 02.05.01-25A, Revised Figure 2.5.1-201

NRC Letter No.: LNP-RAI-LTR-034

NRC Letter Date: May 8, 2009

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.05.01-16

Text of NRC RAI:

FSAR Section 2.5.1.1.4.3.1 (pg 2.5-35) states that the Jay fault was recognized by Barnett (1975) based on truncation of northwest-trending magnetic anomalies which dominate the northern part of the Florida peninsula. FSAR Figure 2.5.1-220 shows that this fault is coincident with the Florida lineament. FSAR Figure 2.5.1-220 also illustrates that the magnetic anomalies which intersect, and appear to be truncated by, this fault trend northeast rather than northwest. The fault itself trends northwest across the Florida peninsula.

In order for the staff to assess the Jay fault, please clarify the statement that northwest-trending magnetic anomalies are truncated by this structure when Figure 2.5.1-220 does not appear to show this relationship.

PGN RAI ID #: L-0300

PGN Response to NRC RAI:

The justification given by Barnett (Reference 2.5.1-239) for the location of the northernmost of the three west-northwest-trending faults crossing the Florida peninsula as shown by on an interpretative subcrop map of the sub-Zuni surface is as follows:

> *By empirically following magnetic lineations on the aeromagnetic map by Taylor and others (1968), it is possible to project the trace of the great Abaco Fault westward across the Bahama Platform to Florida. It then crosses Florida close to the 28th parallel along a west-northwest trend reentrants on the aeromagnetic map This trend truncates the northwest trending magnetic anomalies which dominate the northern part of peninsular Florida.*

RAI 02.05.01-16 Figures 1 and 2 (see Attachments 02.05.01-16A and 02.05.01-16B) show the location of the postulated basement faults of Barnett (Reference 2.5.1-239) and others (Reference 2.5.1-223, Reference 2.5.1-225, Reference 2.5.1-226, Reference 2.5.1 227) relative to aeromagnetic anomaly maps of Taylor et al. (Reference RAI 02.05.01-16 01) and NAMAG (2002) (Reference 2.5.1-256), respectively. The postulated basement faults mapped by Barnett follow the northwest-trending anomalies south of the northernmost of the faults transecting the Florida peninsula rather than the northeast-trending anomalies in the northern part of the Florida peninsula.

The Jay fault, which is shown in two slightly different locations within the same publication of Smith and Lord (Reference 2.5.1-225) and the Florida lineament as shown by Christenson (Reference 2.5.1 227), coincide in part with the fault shown by Barnett.

Figures and text describing the postulated west-northwest to northwest-trending basement shear zones in the study region will be modified in a future revision to clarify uncertainties in the location and character of postulated basement structures (see Response to RAI 02.05.01-18).

References:

RAI 02.05.01-16 01, Taylor, P.T., I. Zietz, and L.S. Dennis, "Geologic Implications of Aeromagnetic Data for the Eastern Continental Margin of the United States." Geophysics, vol.33, pp.755-780, 1968

Associated LNP COL Application Revisions:

See Response to RAI 02.05.01-18 for revisions to text.

Figure 2.5.1-219 and Figure 2.5.1-220 will be modified to Figure 2.5.1-219 (Sheet 1 and Sheet 2), and Figure 2.5.1-220 (Sheet 1 and Sheet 2) in a future revision (see Attachments 02.05.01-16C1 and 16C2 and 02.05.01-16D1 and D2) to include: Sheet 1 that will show the data and Sheet 2 that will show postulated basement structures relative to the aeromagnetic and gravity anomaly data, respectively.

Attachments/Enclosures:

1. 02.05.01-16A, RAI 02.05.01-16 Figure 1
2. 02.05.01-16B, RAI 02.05.01-16 Figure 2
3. 02.05.01-16C1, Revised Figure 2.5.1-219 (Sheet 1)
4. 02.05.01-16C2, Revised Figure 2.5.1-219 (Sheet 2)
5. 02.05.01-16D1, Revised Figure 2.5.1-220 (Sheet 1)
6. 02.05.01-16D2, Revised Figure 2.5.1-220 (Sheet 2)

NRC Letter No.: LNP-RAI-LTR-034

NRC Letter Date: May 8, 2009

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.05.01-18

Text of NRC RAI:

FSAR Section 2.5.1.1.4.3 (pgs 2.5-34 through 2.5-43) describes regional tectonic structures within 320km (200mi) of the LNP site, and states that FSAR Figures 2.5.1-208 and 2.6.1-209 illustrate locations of the principal tectonic features described. However, neither of these figures appear to show locations of the Bahamas fracture zone (Figures 2.5.1-207, 2.5.1-212, and 2.5.1-222 do), the Sunniland fracture zone (Figures 2..5.1-212 and 2.5.1-222 do, and Figure 2.5.1-209 shows a Sunniland arch), the Florida Elbow fault (Figure 2.5.1-222 does), the postulated fault of Applin and Applin, the Suwannee-Wiggins suture (Figure 2.5.1-211 does, but Figure 2.5.1-208 shows a Wiggins uplift and Figure 2.5.1-209 shows a Wiggins arch), the South Georgia rift (Figure 2.5.1-204, and maybe 2.5.1-206, do), the Brevard platform, the Gulf trough (Figure 2.5.1-224 does, seemingly in the area of the South Georgia rift), the Jacksonville basin, the Nassau nose, the Okeechobee basin, the Oscelo low, the Sanford high, the St. Johns platform, and the Suwanee strait.

In order for staff to assess tectonic structures within the LNP site region, please locate all missing features on a map or maps that are correctly referenced in the FSAR, or explain why such a map is not necessary.

PGN RAI ID #: L-0302

PGN Response to NRC RAI:

FSAR Section 2.5.1.1.4.3 and related figures showing tectonic features (Figures 2.5.1-209 and 2.5.1-222) will be modified in a future revision to better describe uncertainties in the locations, ages, and style of deformation for regional tectonic structures. FSAR Section 2.5.1.1.4.3 will be reorganized to group discussion of regional tectonic structures into five categories: Postulated Basement Faults, Paleozoic Tectonic Structures, Mesozoic Tectonic Structures, Cenozoic Tectonic Structures, and Quaternary Tectonic Structures. Alternative interpretations of postulated basement faults are shown on Revised Figure 2.5.1-222 (see Attachment 02.05.01-18A). Paleozoic and Mesozoic tectonic structures are shown on Revised Figure 2.5.1-209 (see Attachment 02.05.01-18B). Cenozoic tectonic structures are shown on RAI 02.05.01-18 Figure 01 (see Attachment 02.05.01-18C). The only speculative Quaternary tectonic features are postulated faults of Vernon (Reference 2.5.1-262), which are shown on Figure 2.5.1-223.

References:

None

Associated LNP COL Application Revisions:

The following changes will be made to the LNP FSAR Chapter 2 in a future revision:

Figure 2.5.1-209 will be revised to show Paleozoic and Mesozoic structures. RAI 02.05.01-18 Figure 1 will be added to show Cenozoic structures. Figure 2.5.1-222 will be revised to label the North Providence Channel fault and to show the Jay fault.

Revise the following portion of FSAR Section 2.5.1.1.4.3 from:

"2.5.1.1.4.3 Regional Tectonic Structures within a 320 km [200 mi.] Radius

Ewing subdivides the structural framework of the Gulf of Mexico basin into three major structural provinces, which correspond to the three major lithofacies provinces that persist from the Late Jurassic to the Holocene. These include (1) the northwestern progradational margin (from northeastern Mexico to Alabama, (2) the eastern carbonate margins (the Florida and Yucatan platforms), and (3) the western compressional margin. (Reference 2.5.1-252) The LNP site lies within the eastern carbonate platform province (Figure 2.5.1-208).

Principal tectonic features in the site region (320 km [200 mi.] radius) and surrounding portions of southeastern United States are shown on Figure 2.5.1-208 and Figure 2.5.1-209. The tectonic features shown on these figures reflect the cumulative deformation of tectonic events throughout the Late Proterozoic to Early Paleozoic, Paleozoic, Mesozoic, and Cenozoic eras. These categories provide the framework for the discussion that follows.

2.5.1.1.4.3.1 Late Proterozoic to Early Paleozoic Basement Structures

Various regional structures have been inferred from synthesis of geological, geophysical, and tectonic information in the study region (Figure 2.5.1-222). Based on geologic data from nearly 80 wells in Florida and Georgia and interpretation of geophysical data, Barnett provided the first comprehensive summary of basement structures (pre-Cretaceous) in Florida that permitted a reconstruction of its tectonic history (Reference 2.5.1-239).

Bahamas Fracture Zone. The Bahamas fracture zone, which trends northwest across southern Florida and the West Florida shelf, forms the northeast margin of the Gulf basin and is a Jurassic transform boundary that joined the Gulf of Mexico spreading center to the Atlantic spreading center. (Reference 2.5.1-223) This fracture zone probably represents a major crustal boundary between continental and thick transitional rocks. (Reference 2.5.1-205) To the northwest, it joins into the Gulf Rim fault zone (also referred to as the Alabama – Arkansas fault zone) (Reference 2.5.1-229), which is a composite fault and graben system that trends northwest across southern Alabama, central Mississippi, northern Louisiana, and central Texas. (Reference 2.5.1-251) The fault zone across the Florida panhandle is referred to as the Jay fault by Smith (Reference 2.5.1-257) and was also recognized by Barnett (Reference 2.5.1-239) based on the apparent truncation of northwest-trending magnetic anomalies, which dominate the northern part of the peninsula. Smith and Lord (Reference 2.5.1-225) speculate that the different basement terranes were moved laterally into their relative positions along strike-slip faults, such as the Jay fault, during the Late Paleozoic closure of the Iapetus Ocean. Smith and Lord (Reference 2.5.1-225) suggest that the fault, which likely experienced right-slip displacement during the Late Paleozoic, appears to have been a major transform structure that accommodated left-lateral strike-slip movement during the opening of the Gulf of Mexico in the Early Jurassic.

Barnett (Reference 2.5.1-239) interprets two additional left-lateral strike-slip faults across the southern part of the Florida peninsula south of the Bahamas fault zone. The northern of these, which is referred to as the Northwest Providence Channel fault, is interpreted based on a linear trend of aeromagnetic lows that extends west-northwest across Florida at the 27th parallel and appears to join a left-lateral fault having 100 km (60 mi.) of offset recognized in the Gulf of Mexico by Gough (Reference 2.5.1-258). Barnett notes that these faults have been inactive since the Late Jurassic period, except for more localized younger depositional flexures (Reference 2.5.1-239). Christenson (Reference 2.5.1-227), who refers to the structure as the Florida Lineament, presents data to suggest that Paleozoic basement terrains that were contiguous before Mesozoic tectonics show minimal lateral offset across this zone and that this boundary is primarily a Triassic – Jurassic extensional rift margin.

Sunniland Fracture Zone. The magnetic and gravity fields over the west Florida shelf, south of the Bahamas fracture zone and northwest of the South Florida basin, are characterized by northeast-trending lineations that are truncated or have discontinuities at the Bahamas, Sunniland, and Cuba fracture zones (Reference 2.5.1-223). The Sunniland fracture zone coincides with the termination of magnetic anomalies between 85 degrees west and 86 degrees west. Southeast of Florida, the Sunniland fracture zone marks the termination of several magnetic and gravity anomalies. (Reference 2.5.1-223) Klitgord et al. (Reference 2.5.1-223) speculate that after the closure of the Atlantic, the Paleozoic or older Guinea Plateau was against the Paleozoic-age central Florida basement complex. The southern edge of the West Africa plate, the Guinea fracture zone, coincides with the Sunniland fracture zone. (Reference 2.5.1-223)

Florida Elbow Fault. The Elbow fault is thought to be the location in which the Florida Straits block migrated approximately 300 km (187 mi.) east-southeast out of the eastern Gulf to its present position beneath the South Florida shelf and western half of the Bahamas. The Florida Elbow fault runs from the southern escarpment of the Paleozoic Florida Middle Ground Arch, continues through the Florida Elbow basin and crosses Florida near Lake Okeechobee, underlies the northwest Providence Channel, and defines the northern margin of Great Bahama Bank. Such a trend is readily seen on a magnetic anomaly contour map. It is further suggested that sinistral motion along the fault system produced the Florida Middle Ground escarpment by translating the Tampa Arch away from the Middle Ground Arch. (Reference 2.5.1-226)

Postulated Fault by Applin and Applin. The Sunniland oil field is situated along the crest of a west-northwestward-trending asymmetrical anticline having the steeper dip toward the northeast. The steep dip northeast of the Sunniland field suggests that the anticline is bounded by a northwestward-trending fault, but subsurface data are lacking to show displacement in the beds of Comanche age. (Reference 2.5.1-259)

2.5.1.1.4.3.2 Paleozoic Tectonic Structures

Peninsular Arch. The term "Peninsular Arch" is applied to two different structural features: a basement high that is defined by well data and a subparallel high in the Upper Cretaceous strata. The exact nature of the structure is unknown, but may have developed during the closing of the Iapetus Ocean in the Upper Paleozoic. The Upper Cretaceous structure has been interpreted by Applin (Reference 2.5.1-260) to be the result of regional movements during the Mesozoic and Cenozoic. (Reference 2.5.1-227) Miller (Reference 2.5.1-240) describes the

Peninsular Arch as a northwest-trending feature that was continuously positive from Early Mesozoic until Late Cretaceous time and was intermittently positive during Cenozoic time. Miller concludes that the shape of the Peninsular Arch and its effect on sedimentation in north-central Florida are consistent with an upwarp produced by compressional tectonics.

Suwanee – Wiggins Suture. An Alleghanian suture, referred to as the Suwannee – Wiggins suture, extends between the North American crust on the north and the Suwannee and Wiggins terranes on the south. (Reference 2.5.1-222) The precise location and tectonic style of the suture are somewhat uncertain. (Reference 2.5.1-222) Nelson et al. (Reference 2.5.1-228) interpret a Consortium for Continental Reflection Profiling (COCORP) profile on the coastal plain of Georgia and northern Florida to support the hypothesis that a prominent magnetic low bordered to the south by discontinuous magnetic highs, which is referred to as the Brunswick anomaly, coincides with this Paleozoic suture. In Georgia, essentially undeformed rocks of the Suwannee terrane extend north to the suture. (Reference 2.5.1-222) Thomas et al. discuss varying interpretations of the tectonic style of the Suwannee – Wiggins suture and conclude that a possible transform or highly oblique transpressional boundary is consistent with the lack of evidence for compressional deformation along the eastern part of the suture, postulated strike-slip faulting implied by paleomagnetic data, structural trends observed near the intersection of the Appalachian trends in Alabama, and Late Paleozoic metamorphism and possible arc volcanism farther west. (Reference 2.5.1-222)

Suwanee Basin. Beneath the coastal plain of southern Georgia, southeastern Alabama, and northern Florida, which encompasses much of the LNP site region, a distinct assemblage of basement and sedimentary cover rocks constitutes the Suwanee terrane of African affinities. (Reference 2.5.1-222) The subsurface distribution of the biostratigraphic units in this region suggests that the Paleozoic sequence occupies a large regional syncline. The structure has come to be known as the Suwannee basin. (Reference 2.5.1-222) The name Suwannee basin has been applied to both the Paleozoic basin of northern Florida and the basement low of the Florida panhandle and southern Georgia. Klitgord et al. have applied the name East Suwannee basin to the Paleozoic basin. (Reference 2.5.1-223) Thomas et al. recommend using the name North Florida basin for the Paleozoic structure, and note that although the basin probably is complicated by faults and perhaps gentle folds, the overall structure is relatively simple. (Reference 2.5.1-222) Available information indicates a low-angle dip to the strata. Northeast-trending magnetic and gravity lows within the basin appear to be related to post-Paleozoic grabens that are filled with Silurian – Devonian rocks. (Reference 2.5.1-222)

2.5.1.1.4.3.3 Mesozoic Tectonic Structures

Apalachicola Basin. The Apalachicola basin is a Jurassic rift basin located southwest of the Bahamas fault zone. The basin is associated with a magnetic high anomaly. (Reference 2.5.1-223) It is a northeast-southwest-trending basin that overlies the southwestern extension of the South Georgia basin, a Triassic – Jurassic rift-related basin. The Apalachicola embayment contains Jurassic and Cretaceous clastic sediments, with a Cretaceous thickness of more than 2000 m (6600 ft.), overlain by 1600 m (5200 ft.) of Tertiary strata. (Reference 2.5.1-252)

Middle Ground Arch. The Middle Ground Arch is a poorly defined positive basement feature. (Reference 2.5.1-227) The arch is underlain by Paleozoic rocks and is coincident with a narrow northeast-trending gravity low. (Reference 2.5.1-223) The Middle Ground Arch, like the Sarasota Arch, formed over blocks of stranded continental crust broken off from the main North American Plate by Late Triassic – Early Jurassic rifting. (Reference 2.5.1-223) The arch formed a north-south clastic to carbonate transition zone in the Tertiary. (Reference 2.5.1-227)

South Florida Basin. The South Florida basin extends from the Florida Straits on the east and south, west to the Florida escarpment, and north to the Peninsular and Sarasota arches. (Reference 2.5.1-227) Limited well control indicates more than 8000 m (26,000 ft.) of uppermost Jurassic through Quaternary carbonate and evaporite strata in the basin. Although the offshore area is not well known, the basin probably overlies, in part, highly extended continental basement. (Reference 2.5.1-252)

South Georgia Rift. A large graben, the South Georgia rift, formed across southern Georgia during Triassic rifting associated with the opening of the Atlantic Ocean. The rift formed nearly along the trace of the Alleghenian suture between Florida and North America. (Reference 2.5.1-225) The southwestern portion of this rift is included in the LNP site region. Shifting of the rift geometry caused the South Georgia rift to become an aulacogen, and as rifting ceased, the basements of the Florida platform, as well as the Yucatan and Bahamas platforms, were left appended to North America. (Reference 2.5.1-225)

Tampa Basin. The Tampa basin is flanked on the north by the DeSoto Canyon Arch and on the south by the Sarasota Arch. The basin coincides with a prominent gravity high. (Reference 2.5.1-227)

2.5.1.1.4.3.4 Cenozoic Tectonic Structures

Brevard Platform. The Brevard platform, which extends south from the Sanford high, is a low, broad ridge or platform expressed on the erosional surface of the Ocala Group. This platform plunges gently to the south-southeast and southeast. (Reference 2.5.1-261)

Gulf Trough or Channel. The Gulf trough or channel extends from the Southeast Georgia embayment to the Apalachicola embayment. It is the Miocene expression of the older Suwannee Strait that separated the siliciclastic facies to the north from the carbonate facies to the south during the Early Cretaceous. The Gulf trough was nearly full of sediments by the Late Oligocene and Early Miocene time, allowing increasing amounts of siliciclastic sediments to invade the carbonate environments of the peninsula. (Reference 2.5.1-261) A northeast-trending series of small faults are boundary faults for a series of small grabens that form the Gulf trough. (Reference 2.5.1-240)

Jacksonville Basin. The Jacksonville basin, located in northwest Florida, is the most prominent low in the northern half of the peninsula. In the deepest part of the basin, the Hawthorn Group sediments exceed 150 m (500 ft.) in thickness. The Jacksonville basin may be considered a subbasin of the larger southeast Georgia embayment, but it is separated from it by the Nassau nose. (Reference 2.5.1-261)

Nassau Nose. The Nassau nose is an eastward-dipping positive feature that separates the southeast Georgia embayment from the Jacksonville basin. (Reference 2.5.1-261)

Ocala Platform. The Ocala platform (commonly referred to as the Ocala Arch or uplift), is the most prominent of the structures in peninsular Florida. Scott (Reference 2.5.1-261) prefers the term "platform" since it does not have a structural connotation. The Ocala platform does not warp or otherwise affect sediments older than Middle Eocene, and it is not considered to be a true uplift. It appears to have been produced by sedimentational processes — either an anomalous buildup of Middle Eocene carbonate sediments, or more likely, differential compaction of Middle Eocene carbonate material shortly after deposition. Drilling on the crest of the Ocala platform shows that the feature is not of deltaic or reefal origin. (Reference 2.5.1-240) The Ocala Uplift passes southeastward into the Peninsular Arch and is bounded to the east by the Southeast Georgia embayment. In the Ocala Uplift area, Lower Cretaceous sediments lie on the Paleozoic sediments and on crystalline basement. (Reference 2.5.1-252) The Ocala Uplift centers around outcrops of Ocala and Avalon limestones in Citrus, Dixie, and Levy counties. (Reference 2.5.1-227) Eocene limestone presently is exposed at the surface, but various researchers believe that the Miocene-age Hawthorn Group once extended across the platform. (Reference 2.5.1-261)

Okeechobee Basin. The Okeechobee basin encompasses most of southern Florida. It is an area where the strata generally gently dip to the south and southeast. Within the basin there have been postulated episodes of faulting and folding. (Reference 2.5.1-261)

Osceola Low. The Osceloa low, which was originally identified as a fault-bounded low with as much as 106 m (350 ft.) of Miocene sediments, does not appear to be associated with a discrete fault, but rather is more likely a possible flexure or zone of displacement (east side up). The Osceola low trends north-south to northeast-southeast, and appears to be the site of increased frequency of karst features developed in the Ocala Group limestones. (Reference 2.5.1-261)

Sanford High. The Sanford high is another positive feature in the northern half of peninsular Florida that was originally considered by Vernon (Reference 2.5.1-262) to be a pre-Miocene structure. The Hawthorn Group and the Ocala Group are missing from the crest of the Sanford high, presumably due to erosion. The Avon Park Formation lies directly below post-Hawthorn sediments. A structural high offshore that was identified using high-resolution seismic reflection profiling may be an offshore extension of the Sanford high. Deformation associated with the offshore high ended prior to Pliocene time. (Reference 2.5.1-261)

Sarasota Arch. The Sarasota Arch is a positive basement feature that parallels a gravity low. Basement, which has been penetrated by several wells, consists of Cambrian granites and Ordovician rhyolites that are overlain by a Jurassic "granitic wash." (Reference 2.5.1-227)

St. Johns Platform. The St. Johns platform, which extends north from the Sanford high, is a low, broad ridge or platform expressed on the erosional surface of the Ocala Group. This platform plunges gently to the north-northwest toward the Jacksonville basin. (Reference 2.5.1-261)

Suwanee Strait. A negative feature in southeastern Georgia, just north of the Peninsular Arch, has been variously named the Suwanee Strait, channel, or saddle. The feature is expressed as a closed depression on the top of Paleocene rocks, but the absence of such a depression in the top of rocks of lower Eocene age or younger shows that the Suwannee Strait ceased to be an actively subsiding basin during the Early Eocene. (Reference 2.5.1-240)"

To read:

"2.5.1.1.4.3 Regional Tectonic Structures within a 320 km [200 mi.] Radius

Ewing subdivides the structural framework of the Gulf of Mexico basin into three major structural provinces, which correspond to the three major lithofacies provinces that persist from the Late Jurassic to the Holocene. These include (1) the northwestern progradational margin (from northeastern Mexico to Alabama, (2) the eastern carbonate margins (the Florida and Yucatan platforms), and (3) the western compressional margin. (Reference 2.5.1-252) The LNP site lies within the eastern carbonate platform province (Figure 2.5.1-208).

