Progress Energy

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December 26, 2008

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

SHEARON HARRIS NUCLEAR POWER PLANT, UNITS 2 AND 3
DOCKET NOS. 52-022 AND 52-023
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 030 RELATED TO BASIC GEOLOGIC AND SEISMIC INFORMATION

Reference: Letter from Manny Comar (NRC) to James Scarola (PEC), dated October 14, 2008, "Request for Additional Information Letter No. 030 Related to SRP Section 02.05.01 for the Harris Units 2 and 3 Combined License Application"

Ladies and Gentlemen:

Progress Energy Carolinas, Inc. (PEC) 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 provided in Enclosure 1. Additional submittals are planned by December 30, 2008 and January 8, 2009 to provide the remaining responses. See page 1 of Enclosure 1 for details. Enclosure 1 also identifies changes that will be made in a future revision of the Shearon Harris Nuclear Power Plant Units 2 and 3 (HAR) application.

Enclosure 2 provides a list of files included on the attached CD. The files have been prepared in accordance with NRC electronic submittal guidance. A pre-flight report is included as Enclosure 3.

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 December 26, 2008.

Sincerely,

Garry D. Miller
General Manager
Nuclear Plant Development

Enclosures/Attachments

Progress Energy Carolinas, Inc.
P.O. Box 1551
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D084
NRO

cc (w/2 of attached CD): Mr. Manny Comar, U.S. NRC Project Manager

cc (w/o attached CD): U.S. NRC Director, Office of New Reactors/NRLPO
U.S. NRC Office of Nuclear Reactor Regulation/NRLPO
U.S. NRC Region II, Regional Administrator
U.S. NRC Resident Inspector, SHNPP Unit 1

bc (w/o attached CD):

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Shearon Harris Nuclear Power Plant Units 2 and 3
Response to NRC Request for Additional Information Letter No. 030 Related to SRP Section 02.05.01 for the Combined License Application, dated October 14, 2008

NRC RAI #	Progress Energy RAI #	Progress Energy Response
02.05.01-1	H-0138	Response enclosed – see following pages
02.05.01-2	H-0139	Response enclosed – see following pages
02.05.01-3	H-0140	Response enclosed – see following pages
02.05.01-4	H-0141	Response enclosed – see following pages
02.05.01-5	H-0142	Response enclosed – see following pages
02.05.01-6	H-0143	Response enclosed – see following pages
02.05.01-7	H-0144	Response enclosed – see following pages
02.05.01-8	H-0145	Response enclosed – see following pages
02.05.01-9	H-0146	Future submittal – expected by 12/30/08
02.05.01-10	H-0147	Future submittal – expected by 1/8/09
02.05.01-11	H-0148	Future submittal – expected by 1/8/09
02.05.01-12	H-0149	Future submittal – expected by 1/8/09
02.05.01-13	H-0150	Response enclosed – see following pages
02.05.01-14	H-0151	Response enclosed – see following pages
02.05.01-15	H-0152	Future submittal – expected by 12/30/08
02.05.01-16	H-0153	Future submittal – expected by 1/8/09
02.05.01-17	H-0154	Future submittal – expected by 12/30/08
02.05.01-18	H-0155	Future submittal – expected by 12/30/08
02.05.01-19	H-0156	Future submittal – expected by 12/30/08
02.05.01-20	H-0157	Response enclosed – see following pages
02.05.01-21	H-0158	Response enclosed – see following pages
02.05.01-22	H-0159	Response enclosed – see following pages
02.05.01-23	H-0160	Response enclosed – see following pages
02.05.01-24	H-0161	Response enclosed – see following pages
02.05.01-25	H-0162	Response enclosed – see following pages
02.05.01-26	H-0163	Response enclosed – see following pages
02.05.01-27	H-0164	Response enclosed – see following pages
02.05.01-28	H-0165	Response enclosed – see following pages
02.05.01-29	H-0166	Response enclosed – see following pages
02.05.01-30	H-0167	Response enclosed – see following pages
02.05.01-31	H-0168	Response enclosed – see following pages