Principal tectonic features in the site region (320 km [200 mi.] radius) and surrounding portions of southeastern United States are shown on Figure 2.5.1-208 and Figure 2.5.1-209. Major regional structures that are shown on Figure 2.5.1-208 range in age from Paleozoic to Cenozoic. Structures beneath the Coastal Plain sediments underlying the Florida platform are largely inferred from sparse deep well data, geophysical anomalies, and limited seismic data. Various alternative locations for the older regional structures, particularly major strike-slip faults and transforms thought to have been involved in the closing of the Iapetus Ocean in the late Paleozoic and the opening of the Gulf of Mexico and Atlantic Ocean in the early Mesozoic, have been inferred from synthesis of geological, geophysical, and tectonic information in the study region (Figure 2.5.1-222). These and other structures inferred to be of Paleozoic and Mesozoic age are shown on Figure 2.5.1-209, Sheet 1 (Figure 2.5.1-209). Younger structures of Cenozoic age (including likely nontectonic structures such as the Ocala platform) are shown on Figure 2.5.1-209, Sheet 2 (RAI 02.05.01-18 Figure 1).

2.5.1.1.4.3.1 Postulated Basement Faults

An erosional surface that formed on rocks ranging in age from Precambrian to Middle Jurassic (referred to as the sub-Zuni surface) defines the top of basement rock in Florida (Reference 2.5.1-239). Postulated 'basement faults' identified by Applin (Reference 2.5.1-260) and Barnett (Reference 2.5.1-239) as shown on Figure 2.5.1-222 are described below.

Postulated Northeast-trending Basement Fault Identified by Applin (Reference 2.5.1-260). With limited subsurface information from deep boreholes that penetrated into pre-Mesozoic rocks in the northern part of the Florida peninsula, Applin (Reference 2.5.1-260) identified a northeast-trending boundary between Ordovician and Silurian rocks and Paleozoic (?) and pre-Cambrian (?) rhyolite, tuffs, and agglomerate that crosses the north-central part of the Florida peninsula. Applin (Reference 2.5.1-260) postulated the existence of a possible basin or graben north of this boundary based on the presence of a thickness of more than 600 m (2000 ft.) of Ordovician and Silurian strata adjacent to and north of the regionally high area in pre-Cambrian (?) crystalline rocks south of the boundary. Applin states that subsurface data are not sufficient to classify the downwarped feature definitely, and the feature, which is depicted as a "pre-Mesozoic basin or graben," is not shown as a fault on maps or in a diagrammatic cross section in the 1951 publication. In a 1965 publication by Applin and Applin (Reference 2.5.1-259) that refers to the earlier Applin study, the northeast-trending feature is shown as a fault, but no additional information on the postulated structure is provided (Figure 2.5.1-222). The feature, basin or graben, is below a postulated peneplaned surface of pre-Mesozoic rocks; Applin indicated that this feature did not affect Mesozoic or Cenozoic sediments (Reference 2.5.1-260). Barnett (Reference 2.5.1-239) does not show the northeast-trending fault inferred by Applin

(Reference 2.5.1-260) and Applin and Applin (2.5.1-259). (See the discussion of the East Suwannee basin in Subsection 2.5.1.1.4.3.2).

Postulated Basement Faults Identified by Barnett (Reference 2.5.1-239). From a review of previous studies, examination of geologic data from nearly 80 wells in Florida and Georgia, and interpretation of geophysical data, Barnett provided a more comprehensive summary of basement structures in Florida that permitted a reconstruction of its tectonic history (Reference 2.5.1-239). Barnett concluded that the Peninsular arch was a tilted and faulted block of Precambrian continental crust covered by Paleozoic sediments. The Paleozoic rocks were subjected to Late Paleozoic uplift with some volcanic activity, followed by uplift with tilting, block faulting, and post-orogeneitic igneous intrusion during the Triassic period. Barnett describes a deep Triassic graben underlying the Apalachicola embayment in the northern part of the LNP site region. Barnett notes that evidence is interpretative for major northwest-trending shear zones in the basement of the Florida-Bahama platform close to and south of the 28th parallel. These structures are discussed further in Subsections 2.5.1.1.4.3.2 and 2.5.1.1.4.3.3. Barnett does not provide detailed descriptions or justification for the location of many of the faults shown on his interpretative subcrop map of the sub-Zuni surface in Florida and Georgia. The rationale is not provided for identifying many of the faults, including a northwest-trending normal fault that is inferred to occur in basement close to LNP site. Further discussion of evidence for basement faults in the LNP site area is provided in Subsection 2.5.1.2.4.

2.5.1.1.4.3.2 Paleozoic Tectonic Structures

Peninsular Arch. The term "Peninsular arch" is applied to two different structural features: (1) a basement high that is defined by well data, and (2) a subparallel high in the Upper Cretaceous strata. The exact nature of the structure is unknown, but it may have developed during the closing of the Iapetus Ocean in the Upper Paleozoic. The Upper Cretaceous structure has been interpreted by Applin (Reference 2.5.1-260) to be the result of regional movements during the Mesozoic and Cenozoic. (Reference 2.5.1-227) Miller (Reference 2.5.1-240) describes the Peninsular arch as a northwest-trending feature that was continuously positive from Early Mesozoic until Late Cretaceous time and was intermittently positive during Cenozoic time. Miller concludes that the shape of the Peninsular arch and its effect on sedimentation in north-central Florida are consistent with an upwarp produced by compressional tectonics.

Suwannee – Wiggins Suture. An Alleghanian suture, referred to as the Suwannee – Wiggins suture, extends between the North American crust on the north and the Suwannee and Wiggins terranes on the south (Reference 2.5.1-222). The precise location and tectonic style of the suture are somewhat uncertain (Reference 2.5.1-222). Nelson et al. (Reference 2.5.1-228) interpret a Consortium for Continental Reflection Profiling (COCORP) profile on the coastal plain of Georgia and northern Florida to support the hypothesis that a prominent magnetic low bordered to the south by discontinuous magnetic highs, which is referred to as the Brunswick anomaly, coincides with this Paleozoic suture. In Georgia, essentially undeformed rocks of the Suwannee terrane extend north to the suture. (Reference 2.5.1-222) Thomas et al. discuss varying interpretations of the tectonic style of the Suwannee – Wiggins suture and conclude that a possible transform or highly oblique transpressional boundary is consistent with the lack of evidence for compressional deformation along the eastern part of the suture, postulated strike-slip faulting implied by paleomagnetic data, structural trends observed near the intersection of the Appalachian trends in Alabama, and Late Paleozoic metamorphism and possible arc volcanism farther west (Reference 2.5.1-222).

East Suwannee Basin (North Florida Basin). Beneath the coastal plain of southern Georgia, southeastern Alabama, and northern Florida, which encompasses much of the LNP site region, a distinct assemblage of basement and sedimentary cover rocks constitutes the Suwannee terrane of African affinities. (Reference 2.5.1-222) The subsurface distribution of the biostratigraphic units in this region suggests that the Paleozoic sequence occupies a large regional syncline. The structure has come to be known as the Suwannee basin. (Reference 2.5.1-222) The name Suwannee basin has been applied to both the Paleozoic basin of northern Florida and the basement low of the Florida panhandle and southern Georgia. Klitgord et al. have applied the name East Suwannee basin to the Paleozoic basin. (Reference 2.5.1-223) Thomas et al. recommend using the name North Florida basin for the Paleozoic structure and note that although the basin probably is complicated by faults and perhaps gentle folds, the overall structure is relatively simple (Reference 2.5.1-222). Available information indicates a low-angle dip to the strata. Northeast-trending magnetic and gravity lows within the basin appear to be related to post-Paleozoic grabens in which Silurian – Devonian rocks are preserved. (Reference 2.5.1-222)

Jay Fault. Smith (Reference 2.5.1-257) identified the Jay fault as a northwest-trending fault zone across the Florida panhandle. The Jay fault, which aligns with the Pickens-Gilberton fault and Bahamas fracture zone as defined by Klitgord et al. (Reference 2.5.1-233), defines a steep, down-to-the-south drop-off of basement. The fault as shown by Smith and Lord (Reference 2.5.1-225) roughly coincides with a basement fault mapped by Barnett (Reference 2.5.1-239) across the Florida peninsula near the 28th parallel. The basement structure identified by Barnett (Reference 2.5.1-239) follows a west-northwest trend of reentrants on the aeromagnetic map and an apparent truncation of northwest-trending magnetic anomalies across the Florida peninsula (Figure 2.5.1-220, Sheet 2).

Smith and Lord (Reference 2.5.1-225) and Smith et al. (Reference 2.5.1-224) speculate that the different basement terranes were moved laterally into their relative positions along strike-slip faults, such as the Jay fault, during the Late Paleozoic closure of the Iapetus Ocean. Smith and Lord (Reference 2.5.1-225) suggest that the fault, which likely experienced right-slip displacement during the Late Paleozoic, appears to have been a major transform structure that accommodated left-lateral strike-slip movement during the opening of the Gulf of Mexico in the Early Jurassic. The fault as shown by Smith and Lord (Reference 2.5.1-225) coincides with the Bahamas fracture zone as described by Klitgord et al. (Reference 2.5.1-223).

2.5.1.1.4.3.3 Mesozoic Tectonic Structures

Bahamas Fracture Zone (Florida Lineament). The Bahamas fracture zone, which trends northwest across southern Florida and the West Florida shelf, forms the northeast margin of the Gulf basin and is a Jurassic transform boundary that joined the Gulf of Mexico spreading center to the Atlantic spreading center (Reference 2.5.1-223). This fracture zone probably represents a major crustal boundary between continental and thick transitional rocks (Reference 2.5.1-205). To the northwest, it joins into the Gulf Rim fault zone (also referred to as the Alabama-Arkansas fault zone) (Reference 2.5.1-229), which is a composite fault and graben system that trends northwest across southern Alabama, central Mississippi, northern Louisiana, and central Texas

(Reference 2.5.1-251). As noted in the preceding section, the Bahamas fracture zone coincides in part with the Jay fault (Reference 2.5.1-225).

Barnett (Reference 2.5.1-239) interprets two additional left-lateral strike-slip faults across the southern part of the Florida peninsula south of the Bahamas fault zone. The northern of these, which is referred to as the Northwest Providence Channel fault, is interpreted based on a linear trend of aeromagnetic lows that extends west-northwest across Florida at the 27th parallel and appears to join a left-lateral fault having 100 km (60 mi.) of offset recognized in the Gulf of Mexico by Gough (Reference 2.5.1-258). Barnett notes that these faults have been inactive since the Late Jurassic period, except for more localized younger depositional flexures (Reference 2.5.1-239). Christenson (Reference 2.5.1-227), who refers to the structure as the Florida lineament, presents data to suggest that Paleozoic basement terrains that were contiguous before Mesozoic tectonics show minimal lateral offset across this zone. This boundary is interpreted to be primarily a Triassic – Jurassic extensional rift margin.

Sunniland Fracture Zone. The magnetic and gravity fields over the west Florida shelf, south of the Bahamas fracture zone and northwest of the South Florida basin, are characterized by northeast-trending lineations that are truncated or have discontinuities at the Bahamas, Sunniland, and Cuba fracture zones (Reference 2.5.1-223). The Sunniland fracture zone coincides with the termination of magnetic anomalies between 85 degrees west and 86 degrees west. Southeast of Florida, the Sunniland fracture zone marks the termination of several magnetic and gravity anomalies. (Reference 2.5.1-223) Klitgord et al. (Reference 2.5.1-223) speculate that after the closure of the Atlantic Ocean, the Paleozoic or older Guinea Plateau was against the Paleozoic-age central Florida basement complex. The southern edge of the West Africa Plate, the Guinea fracture zone, coincides with the Sunniland fracture zone. (Reference 2.5.1-223)

Florida Elbow Fault. The Elbow fault is thought to be the location in which the Florida Straits block migrated approximately 300 km (187 mi.) east-southeast out of the eastern Gulf to its present position beneath the South Florida shelf and western half of the Bahamas. The Florida Elbow fault runs from the southern escarpment of the Paleozoic Florida Middle Ground arch, continues through the Florida Elbow basin, and crosses Florida near Lake Okeechobee; it underlies the northwest Providence Channel and defines the northern margin of Great Bahama Bank. Such a trend is readily seen on a magnetic anomaly contour map. It is further suggested that sinistral motion along the fault system produced the Florida Middle Ground escarpment by translating the Tampa arch away from the Middle Ground arch. (Reference 2.5.1-226)

Apalachicola Basin (Apalachicola Embayment). The Apalachicola basin is a Jurassic rift basin located southwest of the Bahamas fault zone. The basin is associated with a magnetic high anomaly. (Reference 2.5.1-223) It is a northeast-southwest-trending basin that overlies the southwestern extension of the South Georgia basin, a Triassic – Jurassic rift-related basin. The Apalachicola embayment contains Jurassic and Cretaceous clastic sediments, with a Cretaceous thickness of more than 2000 m (6600 ft.), overlain by 1600 m (5200 ft.) of Tertiary strata. (Reference 2.5.1-252)

Middle Ground Arch. The Middle Ground arch is a poorly defined positive basement feature (Reference 2.5.1-227). The arch is underlain by Paleozoic rocks and is coincident with a narrow northeast-trending gravity low (Reference 2.5.1-223). The Middle Ground arch, like the Sarasota arch, formed over blocks of stranded continental crust broken off from the main North American

Plate by Late Triassic – Early Jurassic rifting (Reference 2.5.1-223). The arch formed a north-south clastic-to-carbonate transition zone in the Tertiary (Reference 2.5.1-227).

Sarasota Arch. The Sarasota arch is a positive basement feature that parallels a gravity low. Basement, which has been penetrated by several wells, consists of Cambrian granites and Ordovician rhyolites that are overlain by a Jurassic "granitic wash." (Reference 2.5.1-227)

South Florida Basin. The South Florida basin extends from the Florida Straits on the east and south, west to the Florida escarpment, and north to the Peninsular and Sarasota arches. (Reference 2.5.1-227) Limited well control indicates more than 8000 m (26,000 ft.) of uppermost Jurassic through Quaternary carbonate and evaporite strata in the basin. Although the offshore area is not well known, the basin probably partially overlies highly extended continental basement. (Reference 2.5.1-252)

South Georgia Rift (Northeast-trending Triassic Georgia Embayment System). A large graben, the South Georgia rift, formed across southern Georgia during Triassic rifting associated with the opening of the Atlantic Ocean. The rift formed nearly along the trace of the Alleghenian suture between Florida and North America. (Reference 2.5.1-225) The southwestern portion of this rift is included in the LNP site region. Shifting of the rift geometry caused the South Georgia rift to become an aulacogen, and as rifting ceased, the basements of the Florida platform, as well as the Yucatan and Bahamas platforms, were left appended to North America. (Reference 2.5.1-225)

Pindell (Reference 2.5.1-226) notes the absence of a well-developed Jurassic sedimentary section related to basin subsidence that would be expected if the northeast-trending Triassic Georgia Embayment system were strictly due to crustal extension. Pindell suggests that the system of faults probably was formed by right-lateral strike-slip shear, which caused local uplift and erosion, as well as deposition of Upper Triassic red beds into associated strike-slip basins.

Tampa Basin. The Tampa basin is flanked on the north by the DeSoto Canyon arch and on the south by the Sarasota arch. The basin coincides with a prominent gravity high. (Reference 2.5.1-227)

2.5.1.1.4.3.4 Cenozoic Tectonic Structures

Brevard Platform. The Brevard platform, which extends south from the Sanford high, is a low, broad ridge or platform expressed on the erosional surface of the Ocala Group. This platform plunges gently to the south-southeast and southeast. (Reference 2.5.1-261)

Chattahoochee Anticline. Eocene and Oligocene sediments are exposed near the hinge of the Chattahoochee anticline in the panhandle region of Florida. The deposition of the Citronelle formation (Miocene to Pliocene) does not appear to have been influenced by this structural feature.

Gulf Trough or Channel. The Gulf trough or channel extends from the Southeast Georgia embayment to the Apalachicola embayment. It is the Miocene expression of the older Suwannee Strait that separated the siliciclastic facies to the north from the carbonate facies to the south during the Early Cretaceous. The Gulf trough was nearly full of sediments by the Late Oligocene and Early Miocene time, allowing increasing amounts of siliciclastic sediments to invade the carbonate environments of the peninsula. (Reference 2.5.1-261) A northeast-trending series of small faults are boundary faults for a series of small grabens that form the Gulf trough (Reference 2.5.1-240).

Jacksonville Basin. The Jacksonville basin, located in northwest Florida, is the most prominent low in the northern half of the peninsula. In the deepest part of the basin, the Hawthorn Group sediments exceed 150 m (500 ft.) in thickness. The Jacksonville basin may be considered a subbasin of the larger southeast Georgia embayment, but it is separated from it by the Nassau nose. (Reference 2.5.1-261)

Nassau Nose. The Nassau nose is an eastward-dipping positive feature that separates the southeast Georgia embayment from the Jacksonville basin (Reference 2.5.1-261).

Ocala Platform. The Ocala platform (commonly referred to as the Ocala arch or uplift), is the most prominent of the structures in peninsular Florida. Scott (Reference 2.5.1-261) prefers the term "platform" since it does not have a structural connotation. Vernon (Reference 2.5.1-262) described the approximately 370–km- [230-mi.-] long and about 112–km- [70-mi.-] wide) feature as a gentle flexure developed in Tertiary sediments with a northwest-southeast-trending crest that had been flattened by faulting. Vernon dated the formation of the uplift as being Early Miocene based on the involvement of basal Miocene sediments in the faulting and the wedging out of younger Miocene sediments against the flanks of the platform, which was interpreted to be an island area throughout much of the Miocene. Other researchers conclude that the Ocala platform does not warp or otherwise affect sediments older than Middle Eocene, and is not a true uplift. It appears to have been produced by sedimentational processes — either an anomalous buildup of Middle Eocene carbonate sediments and regional eastward tilting, or — more likely — differential compaction of Middle Eocene carbonate material shortly after deposition. Drilling on the crest of the Ocala platform shows that the feature is not of deltaic or reefal origin. (Reference 2.5.1-240; Reference RAI 02.05.01-11 01) In the Ocala platform area, Lower Cretaceous sediments lie on the Paleozoic sediments and on crystalline basement (Reference 2.5.1-252). Eocene limestone presently is exposed at the surface, but various researchers believe that the Miocene-age Hawthorn Group once extended across the platform. (Reference 2.5.1-261)

The general concensus of researchers familiar with the stratigraphy and structure of the Florida peninsula is that differential subsidence, sedimentation, and erosion have created the dip patterns associated with the Ocala platform (References RAI 02.05.01-11 02, RAI 02.05.01-11 03, and RAI 02.05.01-11 04). Fracturing of the Floridian rocks is likely the result of tensional stresses caused by the differential subsidence of the Florida platform. Another factor that may be affecting the development of the Ocala platform and occurrence of fractures is the concept of isostatic readjustment of the crust related to dissolution of carbonate and associated reduction of the weight of the crust. This effect also could lead to broad uplift. (Reference RAI 02.05.01-11 02)

Okeechobee Basin. The Okeechobee basin encompasses most of southern Florida. It is an area where the strata generally gently dip to the south and southeast. Within the basin there have been postulated episodes of faulting and folding. (Reference 2.5.1-261)

Osceola Low. The Osceola low, which was originally identified as a fault-bounded low with as much as 106 m (350 ft.) of Miocene sediments, does not appear to be associated with a discrete fault, but rather is more likely a possible flexure or zone of displacement (east side up). The Osceola low trends north-south to northeast-southeast and appears to be the site of increased frequency of karst features developed in the Ocala Group limestones. (Reference 2.5.1-261)

Sanford High. The Sanford high is another positive feature in the northern half of peninsular Florida that was originally considered by Vernon (Reference 2.5.1-262) to be a pre-Miocene structure. The Hawthorn Group and the Ocala Group are missing from the crest of the Sanford high, presumably due to erosion. The Avon Park Formation lies directly below post-Hawthorn sediments. A structural high offshore that was identified using high-resolution seismic reflection profiling may be an offshore extension of the Sanford high. Deformation associated with the offshore high ended prior to Pliocene time. (Reference 2.5.1-261)

St. Johns Platform. The St. Johns platform, which extends north from the Sanford high, is a low, broad ridge or platform expressed on the erosional surface of the Ocala Group. This platform plunges gently to the north-northwest toward the Jacksonville basin. (Reference 2.5.1-261)

Suwannee Strait. A negative feature in southeastern Georgia, just north of the Peninsular arch, has been variously named the Suwannee Strait, channel, or saddle. The feature is expressed as a closed depression on the top of Paleocene rocks, but the absence of such a depression in the top of rocks of lower Eocene age or younger shows that the Suwannee Strait ceased to be an actively subsiding basin during the Early Eocene. (Reference 2.5.1-240)

Attachments/Enclosures:

02.05.01-18A, Revised Figure 2.5.1-222

02.05.01-18B, Revised Figure 2.5.1-209

02.05.01-18C, RAI 02.05.01-18 Figure 1

NRC Letter No.: LNP-RAI-LTR-034

NRC Letter Date: May 8, 2009

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.05.01-29

Text of NRC RAI:

FSAR Section 2.5.1.2.1.2 (pgs 2.5-59 and 2.5-60) discusses five marine terraces which occur within the site vicinity (i.e., from oldest to youngest, the Sunderland/Okefenokee, Wicomico, Penholoway, Pamlico, and Silver Bluff terranes) and cites Figure 2.5.1-235. This figure shows a sixth terrace, the Talbot terrace, within the site vicinity. The Talbot terrace is not discussed in this FSAR section.

In order for the staff to understand the potential effects of late Tertiary to Quaternary sea level changes in the site vicinity, please discuss the Talbot terrace or explain why it is not discussed.

PGN RAI ID #: L-0313

PGN Response to NRC RAI:

FSAR Section 2.5.1.2.1.2 should have stated that seven, rather than five, terraces are present within the site vicinity based on county-scale maps as illustrated on Figure 2.5.1-235. The Talbot and the Coharie terraces will be added to the list of terraces that have been mapped within the site vicinity. The statewide map as shown by Healy (Reference 2.5.1-215), which does not differentiate the Talbot terrace in Levy County, shows six terraces in the site vicinity.

Detailed mapping of marine terraces and geochronologic investigations to provide good age control is not available for the marine terraces in the site vicinity or throughout most of the site region. This is due in part to the limited exposures and the paucity of fossils or dateable material in the terrace cover. Tiling (Reference 02.05.01-29 01) states that "Despite numerous attempts to date and correlate Pleistocene deposits in Florida, the numerical ages of these sediments is poorly constrained. Consequently, further analysis is required for an understanding of the timing of sea level change during the Pleistocene."

A minimum age of the marine terrace underlying the LNP site is estimated based primarily on the elevation of the inferred abrasion platform (unconformable contact between Eocene sediments and Quaternary undifferentiated sand deposits) relative to expected paleo-shorelines of Quaternary sea-level highstands. As noted in the final paragraph of FSAR Section 2.5.1.2.1.2, the general elevation of the LNP site (12 to 13.4 m [40 to 44 ft.] NAVD88, suggests that the site is located on the outer edge of the Penholoway terrace or possibly on an unmapped remnant of the Talbot terrace. The elevation, continuity, and age of marine abrasion platforms that may underlie the Penholoway and Talbot terraces, which are defined primarily on the general elevation of the ground surface, are not known. Based on the elevation of the unconformity between the thin mantle of Quaternary sediments and Eocene sediments at the site (approximately 11 ± 1 m [36 ± 3 ft.]) relative to the expected paleosea level elevations of the MIS 5e (approximately 5 to 8 m [16 to 26 ft.]) and the MIS 7 and MIS 9 highstands that probably were formed initially at elevations close to present sea level, it is concluded in the FSAR that the terrace platform at the site likely formed during Middle Pleistocene (pre-MIS 9, 300 to 340 ka) to Early Pleistocene time or possibly Late Pliocene time.

Aminostratigraphic studies in central and south Florida provide additional information that can be used to assess the age of the marine terrace surface underlying the LNP site. Samples of fossiliferous sediments collected at two sites along the Wacasassa River in the site vicinity (Revised Figure 2.5.1-235, see Attachment 02.05.01-29A) were evaluated using aminostratigraphy as part of a regional study to compare the relative ages of stratigraphic units based on aminostratigraphic analysis and numerical ages determined by calibration with U-series age estimates (Reference RAI 02.05.01-29 01). Site 1 samples were collected below water level from a fossiliferous layer within a sand-filled karst feature at the top of exposed Eocene limestone. Due to the presence of *Konis adversa,* this site was initially assumed to be part of the Caloosahatchee formation (late Pliocene to early Pleistocene in age). Site 2 was sampled from a fossiliferous sand layer overlying the karstified limestone bedrock approximately 1.6 km (1 mi.) south of site 1. Shell abundance was less than at site 1 with a different depositional environment indicated by brackish water-fauna. Site 2 was initially proposed to be a different facies of the same stratigraphic unit sampled at site 1. The results of the aminostratigraphic analysis demonstrated that sites 1 and 2 are of two different ages. The Wacasassa River site 2 is correlated to a younger aminozone and possibly the Ft. Thompson formation that represents MIS 5e in central Florida. Site 1 correlates to an older amniozone that includes the Pinecrest Beds, Caloosahatchee and Bermont formations. Aminoacid racemization analysis is not able to resolve for age differences among these units. Tiling does not provide information on the exact locations or elevations of the two sites sampled on the Wacasassa River. The general elevation of the river at the location provided is approximately 5 m (16 ft.), which is not inconsistent with possible inundation during MIS 5e.

Uranium-series analysis of fossil coral samples obtained from Units C, D, and E (correlated to the Caloosahatchee [late Pliocene-early Pleistocene], Bermont [middle Pleistocene], and Ft. Thompson [late Pleistocene] formations) in south Florida indicated ages of greater than 400 ka for Unit C, approximately 230-360 ka for Unit D, and approximately 144 ka for part of Unit E). Since none of the samples of corals from this study experienced ideal closed-system conditions with respect to uranium and its daughter products, only approximate ages could be inferred. The results, however, indicate that marine deposition was extensive over much of southern Florida during the middle Pleistocene.) (Reference 2.5.1-236). RAI 02.05.01-29 Figure 1 (see Attachment 02.05.01-29B) shows the distribution of Pliocene to Pleistocene marine sediments in southern Florida.

The marine terrace that underlies the LNP site may correlate to MIS 11 (approximately 400-440 ka), which is recognized as one of the longer and warmer interglacials of the past 1 Ma (Reference RAI 02.05.01-29 02). Recent and ongoing research regarding MIS 11 suggests that the paleosea level during this highstand may have been higher than during the MIS 5e (approximately 120-125 ka) highstand. Data that constrain the paleosea level during MIS 11 are available from studies in Bermuda and South Africa, both stable intraplates like Florida where marine terrace shorelines are expected to reflect glacio-eustatic sea levels (Reference RAI 02.05.01-29 02 , Reference RAI 02.05.01-29 03). These studies suggest that sea level during MIS 11 was approximately +20 m (66 ft.) and +15 m (49 ft.), respectively, as recorded in Bermuda and South Africa.

The marine terrace platform at the LNP site lies at a similar or slightly lower elevation. A correlation to the MIS 11 highstand cannot be precluded at this time, but additional work is needed to confirm the preliminary age estimates and paleosea level elevation of this highstand in South Africa and in other regions. A minimum estimated age of Middle Pleistocene for the marine terrace at the LNP site as stated in the FSAR is consistent with an inferred age of MIS 11 or older.

References:

The following references were used for this RAI and References 01 through 08 will be added to the FSAR in a future revision:

1. RAI 02.05.01-29 01, Tiling, G., "Aminostratigraphy of the Plio-Pleistocene of Florida," M.S. thesis submitted to the Department of Geology, University of South Florida, 71 pp., 2004
2. RAI 02.05.01-29 02, Olson, S. L., and Hearty, P. J., "A sustained +21 m Sea-level Highstand During MIS 11 (400 ka): Direct Fossil and Sedimentary Evidence From Bermuda," Quaternary Science Reviews, Vol. 28, pp. 271-285, 2009
3. RAI 02.05.01-29 03, Roberts, D. L., Z. Jacobs, P. Karkanas, and C. W. Marean, "Onshore Expression of Multiple Orbitally Driven Late Quaternary Marine Incursions on the Ultra-stable Southern South African Coast," Quaternary International 167-168 (2007) 3-486, pp. 345. Poster presented at the International Quaternary Association (INQUA) 2007 Congress, 2007
4. RAI 02.05.01-29 04, Winkler, C. D., and J. D. Howard, "Correlation of Tectonically Deformed Shorelines on the Southern Atlantic Coastal Plain," *Geology*, Vol. 5, pp. 123-127, 1977
5. RAI 02.05.01-29 05, Opdyke, N.D., D.P. Spangler, D.L. Smith, D.S. Jones, and R.C. Lindquist, "Origin of the Epeirogenic Uplift of Pliocene-Pleistocene Beach Ridges in Florida and Development of the Florida Karst," *Geology*, Vol. 15, 1984, pp. 900 – 903
6. RAI 02.05.01-29 06, Willett, M.A., "Effect of Dissolution of the Florida Carbonate Platform on Isostatic Uplift and Relative Sea-Level Change," M.S. thesis, Florida State University, 2006
7. RAI 02.05.01-29 07, Pirkle, F.L., and L.J. Czel, "Marine Fossils from Region of Trail Ridge, A Georgia-Florida Landform," *Southeastern Geology*, Vol. 24, 1983, pp. 31 – 38
8. RAI 02.05.01-29 08, Means, G. H., "A Marine-influenced Siliciclastic Unit (Citronelle Formation) in Western Panhandle Florida," M. S. thesis submitted to the Department of Geological Sciences, Florida State University, 2009,134 pp

Associated LNP COL Application Revisions:

The following changes will be made to the LNP FSAR Chapter 2 in a future revision as noted below: Figure 2.5.1-235 will be modified, a new figure will be added (RAI 02.05.01-29 Figure 1), Section 2.5.1.2.1.2 text will be revised and eight new references will be added to the FSAR (Reference RAI 02.05.01 01 through 08).

Figures:

Figure 2.5.1-235 revisions are as follows (see Attachment 02.05.01-29A): The legend on Figure 2.5.1-235 will be revised to correct the metric elevations for the individual terraces. Also, the location of the Wacasassa River dating locality of Tiling (Reference 02.05.01-29 01) will be added to Figure 2.5.1-235.

A new figure, RAI 02.05.01-29 Figure 1, will be added that shows Pleistocene and Pliocene deposits in Southern Florida.

Text:

Section 2.5.1.2.1.2 text will be modified from:

"Elevated terraces and related shorelines, beach-ridge plains, and inner-shelf sediments record the long-term effects of late Tertiary to Quaternary sea level changes on the stable Florida platform. The general lowering of sea level from Pliocene time to the present is evident in the decrease in elevation of terrace features with age. Episodic sea-level swings of the late Quaternary and Holocene are identified in the Panhandle Florida region and in southern Florida and the Florida Keys regions, based on both submerged and raised shoreline features preserved in coastal and nearshore areas. (Reference 2.5.1-312)

Based on review of literature and examination of all data on terraces in Florida, Healy (Reference 2.5.1-215) identified eight terrace intervals that were mapped on a statewide basis (Figure 2.5.1-202). They are, in ascending order, the Silver Bluff Terrace, less than 1 to 3 m (0 to 10 ft.) amsl; the Pamlico Terrace, 2.5 to 7.6 m (8 to 25 ft.) amsl; the Talbot Terrace, 7.6 to 12.8 m (25 to 42 ft.) amsl; the Penholoway Terrace, 12.8 to 21.3 m (42 to 70 ft.) amsl; the Wicomico Terrace, 21.3 to 30.4 m (70 to 100 ft.) amsl; the Sunderland (or Okefenokee) Terrace, 30.4 to 51.8 m (100 to 170 ft.) amsl; the Coharie Terrace, 51.3 to 65.5 m (170 to 215 ft.) amsl; and the Hazlehurst Terrace, 65.6 to 97.5 m (215 to 320 ft.) amsl (Figure 2.5.1-202). (Reference 2.5.1-215)

Criteria used in previous investigations to map and correlate terraces relied extensively on topographic position, elevation, morphology, and limited stratigraphic and dating information. There is little agreement amongst the early workers, however, regarding the number or ages of the older, higher terraces. (Reference 2.5.1-313, Reference 2.5.1-215) Many of the terraces originally considered to be Pleistocene in age are now thought to be older. The highest terrace may be of upper Miocene age, and terraces at and above approximately 30 m (100 ft.) amsl are likely Pliocene in age. (Reference 2.5.1-215, Reference 2.5.1-314, Reference 2.5.1-312)

Hoenstein et al. (Reference 2.5.1-309), Lane et al. (Reference 2.5.1-310), and Yon et al. (Reference 2.5.1-311) provide more detailed mapping of the terraces in the site vicinity based on the terrace designations of Healy (Reference 2.5.1-215) and Vernon (Reference 2.5.1-262). Five terraces are present within the site vicinity, as illustrated on Figure 2.5.1-235. From highest (and presumably oldest) to lowest (youngest) the marine terraces are Sunderland/Okefenokee, Wicomico, Penholoway, Pamlico, and Silver Bluff. (Reference 2.5.1-310).

The two terraces and associated shorelines that parallel the coastline in both Levy and Citrus counties are the Silver Bluff and the Pamlico (see Figure 2.5.1-235). The Pamlico terrace and shoreline are well-developed features that are recognized and mapped along the entire Gulf coast of Florida. The Pamlico terrace covers most of west-central Levy County and the eastern third of Citrus County. It is characterized by a number of karst features, including numerous sinkholes and caverns, and there are a number of streams and creeks that flow through this terrace. (Reference 2.5.1-310) Based on the elevation of the inland part of the marine terrace platform underlying the Pamlico terrace (less than 7.6 m [25 ft.] amsl) (Reference 2.5.1-310), this terrace is estimated to have formed during MIS 5e (approximately 120 ka) when sea level stood approximately 6 m (20 ft.) above present sea level. Muhs et al. (Reference 2.5.1-237) summarizes recent studies in southern Florida that suggest that sea level during the last interglacial (MIS 5e) must have been at least 5 – 8 m (16 – 26 ft.) higher than present.

The Silver Bluff terrace in the study area may represent a continuation of the seaward-dipping platform that has a thinner cover of silisticlastic cover. Alternatively, parts of the Silver Bluff terrace may have been reoccupied during a subsequent sea-level high stand during MIS 5a (approximately 80 ka), when sea level may have been close to present levels. Uranium-series ages of approximately 80,000 years for corals from the tectonically stable Atlantic Coastal Plain suggest that sea level at that time was near present, whereas the oxygen isotope record suggests that sea level was then well below present (Reference 2.5.1-237). The elevation of the MIS 5a shoreline in Florida is not well constrained at this time.

The Levy County map shows the site to be located at the inner edge of the Pamlico terrace below the Penholoway terrace (Figure 2.5.1-235). The general elevation of the LNP site (12 to 13.4 m [40 to 44 ft.] NAVD88), however, suggests that the site is located on the outer edge of the Penholoway terrace or possibly on an unmapped remnant of the Talbot terrace. The elevation of the unconformity between the thin mantle of Quaternary sediments and Eocene limestone at the site (approximately 11 ± 1 m) indicates that the site is well above the expected elevation of the Pamlico wave-cut terrace platform (approximately 6 m [20 ft.] amsl), and therefore, is on a terrace surface older than MIS 5e (approximately 120 – 125 ka). As noted previously, dating of marine terraces in southern Florida indicates that the MIS 7 (220 – 230 ka) and MIS 9 (300 – 340 ka) shorelines may have been close to present (Reference 2.5.1-237) indicating that it is not likely the terrace surface at the site was formed during either of those sea-level highstands. It is more likely that the terrace or terraces present within the site location formed earlier during Middle Pleistocene to Early Pleistocene time or possibly Late Pliocene time."

To read:

"Elevated terraces and related shorelines, beach-ridge plains, and inner-shelf sediments record the long-term effects of late Tertiary to Quaternary sea level changes on the stable Florida platform. The general lowering of sea level from Pliocene time to the present is evident in the decrease in elevation of terrace features with age. Episodic sea-level swings of the late Quaternary and Holocene are identified in the Panhandle Florida region and in southern Florida and the Florida Keys regions, based on both submerged and raised shoreline features preserved in coastal and nearshore areas. (Reference 2.5.1-312)

Based on review of literature and examination of all data on terraces in Florida, Healy (Reference 2.5.1-215) identified eight terrace intervals that were mapped on a statewide basis (Figure 2.5.1-202). They are, in ascending order, the Silver Bluff Terrace, less than 1 to 3 m (0 to 10 ft.) amsl; the Pamlico Terrace, 2.5 to 7.6 m (8 to 25 ft.) amsl; the Talbot Terrace, 7.6 to 12.8 m (25 to 42 ft.) amsl; the Penholoway Terrace, 12.8 to 21.3 m (42 to 70 ft.) amsl; the Wicomico Terrace, 21.3 to 30.4 m (70 to 100 ft.) amsl; the Sunderland (or Okefenokee) Terrace, 30.4 to 51.8 m (100 to 170 ft.) amsl; the Coharie Terrace, 51.3 to 65.5 m (170 to 215 ft.) amsl; and the Hazlehurst Terrace, 65.6 to 97.5 m (215 to 320 ft.) amsl (Figure 2.5.1-202). (Reference 2.5.1-215)

Criteria used by Healy and in prior investigations to map and correlate terraces relied extensively on topographic position, elevation, morphology, and limited stratigraphic and dating information. There was little agreement amongst the early workers, however, regarding the number or ages of the older, higher terraces exposed in northern peninsular Florida and the Florida panhandle. Some workers thought the highest sand ridge feature related to a sea level highstand (referred to as Trail Ridge) was Miocene in age (Reference 2.5.1-314), whereas others believed the ridge to be no older than Pliocene (Reference 2.5.1-313). Several researchers suggested that that terraces at and above approximately 30 m (100 ft.) amsl are likely Pliocene in age. (Reference 2.5.1-313, Reference 2.5.1-215, Reference 2.5.1-314, Reference 2.5.1-312). Winkler and Howard (Reference RAI 02.05.01-29 04) using geomorphic evidence concluded that the Trail Ridge sequence and two younger sequences along the Atlantic coastal plain region from North Carolina to south central Florida were deformed by warping and that correlation of terraces strictly by elevation was not meaningful.

Paleo-shoreline features adjacent to Trail Ridge near the border of northern Florida and southern Georgia, subsequently were found to contain marine fossils believed to be late Pliocene or Pleistocene age at elevations of between 42 and 49 m (130 to 161 ft.) above mean sea level (Reference RAI 02.05.01-29 07). Opdyke et al. (Reference RAI 02.05.01-29 05), citing this evidence and previous work by Winkler and Howard (Reference RAI 02.05.01-29 04) and others, noted that Pleistocene shoreline features do not maintain a constant elevation when traced from Georgia into southern Florida. From a low point along the Georgia coast, the shoreline features rise to maximum elevation of about 58 m (190 ft.) in northern peninsular Florida and then gradually drops to elevations of approximately 40 m (130 ft.) in south-central Florida. Opdyke et al. (Reference RAI 02.05.01-29 05) and Willett (Reference RAI 02.05.01-29 06) postulate that isostatic readjustment driven by carbonate dissolution has caused broad epeirogenic uplift in Florida. Readjustment rates calculated by Opdyke et al. (Reference RAI 02.05.01-29 06) were 36 m (118 ft) during the Pleistocene and Holocene. This equates to one meter of limestone every approximately 38,000 years. Willett (Reference RAI 02.05.01-29 06), using a more robust data set, concluded that karst areas in Florida are losing approximately one meter of limestone every 160,000 years and that the impact of long-term carbonate dissolution and mass loss from the Florida platform has led to isostatic uplift of at least 9 m (30 ft.) and as much as 58 m (190 ft.) since the beginning of the Quaternary (~1.6 Ma). This process helps to explain the observed elevations of Pliocene-Pleistocene marine sediments that exceed paleosea level projections and apparent warping of the older marine shoreline features.