Attachments	Associated NRC RAI #	Attachment on CD
Figure 2.5.1-202 (Revised)	02.05.01-1	Attachment 02.05.01-01A
Figure 2.5.1-213 (Revised)	02.05.01-1,6,7,8	Attachment 02.05.01-01B
RAI 02.05.01-02 Figure 1	02.05.01-2	Attachment 02.05.01-02A
RAI 02.05.01-02 Figure 2	02.05.01-2	Attachment 02.05.01-02B
Figure 2.5.1-206 (Revised)	02.05.01-2	Attachment 02.05.01-02C
RAI 02.05.01-03 Figure 1	02.05.01-3	Attachment 02.05.01-03A
RAI 02.05.01-03 Figure 2	02.05.01-3	Attachment 02.05.01-03B
RAI 02.05.01-03 Figure 3	02.05.01-3,7,8	Attachment 02.05.01-03C
Figure 2.5.1-210 (Revised)	02.05.01-3	Attachment 02.05.01-03D
Figure 2.5.1-211 (Revised)	02.05.01-3,4,6,7	Attachment 02.05.01-03E
RAI 02.05.01-03 Figure 4	02.05.01-3,5	Attachment 02.05.01-03F
RAI 02.05.01-05 Figure 1	02.05.01-3,5	Attachment 02.05.01-05A
RAI 02.05.01-05 Figure 2	02.05.01-3,5	Attachment 02.05.01-05B
RAI 02.05.01-05 Figure 3	02.05.01-3,5	Attachment 02.05.01-05C
Figure 2.5.1-216 (Sh. 1&2) (Revised)	02.05.01-8	Attachment 02.05.01-08A
Figure 2.5.1-229 (Revised)	02.05.01-8	Attachment 02.05.01-08B
RAI 02.05.01-08 Figure 1	02.05.01-8	Attachment 02.05.01-08C
Figure 2.5.1-230 (Sh. 1 of 2) (Revised)	02.05.01-8,20,23,28	Attachment 02.05.01-08D
Preliminary Bedrock Geologic Map	02.05.01-13,24	Attachment 02.05.01-13A
Figure 2.5.1-219 (revised)	02.05.01-14	Attachment 02.05.01-14A
RAI 02.05.01-14 Figure 1	02.05.01-14	Attachment 02.05.01-14B
Figure 2.5.1-231 (Revised)	02.05.01-20,23,28	Attachment 02.05.01-20A
RAI 02.05.01-26 Figure 1	02.05.01-20,26	Attachment 02.05.01-20B
RAI 02.05.01-20 Figure 1	02.05.01-20	Attachment 02.05.01-20C1
RAI 02.05.01-20 Figure 2	02.05.01-20	Attachment 02.05.01-20C2
RAI 02.05.01-20 Figure 3	02.05.01-20	Attachment 02.05.01-20C3
RAI 02.05.01-20 Figure 4	02.05.01-20	Attachment 02.05.01-20C4
RAI 02.05.01-20 Figure 5	02.05.01-20	Attachment 02.05.01-20C5
RAI 02.05.01-20 Figure 6	02.05.01-20	Attachment 02.05.01-20C6
RAI 02.05.01-20 Figure 7	02.05.01-20	Attachment 02.05.01-20C7
RAI 02.05.01-20 Figure 8	02.05.01-20	Attachment 02.05.01-20C8
RAI 02.05.01-20 Figure 9	02.05.01-20	Attachment 02.05.01-20D1
RAI 02.05.01-20 Figure 10	02.05.01-20	Attachment 02.05.01-20D2
Figure 2.5.1-236 (Revised)	02.05.01-20	Attachment 02.05.01-20E
Figure 2.5.1-232 (Revised)	02.05.01-20	Attachment 02.05.01-20F
Figure 2.5.1-241 (Revised)	02.05.01-20,29,30	Attachment 02.05.01-20G