Means (Reference RAI 02.05.01-29 08) suggests that lithospheric flexture due to sediment loading is another nontectonic mechanism in addition to isostatic adjustment due to carbonate dissolution that could explain the presence of marine-influenced sediments observed at elevations of over 66 m (216 ft) in the panhandle region of Florida, higher than any maximum sea-level stand of the Miocene, Pliocene, or Pleistocene.

Hoenstein et al. (Reference 2.5.1-309), Lane et al. (Reference 2.5.1-310), and Yon et al. (Reference 2.5.1-311) delineated marine terraces in the site vicinity based on the terrace designations of Healy (Reference 2.5.1-215) and Vernon (Reference 2.5.1-262). Seven terraces are mapped within the site vicinity, as illustrated on Figure 2.5.1-235. From highest (and presumably oldest) to lowest (youngest) the marine terraces are Coharie, Sunderland/Okefenokee, Wicomico, Penholoway, Talbot, Pamlico, and Silver Bluff. (Reference 2.5.1-310) The ages and correlations of the higher terraces as shown, which are generally based on elevation, are very speculative. Detailed mapping of marine terraces and geochronologic investigations to provide good age control is not available for the marine terraces in the site vicinity or throughout most of the site region. This is due in part to the limited exposures and the paucity of fossils or dateable material in the terrace cover.

Aminostratigraphic studies in central and south Florida provide information that can be used to assess the age of the marine terrace surfaces in the LNP site vicinity (Reference RAI 02.05.01-29 01). Samples of fossiliferous sediments collected at two sites along the Wacasassa River in the site vicinity (Figure 2.5.1-235) were evaluated using aminostratigraphy as part of a regional study to compare the relative ages of stratigraphic units based on aminostratigraphic analysis and numerical ages determined by calibration with U-series age estimates (Reference RAI 02.05.01-29 01). Site 1 samples were collected below water level from a fossiliferous layer within a sand-filled karst feature at the top of exposed Eocene limestone. Due to the presence of *Konis adversa,* this site was initially assumed to be part of the Caloosahatchee formation (late Pliocene to early Pleistocene in age). Site 2 was sampled from a fossiliferous sand layer overlying the karstified limestone bedrock approximately 1.6 km (1 mi.) south of site 1. Shell abundance was less than at site 1 with a different depositional environment indicated by brackish water-fauna. Site 2 was initially proposed to be a different facies of the same stratigraphic unit sampled at site 1. The results of the aminostratigraphic analysis demonstrated that sites 1 and 2 are of two different ages. The Wacasassa River site 2 is correlated to a younger aminozone and possibly the Ft. Thompson formation that represents MIS 5e in central Florida. Site 1 correlates to an older amniozone that includes the Pinecrest Beds, Caloosahatchee and Bermont formations. Aminoacid racemization analysis is not able to resolve for age differences among these units.

Uranium-series analysis of fossil coral samples obtained from Units C, D, and E (correlated to the Caloosahatchee [late Pliocene-early Pleistocene], Bermont [middle Pleistocene], and Ft. Thompson [late Pleistocene] formations) in south Florida indicated ages of greater than 400 ka for Unit C, approximately 230-360 ka for Unit D, and approximately 144 ka for part of Unit E). Since none of the samples of corals from this study experienced ideal closed-system conditions with respect to uranium and its daughter products, only approximate ages could be inferred. The results, however, indicate that marine deposition was extensive over much of southern Florida during the middle Pleistocene.) (Reference 2.5.1-236). RAI 02.05.01-29 Figure 1 shows the distribution of Pliocene to Pleistocene marine sediments in southern Florida. The two terraces and associated shorelines that parallel the coastline in both Levy and Citrus counties are the Silver Bluff and the Pamlico (see Figure 2.5.1-235). The Pamlico terrace and shoreline are well-developed features that are recognized and mapped along the entire Gulf coast of Florida. The Pamlico terrace covers most of west-central Levy County and the eastern third of Citrus

County. It is characterized by a number of karst features, including numerous sinkholes and caverns, and there are a number of streams and creeks that flow through this terrace. (Reference 2.5.1-310) Based on the elevation of the inland part of the marine terrace platform underlying the Pamlico terrace (less than 7.6 m [25 ft.] amsl) (Reference 2.5.1-310), this terrace is estimated to have formed during MIS 5e (approximately 120 ka) when sea level stood approximately 6 m (20 ft.) above present sea level. Muhs et al. (Reference 2.5.1-237) summarizes recent studies in southern Florida that suggest that sea level during the last interglacial (MIS 5e) must have been at least 5 to 8 m (16 to 26 ft.) higher than present. The estimated correlation of the deposits at site 2 along the Wacasassa River to MIS 5e suggests they are associated with the Pamlico terrace.Tiling (Reference RAI 02.05.01-29 01) does not provide information on the exact locations or elevations of the two sites sampled on the Wacasassa River. The general elevation of the river at the Wacasassa River locality is approximately 4.5 m (15 ft.), which is consistent with possible inundation during MIS 5e.

The Silver Bluff terrace in the study area may represent a continuation of the seaward-dipping platform that has a thinner cover of silisticlastic cover. Alternatively, parts of the Silver Bluff terrace may have been reoccupied during a subsequent sea-level high stand during MIS 5a (approximately 80 ka), when sea level may have been close to present levels. Uranium-series ages of approximately 80,000 years for corals from the tectonically stable Atlantic Coastal Plain suggest that sea level at that time was near present, whereas the oxygen isotope record suggests that sea level was then well below present (Reference 2.5.1-237). The elevation of the MIS 5a shoreline in Florida is not well constrained at this time.

The Levy County map shows the LNP site to be located at the inner edge of the Pamlico terrace below the Penholoway terrace (Figure 2.5.1-235). The general elevation of the LNP site (12 to 13.4 m [40 to 44 ft.] NAVD88), however, suggests that the site is located on the outer edge of the Penholoway terrace or possibly on an unmapped remnant of the Talbot terrace. The elevation of the unconformity between the thin mantle of Quaternary sediments and Eocene limestone at the site (approximately 11 ± 1 m [36 ± 3 ft.]) indicates that the site is well above the expected elevation of the Pamlico wave-cut terrace platform (approximately 6 m [20 ft.] amsl), and therefore, is on a terrace surface older than MIS 5e (approximately 120 – 125 ka). As noted previously, dating of marine terraces in southern Florida indicates that the MIS 7 (220 – 230 ka) and MIS 9 (300 – 340 ka) shorelines may have been close to present (Reference 2.5.1-237) indicating that it is not likely the terrace surface at the site was formed during either of those sea-level highstands.

The marine terrace that underlies the LNP site may correlate to MIS 11 (approximately 400-440 ka), which is recognized as one of the longer and warmer interglacials of the past 1 Ma (Reference RAI 02.05.01-29 02). Recent and ongoing research regarding MIS 11 suggests that the paleosea level during this highstand may have been higher than during the MIS 5e (approximately120-125 ka) highstand. Data that constrain the paleosea level during MIS 11 are available from studies in Bermuda and South Africa, both stable intraplate like Florida where marine terrace shorelines are expected to reflect glacio-eustatic sea levels (Reference RAI 02.05.01-29 02, Reference RAI 02.05.01-29 03). These studies suggest that sea level during MIS 11 was approximately +20 m (66 ft.) and +15 m (49 ft.), respectively, as recorded in Bermuda and South Africa. The marine terrace platform at the LNP site lies at a similar or slightly lower elevation. A correlation to the MIS 11 highstand cannot be precluded at this time, but additional work is needed to confirm the preliminary age estimates and paleosea level elevation of this highstand in South Africa and in other regions.

Based on these observations, the marine terrace underlying the LNP site is estimated to be Middle Pleistocene (approximately 400-440 ka) or older (early Pleistocene to possibly late Pliocene) in age."

Attachments/Enclosures:

02.05.01-29A, Revised Figure 2.5.1-235

02.05.01-29B, RAI 02.05.01-29 Figure 1

NRC Letter No.: LNP-RAI-LTR-034

NRC Letter Date: May 8, 2009

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.05.01-30

Text of NRC RAI:

FSAR Section 2.5.1.2.1.3 (pg 2.5-61) states that Figure 2.5.1-237 shows the LNP site is located where sinkholes are few and gradually develop. For sinkhole type, the figure legend indicates that solution sinkholes dominate. However, the inset map in that same figure apparently assesses future sinkhole risk and appears to indicate that a high density of sinkholes could develop at the site, with a moderate intensity of surface collapse possible. There is no quantitative expression of the future risk of sinkhole development at the site.

In order for the staff to assess the risk of future sinkhole development at the site, please discuss information presented in the inset map of Figure 2.5.1-237 in regard to potential implications for increased hazard due to future sinkhole development at the site.

PGN RAI ID #: L-0314

PGN Response to NRC RAI:

The inset map on Figure 2.5.1-237 was obtained from Upchurch and Randazzo (FSAR reference 2.5.1-319). In that reference, the map is misattributed to Sinclair and Stewart (FSAR reference 2.5.1-317). Dr. Sam Upchurch, the senior author on FSAR reference 2.5.1-319, does not know the origin of the figure and has attempted to get the proper reference from the junior author, Randazzo, without success (Reference RAI 02.05.01-30 01). Figure 2.5.1-237 will be revised in a future revision to clarify the author references (see Attachment 02.05.01-30A).

The inset map is not a predictor of future sinkhole activity, and was not intended for that purpose. It utilizes an understanding of the Florida Geological Survey geologic framework to show that in certain areas the possibility of sinkholes forming is greater than in other areas with different geology. The map is a very broad-brush approach to understanding the karstic nature of the Florida Platform. At the map scale, local variability such as at the scale of the LNP site cannot be seen.

Present and future sinkhole formation risk in the Avon Park Formation of the Gulf Hammock (LNP site) area are believed to be low relative to other areas, as discussed in the following excerpt from a personal communication from Dr. Upchurch (Reference RAI 02.05.01-30 01):

"SDII maintains the largest sinkhole database in the state. It includes the state's database (Florida Geological Survey + Florida Sinkhole Research Center data), the results of over 8,000 sinkhole investigations by SDII, and a large number of sinkhole incidence reports provided by SDII's client insurance companies. While the Gulf Hammock area is sparsely populated, the database shows only one, questionable sinkhole occurrence on US19 north of Otter Creek. Otherwise, there is no indication of modern (1985 - 2009) sinkhole development in the Gulf Hammock area. The area has one of the lowest sinkhole risks in the Florida peninsula.

As an "expert" on the karst of the Avon Park outcrop area because of SDII's analysis of the karst in the Waccasassa River MFL document, I can state that Figure 13.15 is apparently incorrect with respect to the Avon Park exposure area at Gulf Hammock. It is certainly incorrect in suggesting that the area is at the highest or next highest sinkhole risk in the state. That rating might be appropriate for the Ocala Limestone areas further inland, but not in the Gulf Hammock area."

As discussed in FSAR Section 2.5.1.2.5.2, the Ocala Limestone is not present at the LNP site.

References:

RAI 02.05.01-30 01, Upchurch, S., Personal Communication via e-mail, June 3, 2009

Associated LNP COL Application Revisions:

Figure 2.5.1-237 will be revised in a future revision of the FSAR as follows: The inset map will be removed from Figure 2.5.1-237 and the source information will be revised to state "Upchurch and Randazzo 1997, modified from Sinclair and Stewart 1985" (see Attachment 02.05.01-30A).

Attachments/Enclosures:

02.05.01-30A, Revised Figure 2.5.1-237

02.05.01-30B, Reference RAI 02.05.01-30 01

NRC Letter No.: LNP-RAI-LTR-034

NRC Letter Date: May 8, 2009

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.05.01-34

Text of NRC RAI:

FSAR Section 2.5.1.2.3 (pg 66) references FSAR Figure 2.5.1-244 which presents a site vicinity geologic map. The legend on this figure does not show the correct sequence of stratigraphic units, commonly presented with oldest at the bottom of the legend to youngest at the top, to enable interpretation of the correct stratigraphic sequence. In addition, this site vicinity geologic map appears to be based on the 1:1,000,000-scale geologic map of Florida prepared by Scott and others (2001) which may lack sufficient detail to properly portray geologic structures and stratigraphy at the scale of the site vicinity.

Figure 2.5.1-244 also shows the locations of three drillholes (W-7534, W-7538, and W-7453) which are not presented in cross sections in the FSAR. These data are potentially useful for helping to assess the presence of faults such as those proposed by Vernon (1951). The drill holes presented in the cross section shown in FSAR Figure 2.5.1-245 are not located on the geologic map of Figure 2.5.1-244.

In order for the staff to understand the stratigraphic sequence and assess all existing information regarding subsurface geology and potential structures in the site vicinity, please correct the legend of Figure 2.5.1-244 to show stratigraphic sequence from oldest at the bottom of the legend to youngest at the top since that is the standard way of presenting such geologic data. Please also justify the use of a 1:1,000,000-scale geologic map to illustrate structure and stratigraphy at the site vicinity scale. In addition, please locate drill holes W-7534, W-7538, and W-7453 on Figure 2.5.1-244 and present drillhole data in a cross section to enable assessment of the presence of faults such as those proposed by Vernon (1951).

PGN RAI ID #: L-0318

PGN Response to NRC RAI:

The legend of Revised Figure 2.5.1-244 will be modified in a future revision to show stratigraphic units in the correct stratigraphic order. Drill holes W-14519, W-15075, W-6903, W-15643, and W-8883 which are shown in the cross section on Figure 2.5.1-245 will be added to Revised Figure 2.5.1-244 in a future revision. The projected locations of drillholes W-7534, W-7538, and W-7453 will be shown on Revised Figure 2.5.1-245. A cross section across postulated Vernon (Reference 2.5.1-262) faults that incorporates available data from these wells (primarily velocity profiles) will be provided in response to RAI 02.05.01-19.

The Scott et al. (Reference RAI 02.05.01-34 01) geologic map of Florida was originally published at 1:750,000 scale. A subsequent release was at a 1:1,000,000 scale with no change in data. A digital version, which was used to create Figure 2.5.1-244, is also available from the Florida Geological Survey (FGS). A 1:126,720 scale map of Levy County was published as a FGS Open-file Map Series (Reference RAI 02.05.01-34 02). All existing data available to the

FGS was utilized for the Campbell map but no additional fieldwork was conducted. All counties in Florida were mapped at this scale as part of a statewide radon investigation (Reference RAI 02.05.01-34 03). These 1:126,720 scale maps were combined and edge matched to create the basis for the Scott et al. (2001) map. Additional mapping was conducted in portions of the state to better define the geology.

The most detailed mapping in the State has been done under the STATEMAP portion of the National Cooperative Geologic Mapping Act funded through the US Geological Survey. The FGS has participated in the STATEMAP Program for a number of years. The resultant maps are incorporated into an evolving digital geologic map. However, the Levy County area has yet to be mapped in detail.

The 1:1,000,000 map scale was deemed appropriate due to the very slight dip of Florida's Cenozoic stratigraphic units, which is commonly on the order of less than one tenth of a degree or less than 10 feet per mile. The occurrence of exposures also helped to dictate the final publication scale. Florida is a state with very limited exposures. It should be noted that in creating the Scott et al. (Reference RAI 02.05.01-34 01) map up to six meters (twenty feet) of undifferentiated sediments were removed in order to map the first recognizable formal lithostratigraphic unit. If the undifferentiated sediments exceeded six meters, the undifferentiated sediments were considered a mappable unit and placed on the final map.

References:

1. RAI 02.05.01-34 01, Scott, T.M., Campbell, K.M., Rupert, F.R., Arthur, J.D., Missimer, T.M., Lloyd, J.M., Yon, J.W. and Duncan, J.G., "Geologic Map of the State of Florida", Florida Geological Survey Open File Report No. 80, Produced by the Florida Geological Survey in cooperation with the Florida Department of Environmental Protection, 2001.
2. RAI 02.05.01-34 02, Campbell, K., "Geologic Map of Levy County, Florida", Florida Geological Survey Open File Report No. 11, Scale 1:126,720, 1992.
3. RAI 02.05.01-34 03, Nagda, N.L., Koontz, M.S., Fortmann, R.C., Schoenborn, W.A., Mehegan, L.L., "Florida Statewide Radiation Study", Prepared by GEOMET Technologies, Publication No. 05-029-057, 458 pp., 1987

Associated LNP COL Application Revisions:

Revisions to Figure 2.5.1-244 and Figure 2.5.1-245

Attachments/Enclosures:

02.05.01-28A, Revised Figure 2.5.1-244

02.05.01-34A, Revised Figure 2.5.1-245

NRC Letter No.: LNP-RAI-LTR-034

NRC Letter Date: May 8, 2009

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 02.05.01-36

Text of NRC RAI:

FSAR Section 2.5.1.2.3.8 (pg 2.5-73) indicates Arthur and others (2001) documented that the Lower Oligocene Suwannee Limestone is not present within the LNP site area. However, there is no summary of data used by Arthur and others (2001) to draw this conclusion.

In order for the staff to fully assess the stratigraphic units which lie within the site area, please summarize the data from Arthur and others (2001) used to document the conclusion that the Suwannee Limestone is not present.

PGN RAI ID #: L-0320

PGN Response to NRC RAI:

Detailed lithologic descriptions, gamma-ray logs and hydrologic data comprise the bulk of the information used to develop the cross sections. The dominant sources of information for cross section control are Southwest Florida Water Management District (SWFWMD) ROMP wells; Florida Geological Survey (FGS) wells were included to fill out appropriate data-point coverage for the cross sections. Where no lithologic data was available, borehole geophysical logs were used. Of these geophysical logs, gamma-ray logs were the most readily available and generally useful for correlative purposes. Gamma-ray logs were included in the Arthur et al. 2001 (Reference 2.5.1-321) cross sections to allow comparison of the gamma-ray signatures relative to each stratigraphic unit.

Geological maps of Florida including Vernon and Puri (1964) (Reference RAI 02.05.01-36 01) available online at http://image11.fcla.edu/cgi/i/image/image-idx?q1=UF00015048&rgn1=Identifier&type=boolean&view=thumbnail&c=map and Scott, 2001 (FSAR Reference 2.5.1-204) were consulted during FSAR preparation to determine formations mapped in selected areas of the State.

The Suwannee Limestone occurs within 40 km (25 mi) of the site. The nearest occurrences are approximately 23 mi (37 km) south of the site. These occurrences are outliers of the Suwannee Limestone in areas where most of the unit has been removed by erosion and dissolution. (Reference RAI 02.05.01-36 01, Reference RAI 02.05.01-36 02 and FSAR Reference 2.5.1-204)

To attempt to tie the discussion by Arthur and others (2001) (Reference 2.5.1-321) into the LNP site-specific geology, detailed lithologic descriptions for the Suwannee Limestone and other geologic formations were obtained from the Florida Geological Survey online document "Guide to Florida Rocks and Minerals" available at the following link: http://www.dep.state.fl.us/geology/geologictopics/rocks/florida_rocks.htm (Reference RAI 02.05.01-36-02)

These differentiating factors as well as other lithologic information such as the well log from the Robinson No. 1 petroleum test well (Reference FSAR 2.5.3-206, Figure 5) and Coastal Petroleum's Ragland No.1 well (Reference FSAR 2.5.3-206, Appendix pg. B87) were used during the geotechnical field program to confirm that the site-specific stratigraphy observed was consistent with the published literature.

In order to further clarify and update the sources of information utilized to develop the LNP site stratigraphic conceptual model, Section 2.5.1.2.3, Stratigraphy of Site Vicinity and Site Area will be changed as discussed below in a future revision of the FSAR.

References:

1. RAI 02.05.01-36 01, Vernon, R.O., and Puri, H.S., 1964, Geologic map of Florida, Florida Bureau of Geology Map Series 18
2. RAI 02.05.01-36 02, T. Scott, Personal Communication, June 8, 2009
3. RAI 02.05.01-36 03, Florida Geological Survey online document "Guide to Florida Rocks and Minerals" at the following link: http://www.dep.state.fl.us/geology/geologictopics/rocks/florida_rocks.htm
4. RAI 02.05.01-36 04, Scott, 1992, Geological Overview of Florida FGS OFR 50,pg 24, 25, 28 FGS pubs online at http://www.uflib.ufl.edu/ufdc/UFDC.aspx?s=fgs&b=UF00001048&v=00001

Associated LNP COL Application Revisions:

The following modification will be made to FSAR Section 2.5.1.2.3 in a future revision to provide additional discussion of the erosional episodes evidenced by unconformities between Tertiary and Quaternary units in the vicinity of the Ocala platform.

Text in Section 2.5.1.2.3 Stratigraphy of Site Vicinity and Site Area will be modified from:

"The oldest rocks penetrated within the site vicinity (40 km [25 mi.] radius) and site area (8 km [5 mi.] radius) are Paleozoic shales and quartzite pebble sands that are overlain by Triassic diabase. Overlying these sediments is a thick section of Cretaceous and Cenozoic carbonates (limestone and dolomite) that are overlain by undifferentiated Pleistocene to Holocene age surficial sands, clayey sands, and alluvium.

The following descriptions of the geologic units from Paleozoic through to Early Eocene were summarized from Vernon (Reference 2.5.1 262), and geologic units from Middle Eocene through to the Holocene were taken from Scott (Reference 2.5.1 204) and Arthur et al. (Reference 2.5.1 321) Geologic units included on the State of Florida geological map range from Middle Eocene to Holocene and are shown on Figure 2.5.1 244. A geologic cross section illustrating the Cretaceous geologic units beneath Levy County is shown on Figure 2.5.1 243, and a geologic cross section illustrating the Middle Eocene to Holocene units through the site is shown on Figure 2.5.1 245. A geologic column of the lithostratigraphic units from the Lower Cretaceous through to the Holocene is shown on Figure 2.5.1 214."

To read:

"The oldest rocks penetrated within the site vicinity (40 km [25 mi.] radius) and site area (8 km [5 mi.] radius) are Paleozoic shales and quartzite pebble sands that are overlain by Triassic diabase. Overlying these sediments is a thick section of Cretaceous and Cenozoic carbonates (limestone and dolomite) that are overlain by undifferentiated Pleistocene to Holocene age surficial sands, clayey sands, and alluvium.

The Eocene to Quaternary geologic history of the Ocala platform is marked by significant erosional episodes. At the LNP site, the Middle Eocene Avon Park Formation lies immediately below Quaternary sediments with the Ocala Limestone, Suwannee Limestone and the Hawthorn Group missing. It has been postulated that these units were deposited over the Ocala platform and subsequently removed by dissolution and mechanical erosion (Reference 02.05.01-36 04; Reference 2.5.1-231, Reference 2.5.1-235, Reference 2.5.1-308 . Timing of the erosional episodes is not precisely known.

The contact between the Avon Park Formation and the Ocala Limestone may be unconformable to conformable (Reference 2.5.1-231) and may locally have several meters of relief. The Ocala/Suwannee contact appears conformable with no significant erosion (Reference 2.5.1-231). Both the Ocala Limestone contact and the Suwannee Limestone contact with the Hawthorn Group are unconformable and may exhibit many meters of relief (Reference 2.5.1-235, Reference 2.5.1-261). These relationships suggest that some of the sediment removal occurred during the Late Oligocene prior to Hawthorn Group deposition. However, the Hawthorn Group sediments covered the Ocala platform and were removed by post-Middle Miocene erosion (Reference 2.5.1-235). As Hawthorn Group sediments were removed, the Suwannee Limestone and the Ocala Limestone were removed from the crest of the Ocala platform. Subsequently, Quaternary sediments were deposited covering the Avon Park Formation surface and the remnants of the Ocala Limestone and Suwannee Limestone. The weathering of the Ocala and Suwannee Limestones resulted in significant karst development. The Avon Park Formation, which was pervasively dolomitized in the Oligocene (Reference 2.5.1-231), was not heavily karstified.

The following descriptions of the geologic units from Paleozoic through to Early Eocene were summarized from Vernon (Reference 2.5.1 262), and geologic units from Middle Eocene through to the Holocene were taken from Scott (Reference 2.5.1 204) and Arthur et al. (Reference 2.5.1 321) Geologic units included on the State of Florida geological map range from Middle Eocene to Holocene and are shown on Figure 2.5.1 244. A geologic cross section illustrating the Cretaceous geologic units beneath Levy County is shown on Figure 2.5.1 243, and a geologic cross section illustrating the Middle Eocene to Holocene units through the site is shown on Figure 2.5.1 245. A geologic column of the lithostratigraphic units from the Lower Cretaceous through to the Holocene is shown on Figure 2.5.1 214."

Attachments/Enclosures:

None

Attachments To Letter NPD-NRC-2009-134

Attachment 02.05.01-11A

Schaeffer, Jen/SEA

From: Thomas Scott [tscott@sdii-global.com]
Sent: Saturday, May 30, 2009 4:49 PM
To: 'Thomas Scott'; Elliott, William/GNV; Schaeffer, Jen/SEA; Kathryn.Hanson@amec.com
Cc: Alexis.Lavine@amec.com
Subject: RE: FSAR RAI 2.5.1-11
Attachments: Origin of the Ocala Platform by T Scott.doc

Here is a personal communication concerning this FSAR RAI. Additional info added.

The question of the origin of the Ocala Platform is one that has been extensively discussed at the Florida Geological Survey during my thirty-five years there. Discussions focused on how the feature formed since there was no viable evidence for a true uplift. Winston (1976) published the idea of the Ocala "Blister Dome" that formed in response to an anomalous thickening in the Middle Eocene Lake City Limestone (now part of the expanded Avon Park Formation). Winston mapped the thickness of the Lake City Limestone and interpreted a significantly thicker sequence of carbonate sediments was deposited during this time. Winston thought that subsequent units draped across the feature creating the appearance of an uplift without any true structural origin.

Many years of describing cores and well cuttings from around the peninsula and reviewing pertinent literature led me to formulate a hypothesis concerning the origin of the Ocala Platform (I initiated the use of this term in 1988). Although this idea has not been published, a number of geologists believe it accurately describes the feature's origin. I relied on research by numerous geologists on the structure and geologic history of plate boundaries (the trailing edge of the North American Plate and the interaction with the Caribbean Plate) and the formation of the Gulf of Mexico.

The central and northern portions of the Florida Platform developed on stable continental crust, a piece of the African Plate left attached to the North American Plate when the plates parted in mid-Jurassic. The southern portion of the platform lies on transitional crust. Post mid-Jurassic sediments were deposited on the transitional crust and onlapping, eventually covering, the continental crust. The pattern of thickening of these sediments southward from a hinge line in the central portion of the platform indicates slight downwarping toward the distal edge of the plate creating a significantly thick sequence of Jurassic to Quaternary sediments in the southern portion of the Florida Platform.

The trailing edge of the North American Plate has undergone slow subsidence from thermal contraction that occurred as the distance from the spreading center increased. This caused the eastern portion of the Florida Platform to subside slowly. At the same time, the Gulf of Mexico Basin formed and has undergone significant subsidence that appears to be continuing at the present. The Ocala Platform's "crest" occurs at the juncture of the trailing edge subsidence and that associated with the Gulf of Mexico. The fragment of the African Plate that forms the basement rocks of the Florida Platform has subsided less than the trailing edge of the North American Plate and the Gulf of Mexico Basin creating the appearance of an "uplift." It is simply a slightly more "stable" portion of the Florida Platform.

Differential subsidence, sedimentation and erosion have created the dip patterns seen related to the feature. Fracturing of the Floridian rocks is the result of tensional stresses caused by the differential subsidence of the Florida Platform.

One other factor that may be affecting the development of the Ocala Platform and the occurrence of fractures is the concept of Isostatic readjustment or uplift. The concept in Florida was suggested by Opdyke et al (1984) to suggest that dissolution of carbonate and the subsequent reduction of weight caused a rebound effect thus uplifting a broad area. Willet (2006) and Means (2009) discussed the possibility of Isostatic readjustment as a possibility for broad uplift in the southeast.

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-----Original Message-----
From: Sam Upchurch [mailto:SUpchurch@sdii-global.com]
Sent: Thursday, May 28, 2009 10:45 AM
To: Thomas Scott; Harley Means (E-mail)
Subject: RE: Origin of the Ocala Platform

i think the best argument is couched in a question? What, tectonically, would cause an uplift? The answer is none for Middle Tertiary times. Both sides of the Florida peninsula are passive continental margins. Subsidence of the margins seems the only way that the Platform can be explained tectonically. This is consistent with the apparent faults mapped by Barnett and Klitgourd. The faults, if present, are apparently strike-slip features associated with the break up and spreading of the Atlantic, too.

Coleman's thesis shows the break up faulting (as interpreted by microgravity) on the west coast; a USF thesis by Lynn O'Conner found the same thing on the east coast at the same latitude. These are normal faults with horst and graben structures. Since the Ocala Platform is so much later than these, the only way I can see for formation of the Platform is continued, down-to-the-sea relaxation of these marginal, passive margin features.

Sam B. Upchurch, Ph.D., P.G.
Vice President and Principal Geologist
SDII Global Corporation
4509 George Road
Tampa, Florida 33634
Office: 813-496-9634
Fax: 813-496-9664

-----Original Message-----
From: Means, Guy [mailto:Guy.Means@dep.state.fl.us]
Sent: Thursday, May 28, 2009 4:28 PM
To: tscott@sdii-global.com; Sam Upchurch (E-mail)
Subject: RE: Origin of the Ocala Platform

Tom,

I agree with both you and Sam. I might add that karstification of the platform may have led to some "uplift" as postulated by Opdyke et al, 1984 and Willett, 2005??. Would it be possible to have some preferential adjustment in areas that are more highly karstified (like the Ocala Platform). Remember in my thesis I postulated that the anomalously high portions of the Citronelle Formation in western Florida may exist because of a flexure due to sediment loading in the Gulf of Mexico basin. I think is is pretty well accepted that there has been some marginal subsidence on both sides of the Florida Platform, as Sam pointed out. I am certainly in agreement that some subsidence has occurred at the platform margins and don't see how any tectonic mechanism can be invoked to explain the apparent high on the Ocala Platform. You and I have discussed your idea many times and it seems very plausible to me.

Harley Means

Attachment 02.05.01-14A

Moore-Butler, Geraldine

From:	Thomas Scott [tscott@sdii-global.com]
Sent:	Monday, June 01, 2009 3:57 PM
To:	Hanson, Kathryn
Cc:	Jen.Schaeffer@CH2M.com; William.Elliott@CH2M.com; Lavine, Alexis
Subject:	RAI 2.5.1-14
Attachments:	T Scott Pers Comm Barrier Island District.doc

During the last ten years, I have been working on an updated geomorphic map of Florida. In an effort to remove interstate discrepancies, I brought the Barrier Island Sequence District, part of Georgia's Sea Island Section (Clark and Zisa, 1976), into Florida. This geomorphic district extends well south along the east coast of Florida. This encompasses the area discussed in RAI 2.5.1-14. The Atlantic Coastal margin of the Barrier Island District is slowly being inundated as sea level rises.

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Coppersmith, Ryan

From: Thomas Scott [tscott@sdii-global.com]
Sent: Tuesday, June 09, 2009 3:53 AM
To: Hanson, Kathryn
Cc: Jen.Schaeffer@CH2M.com; Perman, Roseanne C
Subject: RE: 2.5.1-14 one last VAL

Kathryn, here is a portion of the text I'm preparing for the new geomorphic map of Florida. This is part of the discussion of the Barrier Island Sequence District.

Barrier Island Sequence District

The Barrier Island Sequence District extends in to Florida from Georgia. The district is characterized by beach ridges, dunes and paleo-lagoons. In Florida, the district extends from the Georgia-Florida state line southward to the vicinity of Lake Okeechobee. It lies to the east of the Okeefenokee Basin District. the Ocala Karst District, the Central Lakes District, and the Sarasota River District. It lies north of the eastern portion of the Everglades District. The surficial and shallow subsurface sediments of the district were deposited during the Plio-Pleistocene and lie unconformably on sediments ranging from the Middle Eocene Avon Park Formation to the Oligocene-Miocene Hawthorn Group.

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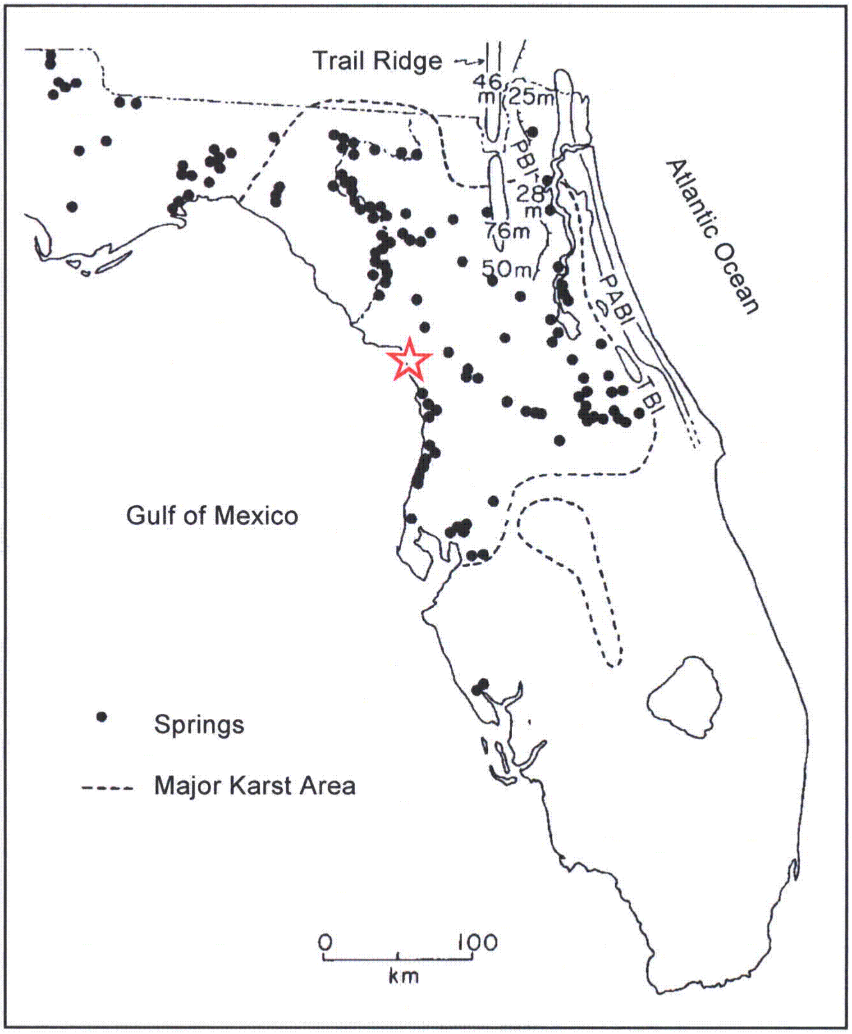
-----Original Message-----
From: Hanson, Kathryn [mailto:Kathryn.Hanson@amec.com]
Sent: Monday, June 08, 2009 7:23 PM
To: Thomas Scott
Cc: Jen.Schaeffer@CH2M.com; Perman, Roseanne C
Subject: 2.5.1-14 one last VAL

N



Relict shoreline features:

Older	PABI	Pamlico Barrier Islands
	TBI	Talbot Barrier Islands
	PBI	Penholoway Barrier Islands

Trail Ridge (Coast-parallel transgressive dune complex, Force and Rich, 1989)

Source: Opdyke et, al. (1984).

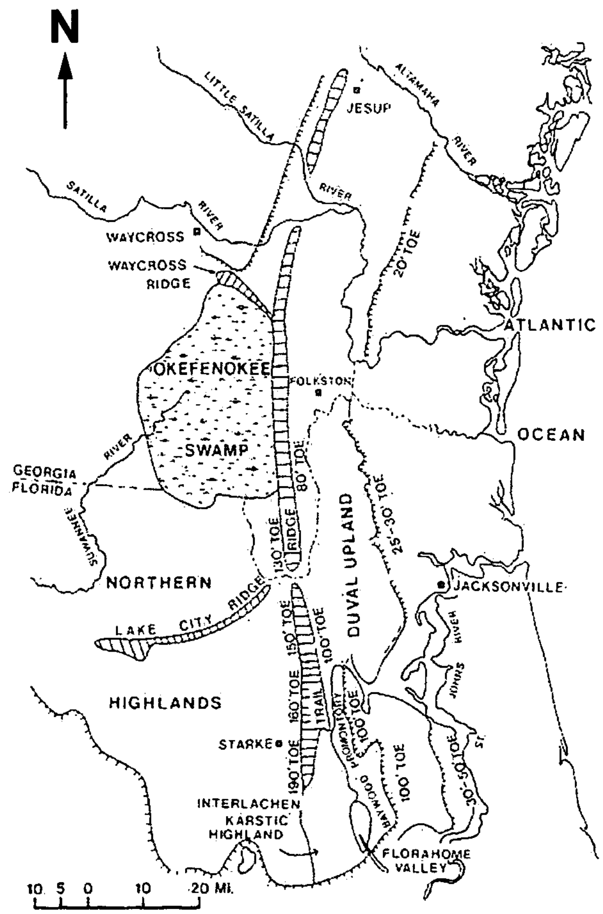
LEGEND

☆ LNP Site

Progress Energy Florida

Levy Nuclear Plant
Units 1 and 2
Part 2, Final Safety Analysis Report

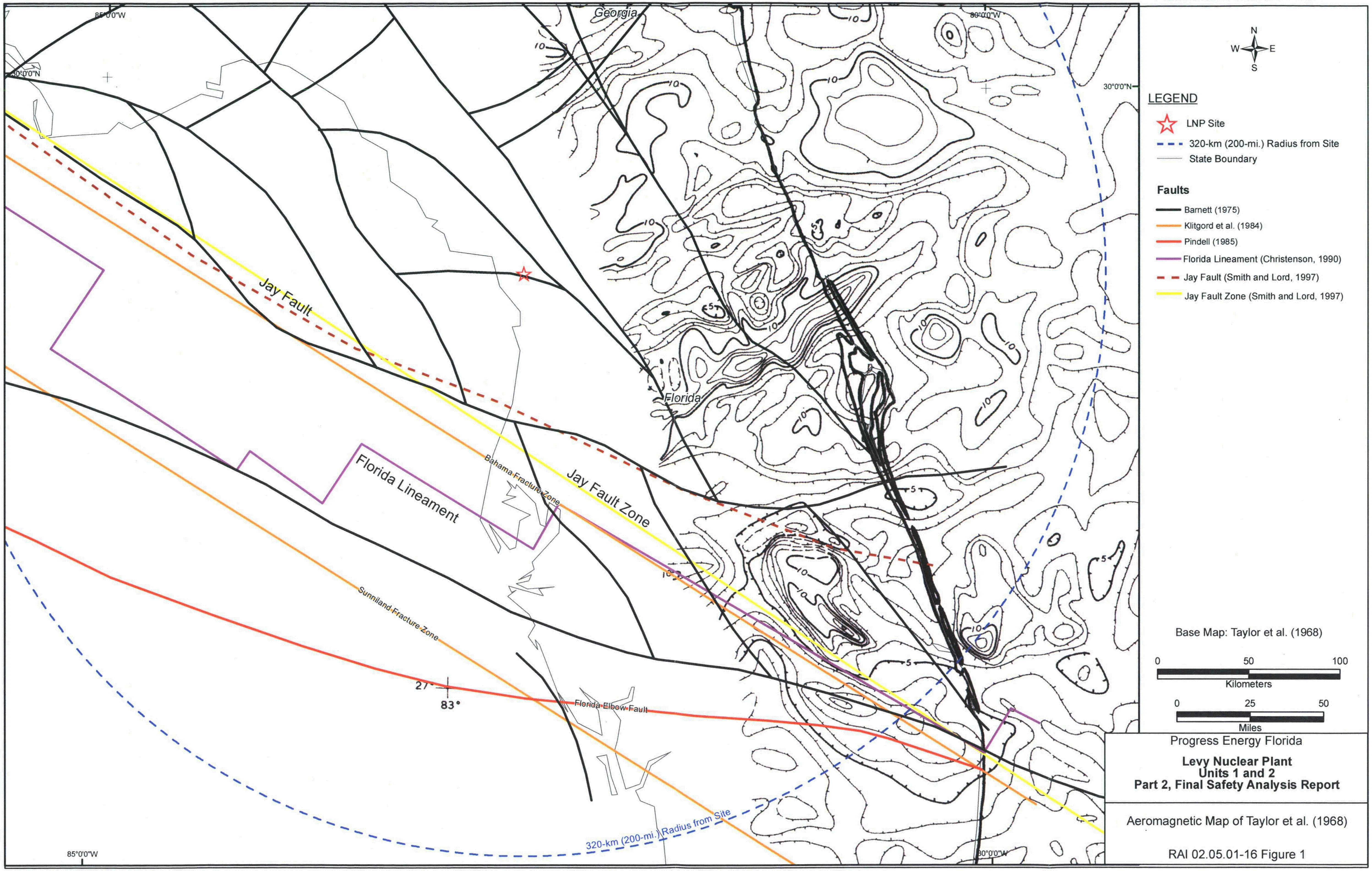
Map Showing Varying Elevation of Postulated Pleistocene Shoreline Features in Southern Georgia and Northern Florida
RAI 02.05.01-14 Figure 1



Source: Pirkle and Czel (1983).