Attachments	Associated NRC RAI #	Attachment on CD
RAI 02.05.01-21 Figure 1	02.05.01-21	Attachment 02.05.01-21A
Figure 2.5.1-237, Sheet 1 (Revised)	02.05.01-21	Attachment 02.05.01-21B1
RAI 02.05.01-21 Figure 2	02.05.01-21	Attachment 02.05.01-21B2
RAI 02.05.01-23 Figure 1	02.05.01-23	Attachment 02.05.01-23A1
RAI 02.05.01-23 Figure 2	02.05.01-23	Attachment 02.05.01-23A2
RAI 02.05.01-23 Figure 3	02.05.01-23	Attachment 02.05.01-23A3
RAI 02.05.01-23 Figure 4	02.05.01-23	Attachment 02.05.01-23A4
RAI 02.05.01-23 Figure 5	02.05.01-23	Attachment 02.05.01-23A5
FSAR Section 2.5.3 Draft 11-2-08	02.05.01-23	Attachment 02.05.01-23B
Geomatrix Field Documentation	02.05.01-24	Attachment 02.05.01-24A
RAI 02.05.01-25 Figure 1	02.05.01-25	Attachment 02.05.01-25A
RAI 02.05.01-25 Figure 2	02.05.01-25	Attachment 02.05.01-25B
RAI 02.05.01-25 Figure 3	02.05.01-25	Attachment 02.05.01-25C
RAI 02.05.01-25 Figure 4	02.05.01-25	Attachment 02.05.01-25D
Figure 2.5.3-206 (Revised)	02.05.01-27,29	Attachment 02.05.01-27A
Figure 2.5.3-207 (Revised)	02.05.01-27	Attachment 02.05.01-27B
Email from Tyler Clark	02.05.01-28	Attachment 02.05.01-28A
Figure 2.5.3-203 (Revised)	02.05.01-29,30	Attachment 02.05.01-29A

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-1

Text of NRC RAI:

FSAR Section 2.5.1.1.1 provides a discussion with figures about the regional geology around the Shearon Harris Nuclear Power Plants Units 2 and 3. (HAR)

a) Figure 2.5.1-202 (p. 2.5-13) illustrates the rift basins in the region. The figure does not have labeling to indicate where the Deep River basin lies with respect to other basins that are labeled on the figure. In order for the staff to follow the discussion in text please provide additional labels to the figure.

b) FSAR Section 2.5.1.1.1.5 (p. 2.5-16) states: "Near the transition between the embayed and Sea Island sections, the emerged Coastal Plain has been tectonically active during the Cretaceous and Cenozoic ages. This is observed at the surface with the expression of the structural Cape Fear Arch." The text has introduced a young tectonically active structure in the region that may impact issues of fault capability but does not provide enough detail for the staff to evaluate. Please provide further explanation about the limits of timing on this feature and include a map or illustration.

PGN RAI ID #: H-0138

PGN Response to NRC RAI:

a) Figure 2.5.1-202 will be modified in a future revision to only show the Deep River Basin. Additionally, the text states that "The Deep River basin is subdivided into three smaller basins named, from north to south, the Durham, Sanford, and Wadesboro basins" (p. 2.5-1 and 2.5-13). The sub-basins will be clearly shown on the revised Figure 2.5.1-202 Attachment 02.05.01-01A.

b) Section 2.5.1.1.1.5 discusses physiography and topography of the Coastal Plain. The basin and arch architecture of the U.S. Atlantic margin, likely reflects strain associated with the application and removal of vertical loads in the form of denuded landscapes, sedimentary basin deposition, or ice, that manifest as flexural isostatic responses; this broad regional deformation is considered nontectonic in that it is not localized specifically on preexisting faults (Reference 2.5.1-267). The text in Section 2.5.1.1.1.5 will be modified to indicate that the deformation is due to regional warping. A more detailed discussion of the Cape Fear Arch and Neuse hinge will be added to Section 2.5.1.1.4.2.4 (Cenozoic Tectonic Structures). The locations of the Cape Fear Arch and Neuse hinge are shown on Figure 2.5.1-213 (Attachment 02.05.01-01B) which will be updated in a future revision. The embayed/sea island sections are shown on Figure 2.5.1-201.

Associated HAR COL Application Revisions:

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

1. Revise the last paragraph of FSAR Section 2.5.1.1.1.5 from:

Because there are significant differences in both geology and topography within the Coastal Plain province, it has been divided into six sections (Reference 2.5.1-206). The two sections that lie within a 320-km (200-mi.) radius of the HAR site are the embayed section on the north and the Sea Island section on the south. In the embayed section, estuarine embayments divide the Coastal Plain into broad peninsular tracts. The Sea Island section is characterized by youthful to mature terraced coastal plain. The Sea Island section shows less marked drowning of valleys than does the embayed section, and its terraces do not reach back to the inner border of the section. Near the transition between the embayed and Sea Island sections, the emerged Coastal Plain has been tectonically active during the Cretaceous and Cenozoic ages, with uplift centered on the Cape Fear arch. (Reference 2.5.1-209)