	Progress Energy Florida **Levy Nuclear Plant Units 1 and 2 Part 2, Final Safety Analysis Report**
	Location Map Showing Trail Ridge and Other Major Physiographic Features RAI 02.05.01-14 Figure 2

Attachment 02.05.01-16A

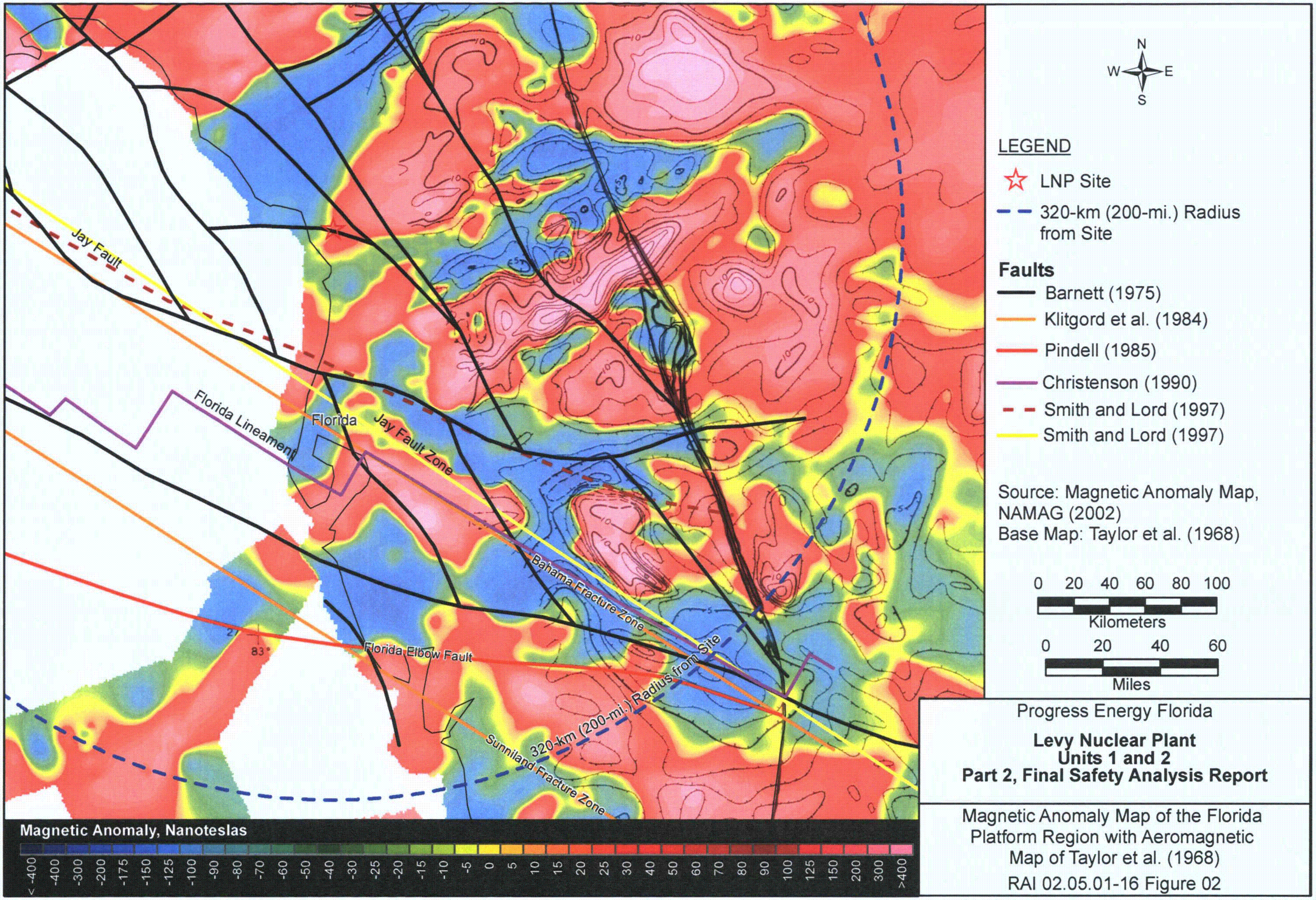


Progress Energy Florida

Levy Nuclear Plant Units 1 and 2 Part 2, Final Safety Analysis Report

Aeromagnetic Map of Taylor et al. (1968)

RAI 02.05.01-16 Figure 1



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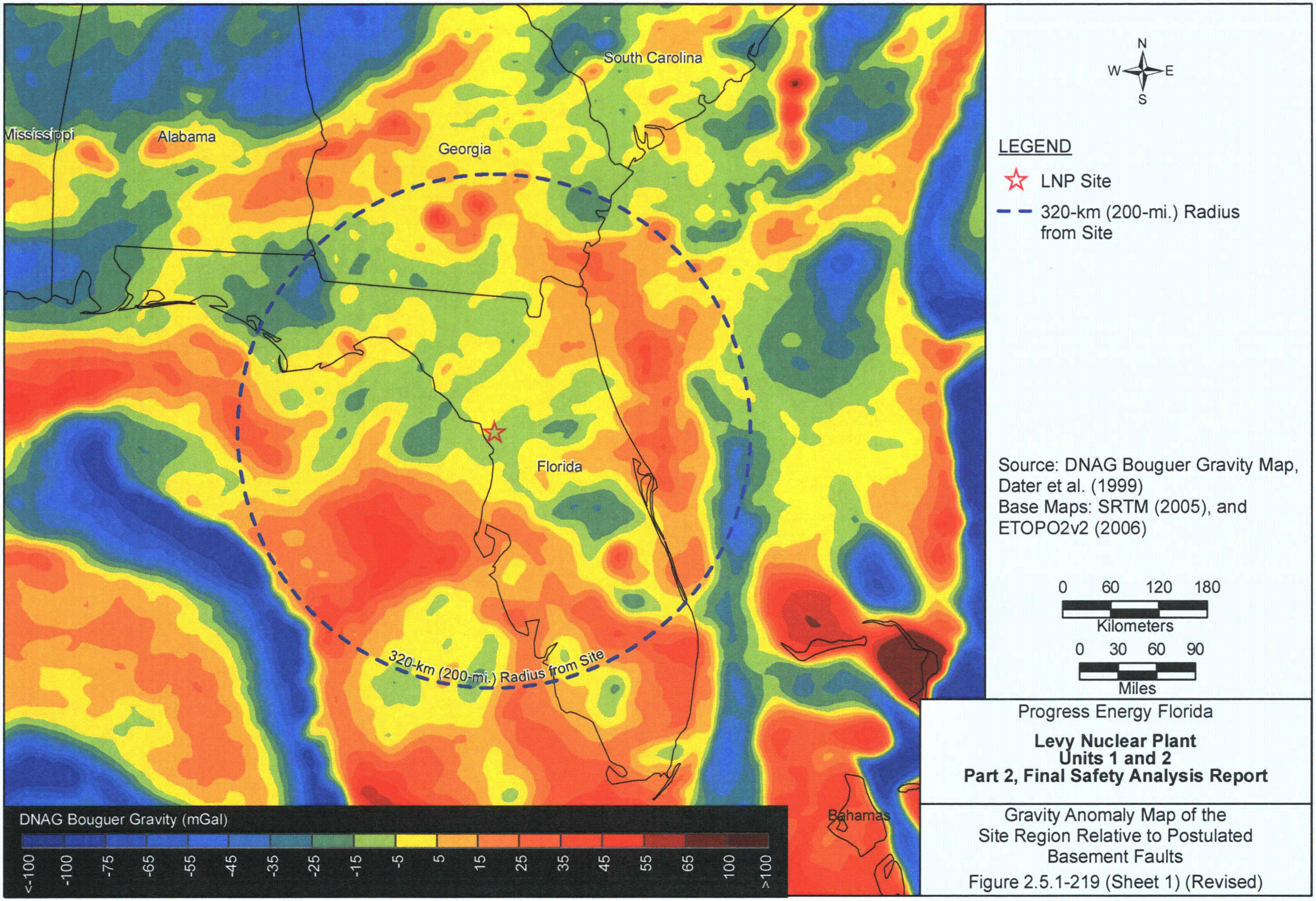
Units 1 and 2
Part 2, Final Safety Analysis Report

Magnetic Anomaly Map of the Florida Platform Region with Aeromagnetic Map of Taylor et al. (1968)

RAI 02.05.01-16 Figure 02

Attachment 02.05.01-16B



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Levy Nuclear Plant
Units 1 and 2
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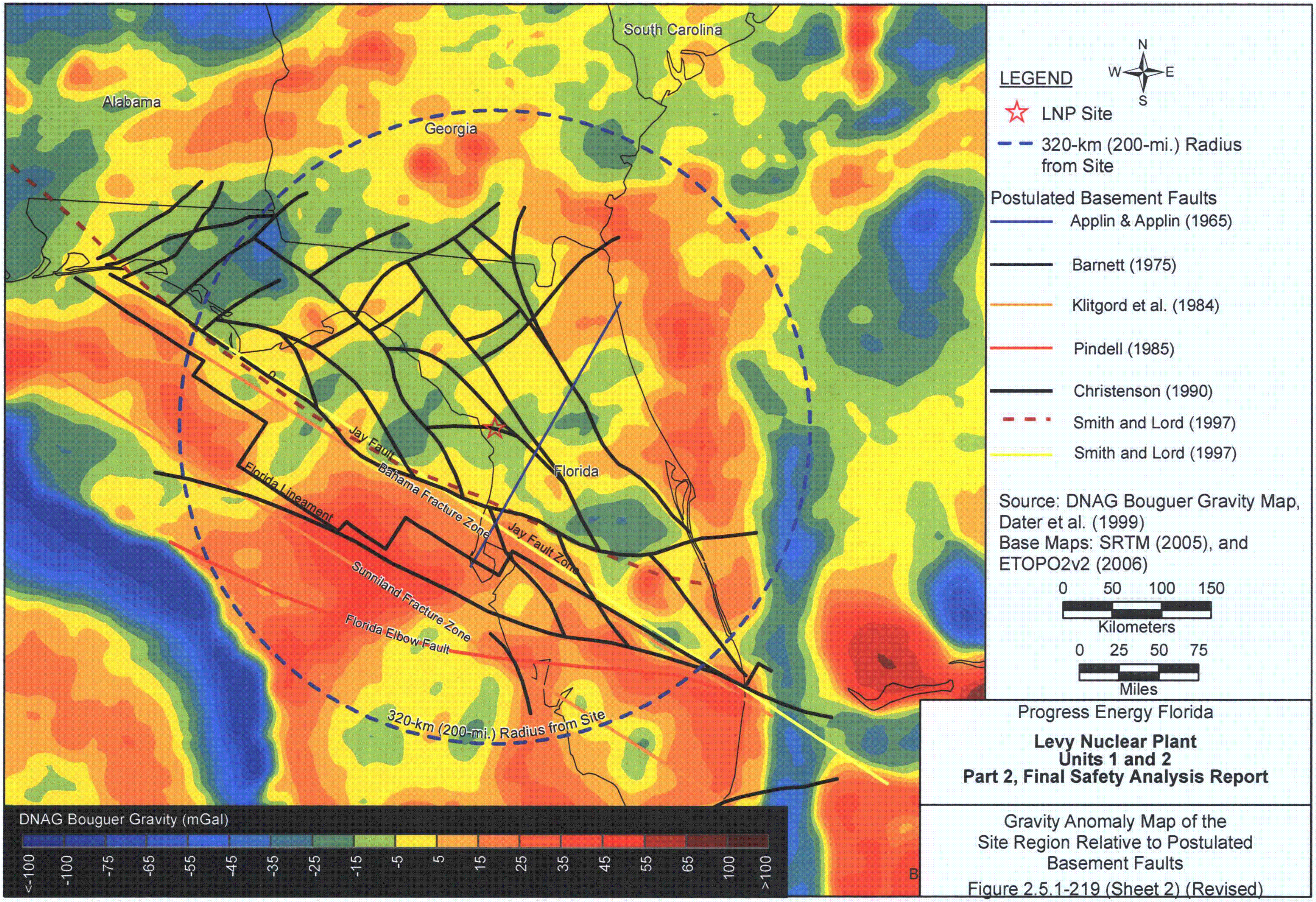
Gravity Anomaly Map of the Site Region Relative to Postulated Basement Faults

Figure 2.5.1-219 (Sheet 1) (Revised)

Attachment 02.05.01-16C1



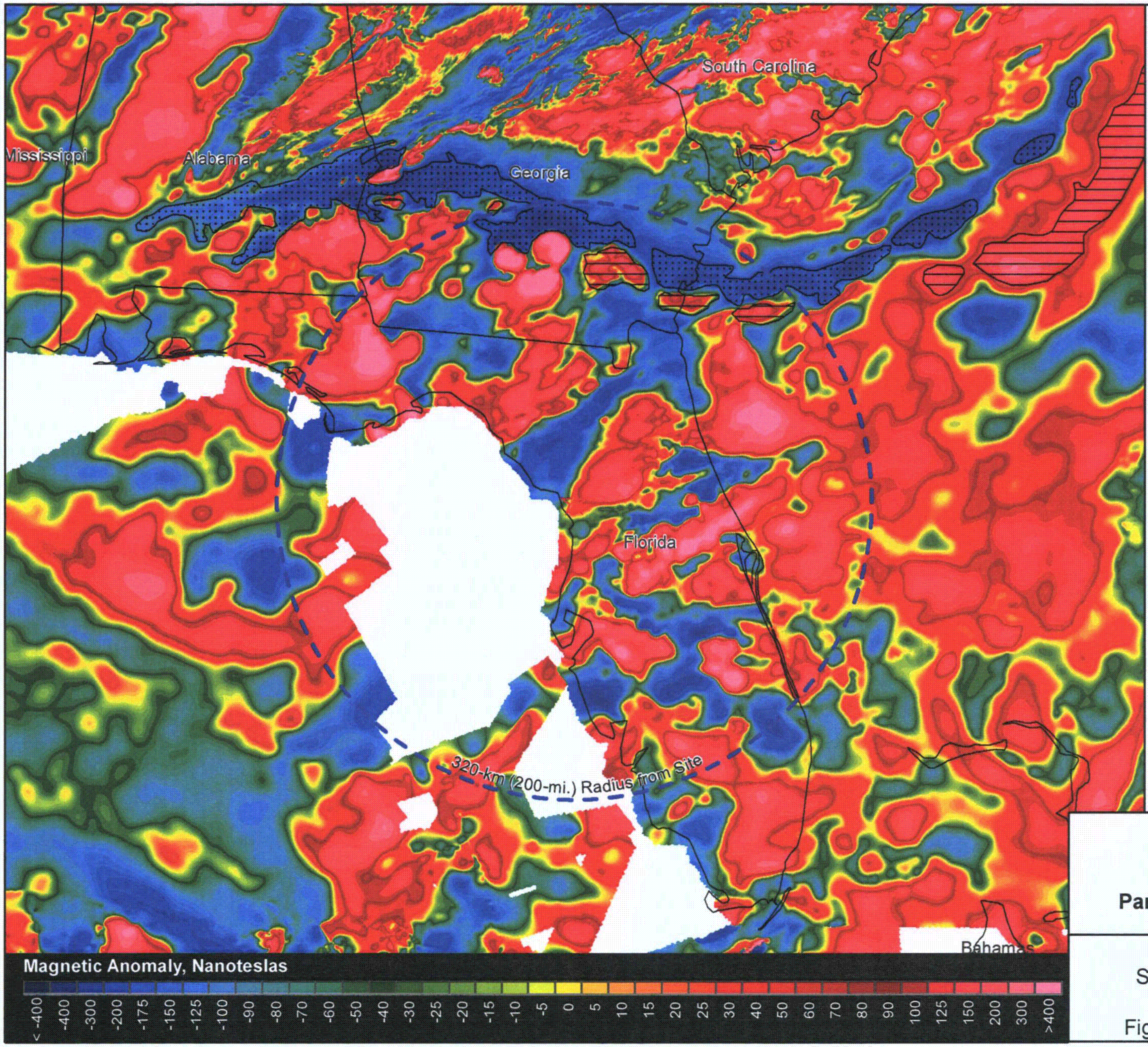
Progress Energy Florida

Levy Nuclear Plant Units 1 and 2 Part 2, Final Safety Analysis Report

Gravity Anomaly Map of the Site Region Relative to Postulated Basement Faults

Figure 2.5.1-219 (Sheet 2) (Revised)

Attachment 02.05.01-16C2



LEGEND

- LNP Site
- 320-km (200-mi.) Radius from Site
- Brunswick Anomaly
- East Coast Magnetic Anomaly

Source: Nelson et al. (1985)

Source: Magnetic Anomaly Map, NAMAG (2002)
Base Maps: SRTM (2005), and ETOPO2v2 (2006)

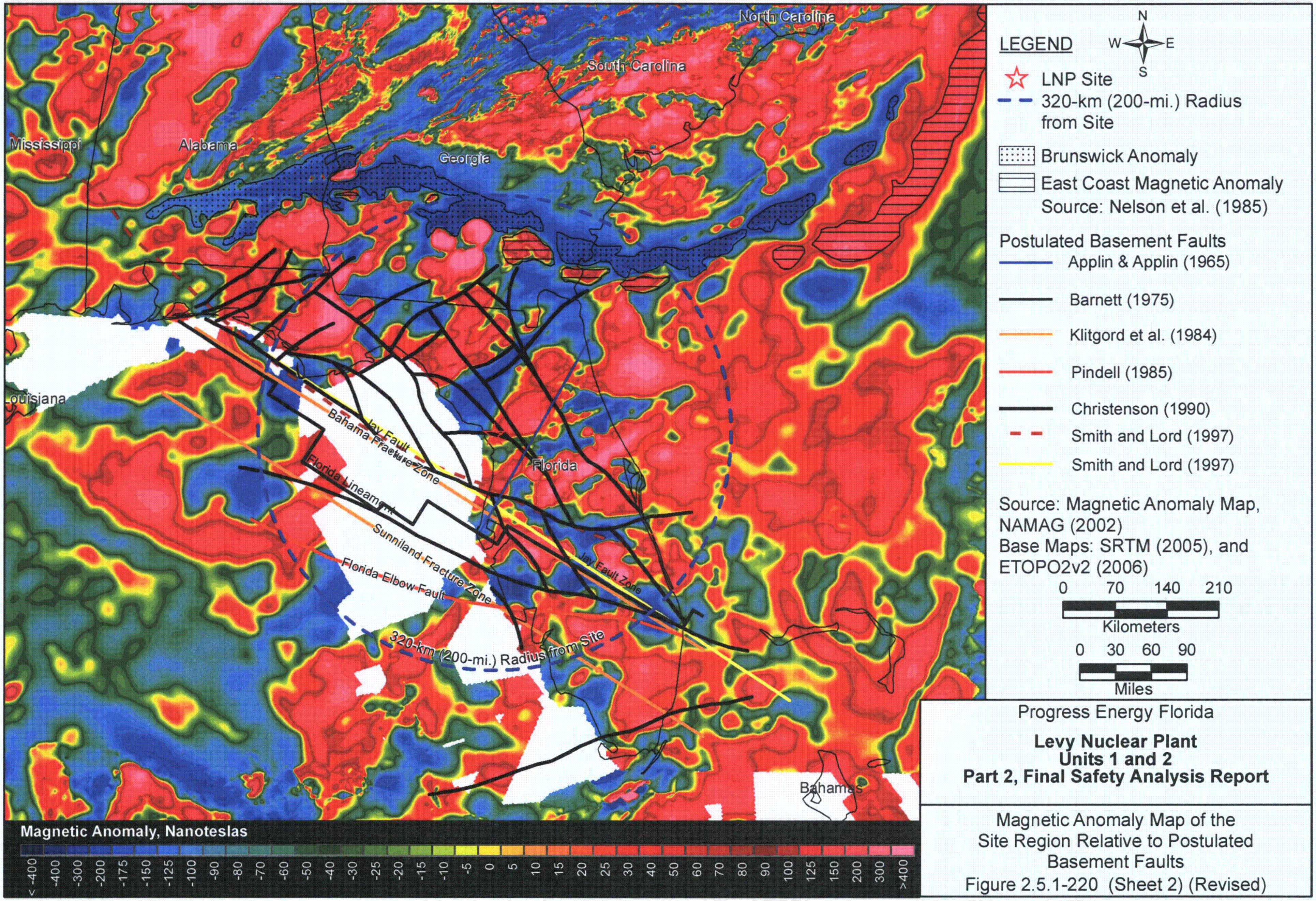
Progress Energy Florida

Levy Nuclear Plant
Units 1 and 2
Part 2, Final Safety Analysis Report

Magnetic Anomaly Map of the Site Region Relative to Postulated Basement Faults

Figure 2.5.1-220 (Sheet 1) (Revised)

Attachment 02.05.01-16D1



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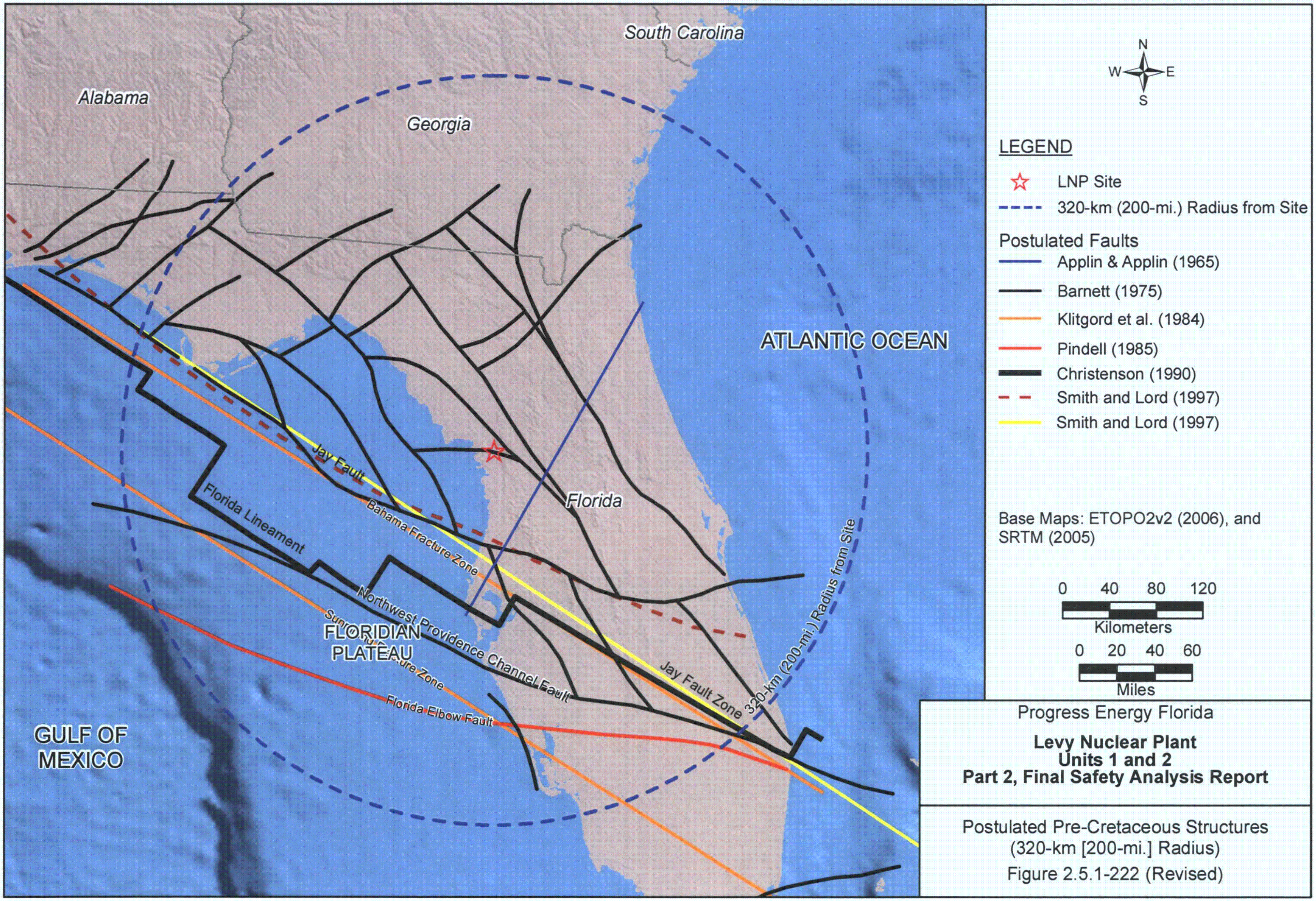
Levy Nuclear Plant
Units 1 and 2
Part 2, Final Safety Analysis Report

Magnetic Anomaly Map of the Site Region Relative to Postulated Basement Faults

Figure 2.5.1-220 (Sheet 2) (Revised)

Attachment 02.05.01-16D2



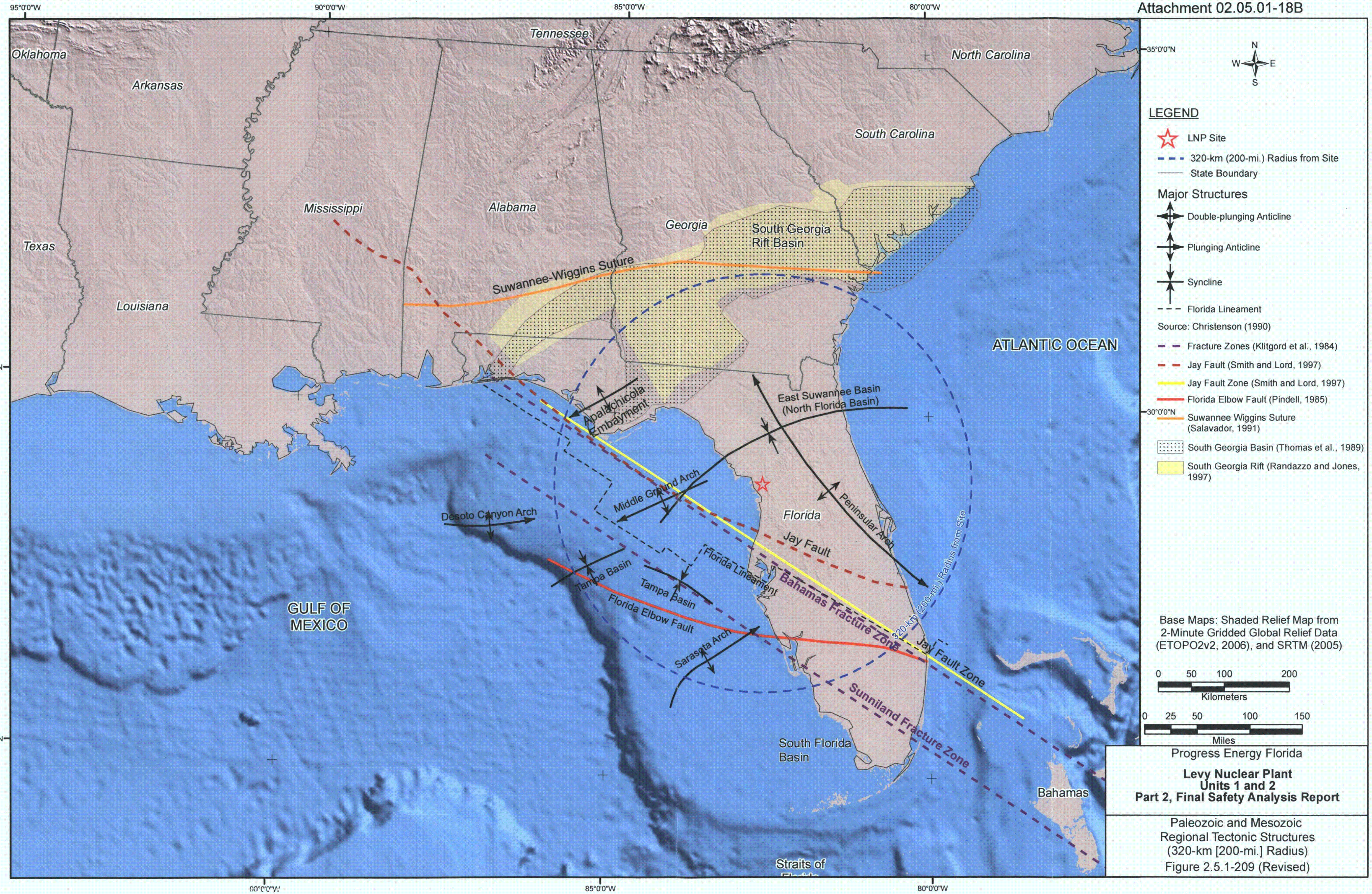
Progress Energy Florida

Levy Nuclear Plant
Units 1 and 2
Part 2, Final Safety Analysis Report

Postulated Pre-Cretaceous Structures
(320-km [200-mi.] Radius)
Figure 2.5.1-222 (Revised)

Attachment 02.05.01-18A

Attachment 02.05.01-18B



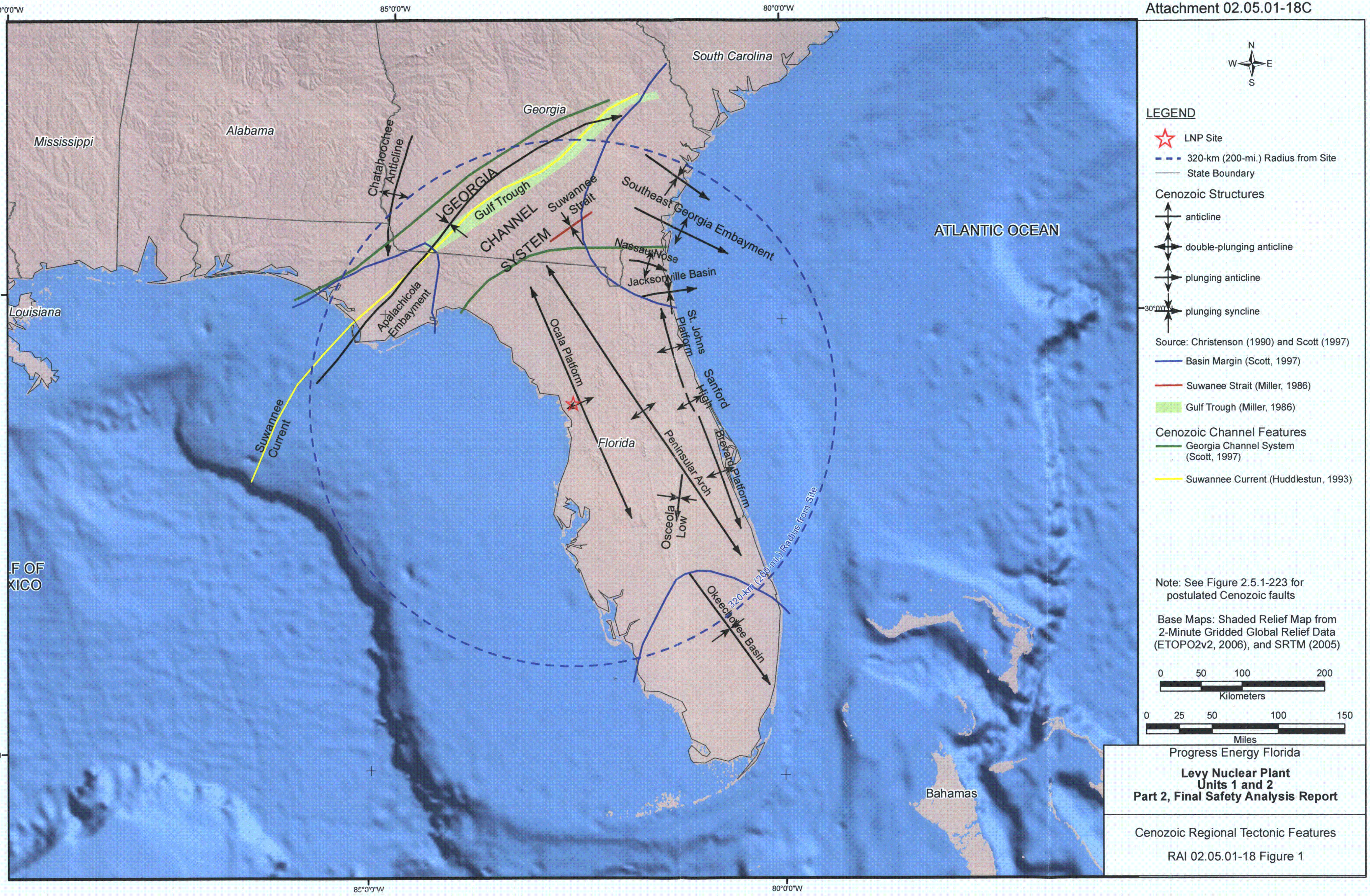
Progress Energy Florida

Levy Nuclear Plant Units 1 and 2 Part 2, Final Safety Analysis Report

Paleozoic and Mesozoic Regional Tectonic Structures (320-km [200-mi.] Radius)

Figure 2.5.1-209 (Revised)

Attachment 02.05.01-18C



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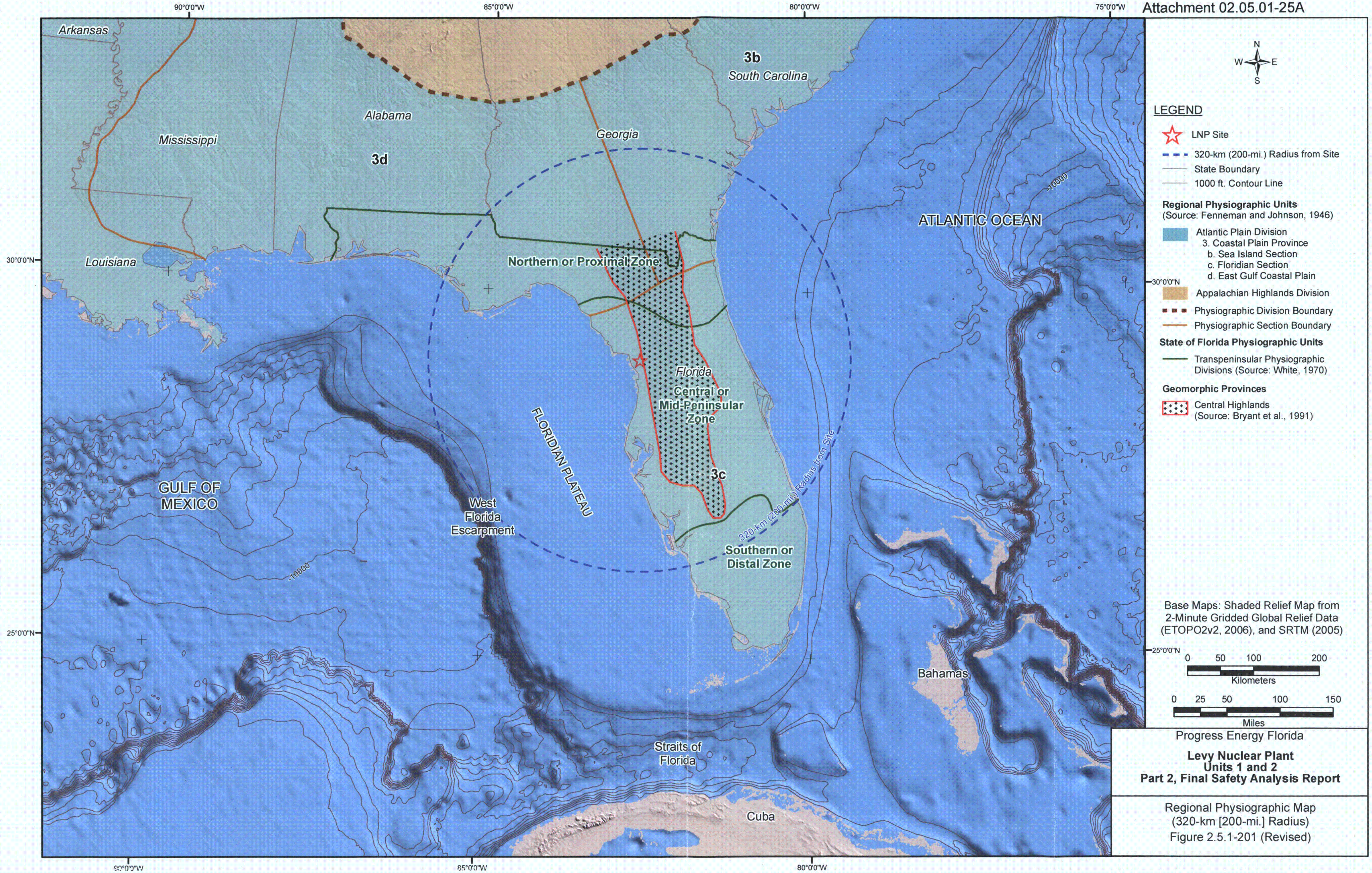

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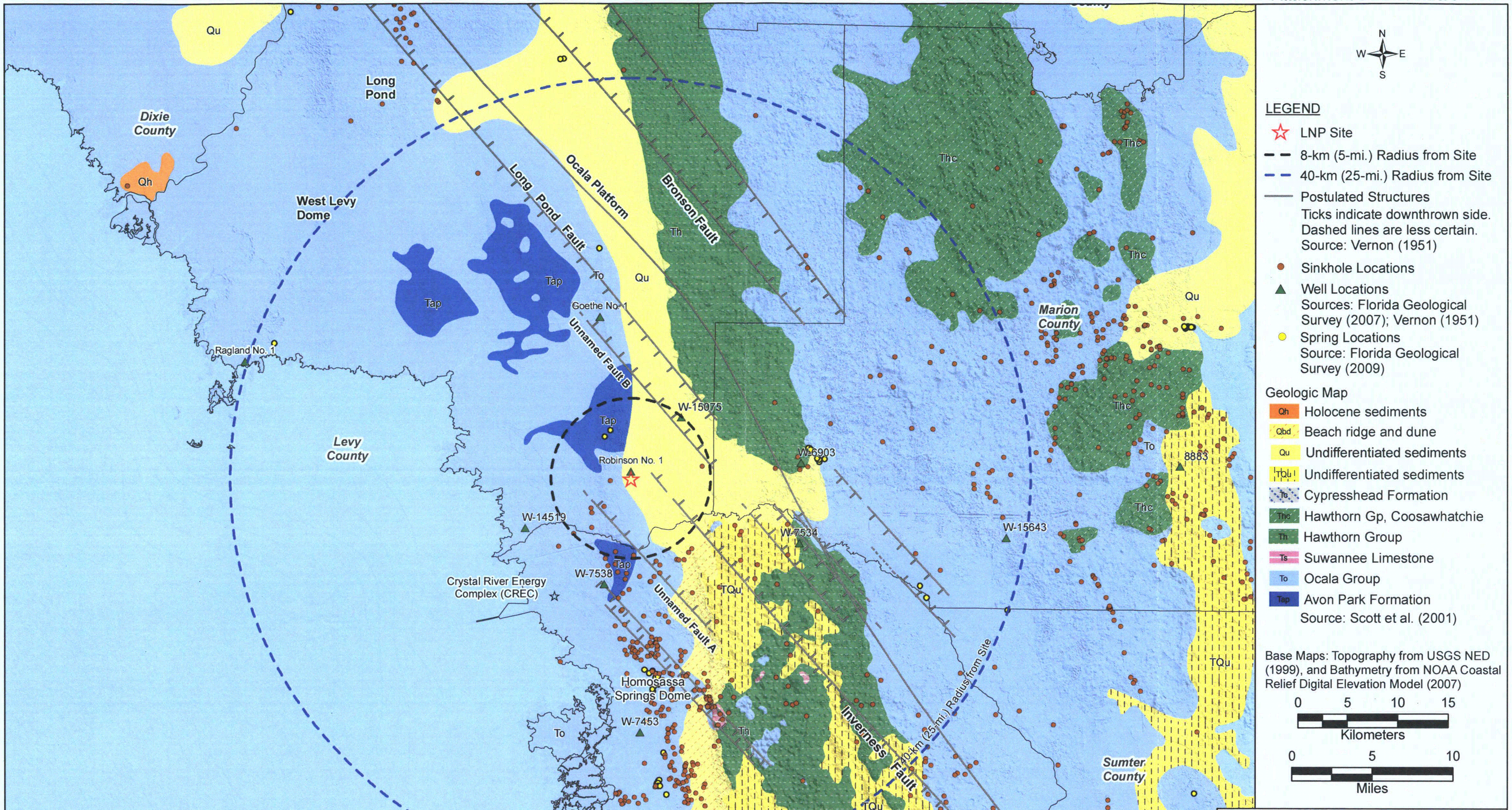
Levy Nuclear Plant Units 1 and 2 Part 2, Final Safety Analysis Report

Regional Physiographic Map (320-km [200-mi.] Radius)
Figure 2.5.1-201 (Revised)

Attachment 02.05.01-28A



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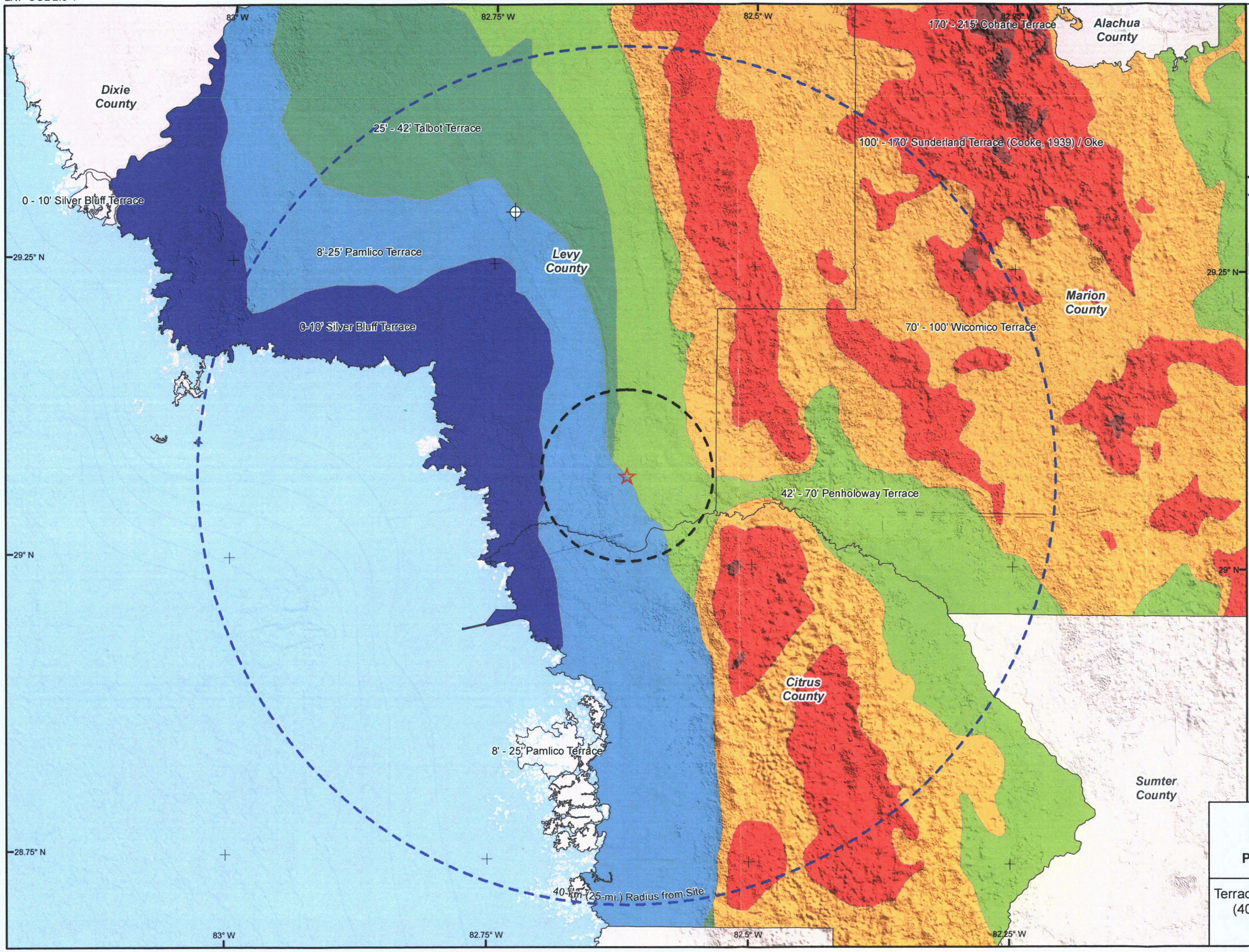
Levy Nuclear Plant Units 1 and 2 Part 2, Final Safety Analysis Report

Site Vicinity Geologic Map (40-km [25-mi.] and 8-km [5-mi.] Radius)
Figure 2.5.1-244 (Revised)



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LEGEND

- LNP Site
- River Dating Locality (Tilings,2004)
- 8-km (5-mi.) Radius from Site
- 40-km (25-mi.) Radius from Site
- County Boundary (ESRI, 2006)

Terraces and Shorelines
- 0-3 m (0-10 ft.) Silver Bluff Terrace
- 2.5-7.6 m (8-25 ft.) Pamlico Terrace
- 7.6-12.8 m (25-42 ft.) Talbot Terrace
- 12.8-21.3 m (42-70 ft.) Penholoway Terrace
- 21.3-30.4 m (70-100 ft.) Wicomico Terrace
- 30.4-51.8 m (100-170 ft.) Sunderland Terrace
- 51.3-65.5 m (170-215 ft.) Coharie Terrace

Source: Healy (1975)

Sources: Citrus County map from Yon et al. (1988); Levy County map from Lane et al. (1988); Marion County map from Hoenstine et al. (1988)

Base Maps: Topography from USGS NED (1999), and Bathymetry from NOAA Coastal Relief Digital Elevation Model (2007)

0 5 10 15
Kilometers

0 5 10
Miles

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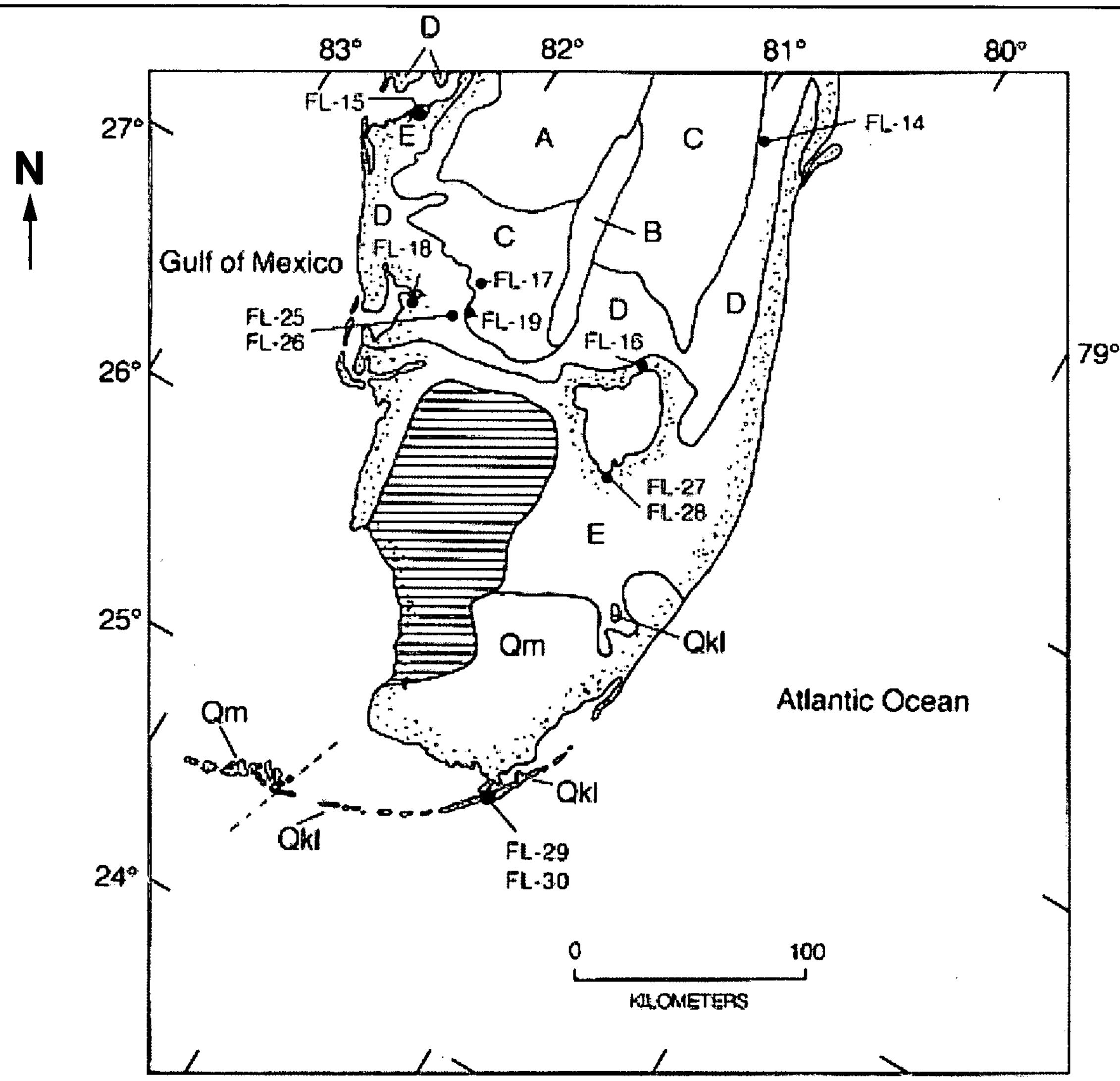
Units 1 and 2
Part 2, Final Safety Analysis Report

Terraces and Shorelines within the Site Vicinity (40-km [25-mi.] and 8-km [5-mi.] Radius)

Figure 2.5.1-235 (Revised)

Attachment 02.05.01-29B



LEGEND

E Late Pleistocene marine deposits, undifferentiated, includes Anastasia and Fort Thompson Formations

Qm Miami colite

QKL Key Largo limestone

Thin freshwater limestone and swamp muck

D Middle Pleistocene marine deposits

C Early Pleistocene to latest Pliocene marine deposit; includes Caloosahatchee marl

B Younger late Pliocene marine deposits, undifferentiated

A Older late Pliocene marine deposits, undifferentiated

Source: Muhs et. al (1992)

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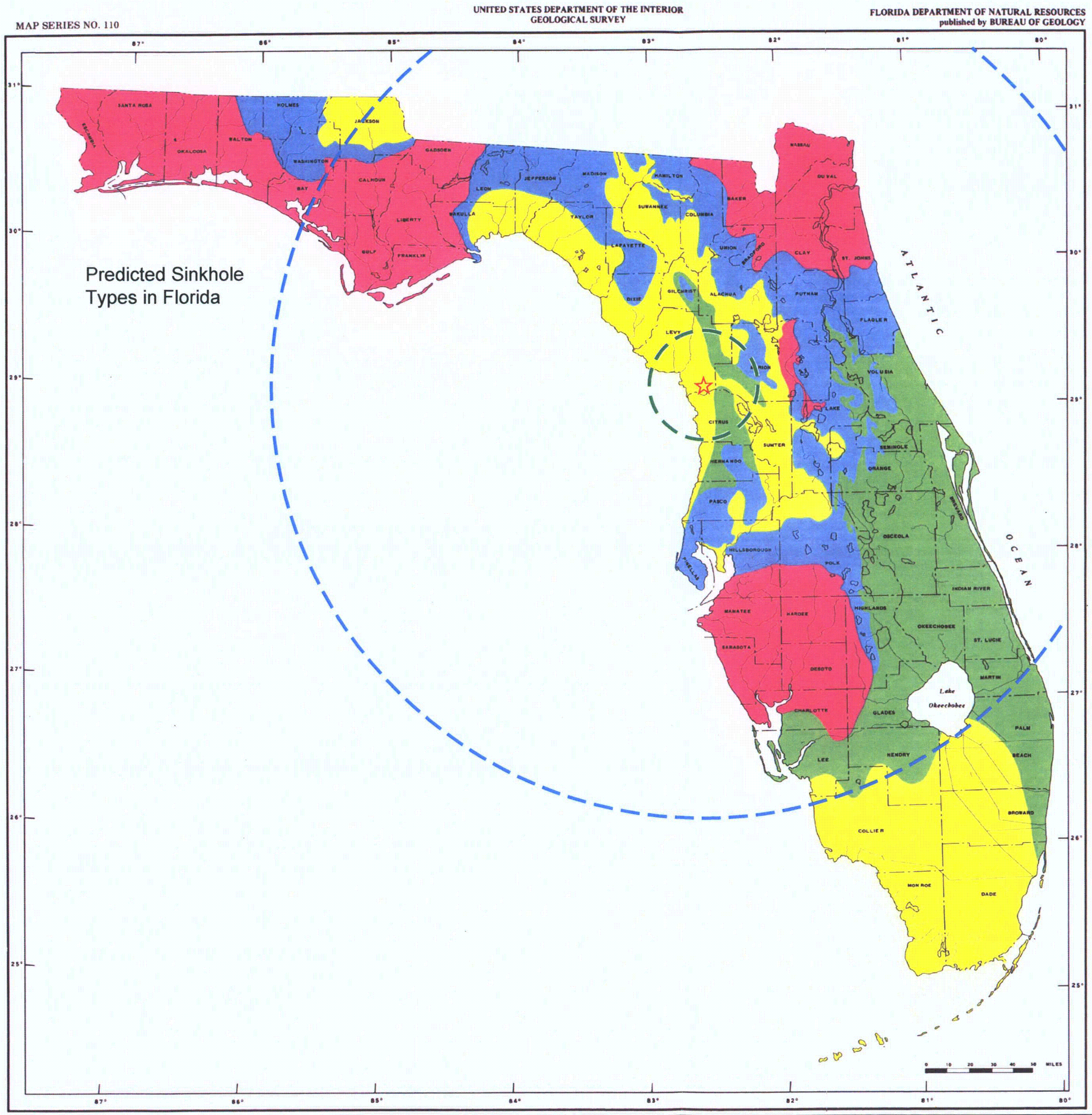
Map Showing Pleistocene and Pliocene Deposits in Southern Florida

RAI 02.05.01-29 Figure 01



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LEGEND

☆ LNP Site

320-km (200-mi) Radius from Site

40-km (25-mi) Radius from Site

AREA I. BARE OR THINLY COVERED LIMESTONE
Sinkholes are few, generally shallow and broad, and develop gradually. Solution sinkholes dominate.

AREA II. COVER IS 30 TO 200 FEET THICK
Consists mainly of incohesive and permeable sand. Sinkhole are few, shallow, of small diameter, and develop gradually. Cover-subsidence sinkholes dominate.

AREA III. COVER IS 30 TO 200 FEET THICK
Consists mainly of cohesive clayey sediments of low permeability. Sinkholes are most numerous, of varying size, and develop abruptly. Cover-collapse sinkholes dominate.

AREA IV. COVER IS MORE THAN 200 FEET THICK
Consists of cohesive sediments interlayered with discontinuous carbonate beds. Sinkholes are very few, but several large diameter, deep sinkholes occur. Cover-collapse sinkholes dominate.

Source: Upchurch and Randazzo (1997), modified from Sinclair and Stewart (1985, FGS Map Series 110)

0 50 100 150
Kilometers

0 50 100
Miles

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Part 2, Final Safety Analysis Report

Sinkhole Types and
a Sinkhole Risk Map
Figure 2.5.1-237 (Revised)

Attachment 02.05.01-30B

-----Original Message-----
From: Sam Upchurch [mailto:SUpchurch@sdii-global.com]
Sent: Wednesday, June 03, 2009 11:08 AM
To: Thomas Scott
Subject: Figure 13.15, Environmental Geology of Florida

Dear Tom:

This email is to inform you of the status of Figure 13.15 in Chapter 13, The Environmental Geology of Florida by Upchurch and Randazzo (Randazzo and Smith (eds.), 1997. The Geology of Florida, University Presses of Florida).

Figure 13.14 is legitimate and was published by Sinclair and Stewart in 1985. It should be used as a general indication of the types of sinkholes that develop in Florida; not as a predictor of the types or frequencies of sinkholes.

Figure 13.15 is not a map of sinkhole possibilities and has an unknown provenance. It was not published by Sinclair and Stewart in their 1985 report. I have spent a considerable amount of time looking for this map, with no success. When the book went to press I was out of the country and asked Dr. Randazzo to complete the chapter for me. That is how he became junior author. Figure 13.15 was supposed to be a map showing sinkhole risk in Hillsborough County, Florida (the first page of this reference is attached) by Littlefield and me. Randazzo substituted the Figure 13.15 and has not been able to provide me with an adequate source. Therefore, I would not rely on Figure 13.15 at all.

SDII maintains the largest sinkhole database in the state. It includes the state's data base (FGS + Florida Sinkhole Research Center data), the results of over 8,000 sinkhole investigations by SDII, and a large number of sinkhole incidence reports provided by SDII's client insurance companies. While the Gulf Hammock area is sparsely populated, the database shows only one, questionable sinkhole occurrence on US19 north of Otter Creek. Otherwise, there is no indication of modern (1985 - 2009) sinkhole development in the Gulf Hammock area. The area has one of the lowest sinkhole risks in the Florida peninsula.

As an "expert" on the karst of the Avon Park outcrop area because of SDII's analysis of the karst in the Waccasassa River MFL document, I can state that Figure 13.15 is apparently incorrect with respect to the Avon Park exposure area at Gulf Hammock. It is certainly incorrect in suggesting that the area is at the highest or next highest sinkhole risk in the state. That rating might be appropriate for the Ocala Limestone areas further inland, but not in the Gulf Hammock area.

<<pdf-preview.png>>

Sam B. Upchurch, Ph.D., P.G.
Vice President and Principal Geologist
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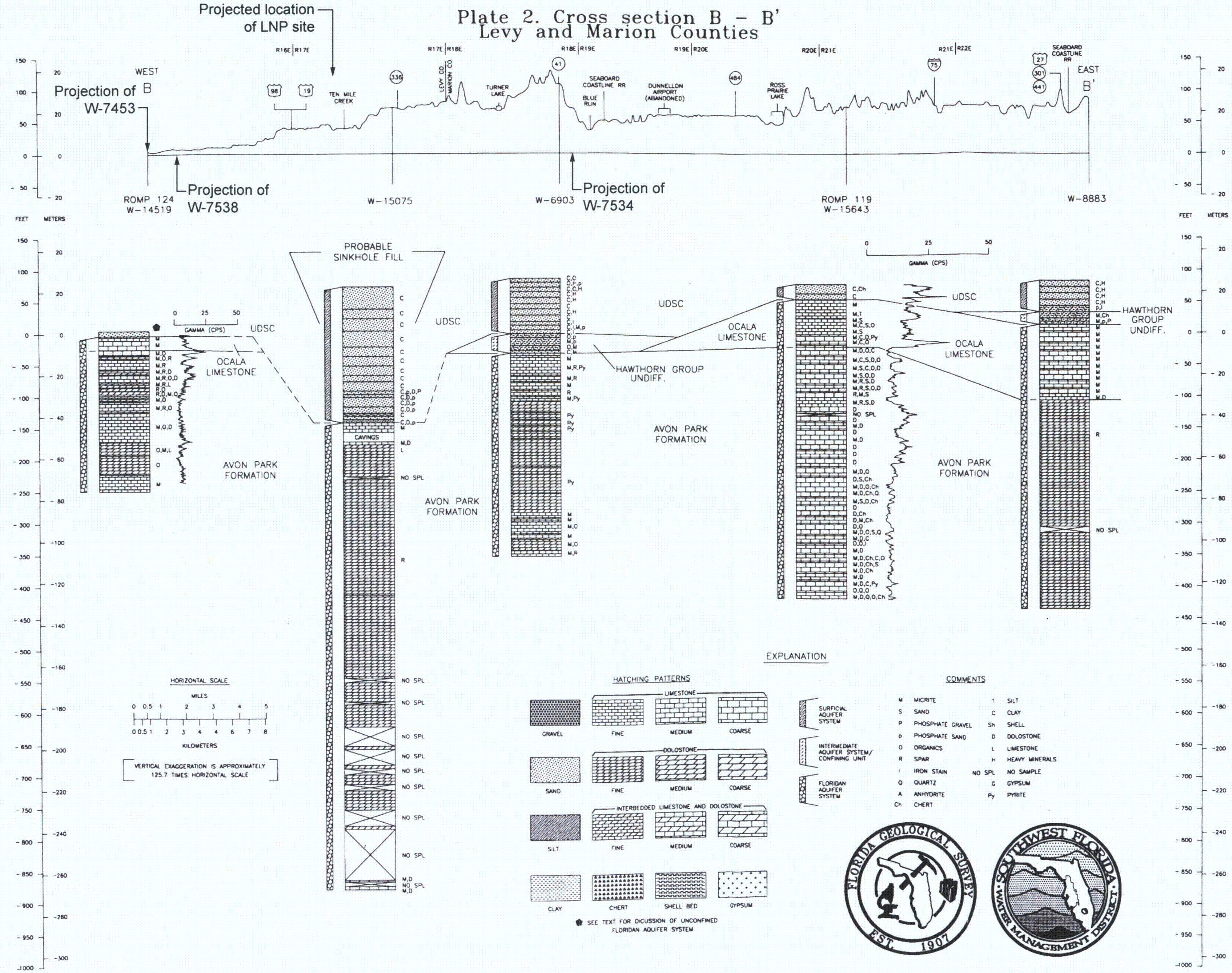
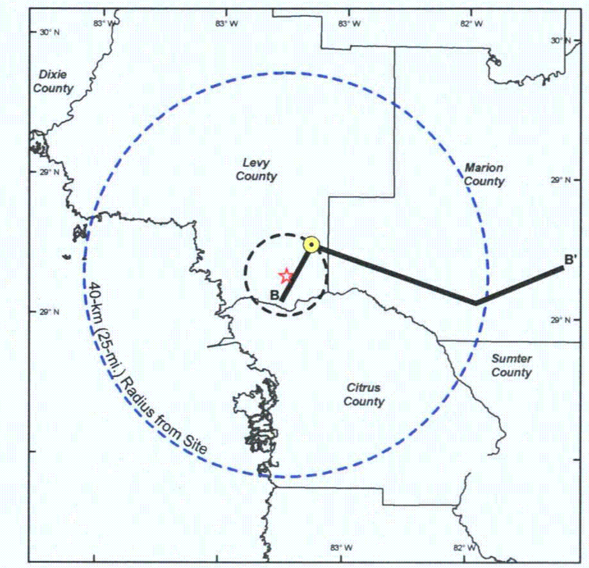
Tampa, Florida 33634
Office: 813-496-9634
Fax: 813-496-9664





LEGEND

- LNP site
- 8-km (5-mi.) Radius from Site
- 40-km (25-mi.) Radius from Site
- W-15075 Lithologic Log Location
- Geologic Cross Section

Source: Arthur et al. (2001)

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Units 1 and 2
Part 2, Final Safety Analysis Report

Geologic Cross Section through the Site Vicinity

Figure 2.5.1-245 (Revised)