To read:

Because there are significant differences in both geology and topography within the Coastal Plain province, it has been divided into six sections (Reference 2.5.1-206). The two sections that lie within a 320-km (200-mi.) radius of the HAR site are the embayed section on the north and the Sea Island section on the south. In the embayed section, estuarine embayments divide the Coastal Plain into broad peninsular tracts. The Sea Island section is characterized by youthful to mature terraced coastal plain. The Sea Island section shows less marked drowning of valleys than does the embayed section, and its terraces do not reach back to the inner border of the section. (Reference 2.5.1-209) The transition between the embayed and Sea Island sections, which is generally coincident with the northern flank of the Cape Fear arch, is typical of the basin and arch architecture of the U.S. Atlantic margin where broad regional flexural warping in response to isostatic loading and unloading of the emerged Coastal Plain is evidenced by depositional patterns during the Cretaceous and Cenozoic. (Reference 2.5.1-267).

2. Revise the first paragraph of FSAR Section 2.5.1.1.4.2.4 from:

"Regional studies have identified broad areas of uplift and subsidence that have influenced Cenozoic sedimentation, providing evidence of regional tectonism (Reference 2.5.1-242, Reference 2.5.1-255). The uplift, tilting, and subsidence were manifested as arches, embayments, and troughs, which then were modified further by sediment loading (Reference 2.5.1-242). The most significant example of regional Cenozoic tectonism in the Carolinas is the Cape Fear arch, a feature along the North Carolina-South Carolina border that has affected the thickness and distribution of strata ranging in age from Late Cretaceous to late Tertiary (Reference 2.5.1-242). North of this feature the North Carolina Coastal Plain consists of two blocks, the Onslow block and, farther north, the Albermarle block, which are separated by the northwest-southeast-trending Neuse hinge, a tectonic feature that also has persisted since the Mesozoic (Reference 2.5.1-255). This tectonic feature has affected the spatial distribution of Paleogene and perhaps Neogene sediments (Reference 2.5.1-255)."

To read:

"<u>Arches and Embayments.</u> Regional studies have identified broad areas of uplift and subsidence that have influenced Cenozoic sedimentation. (Reference 2.5.1-242, Reference 2.5.1-255). The uplift, tilting, and subsidence were manifested as arches, embayments, and troughs, which then were modified further by sediment loading

(Reference 2.5.1-242). The basin and arch architecture of the U.S. Atlantic margin, likely reflects strain associated with the application and removal of vertical loads in the form of denuded landscapes, sedimentary basin deposition, or ice, that manifest as flexural isostatic responses; this broad regional deformation is considered nontectonic in that it is not localized specifically on preexisting faults (Reference 2.5.1-267). In the Carolinas the Cape Fear arch, a southeast-dipping basement high is a prominent feature along the North Carolina-South Carolina border (Figure 2.5.1-213) that has affected the thickness and distribution of strata ranging in age from Late Cretaceous to late Tertiary (Reference 2.5.1-242). Regional uplift on the arch has caused Cretaceous sediments to thin on the axis and sediments to thicken on the flanks. This is evident in the geomorphic differences between the Cape Fear River valley and the adjacent Pee Dee River to the south. (Reference 2.5.1-209). The Pee Dee river valley lies far down the southern limb of the Cape Fear Arch, and is dominated by finer sediment. Sustained uplift related to the Cape Fear Arch to the north-northeast of the Cape Fear river valley has forced the river to migrate southward over time. Five river terraces, ranging in age from 2.75 to 0.1 Ma, are present on the northeast side of the Cape Fear River. The terraces are preserved only on the northeast side of the river because the river is eroding its southwest bank. (Reference 2.5.1-266) From analysis of longitudinal terrace profiles in the Cape Fear River valley, it is estimated that localized uplift rates on the Cape Fear arch since the late Pliocene have ranged from 0.06 to perhaps as much as 6 m/100,000 years, while a more regional uplift associated with the arch or Coastal Plain in general has been at a rate of approximately 0.6m/100,000 years (Reference 2.5.1-209). Based on biostratigraphic data from marine deposits associated with the Cape Fear Arch, vertical crustal movements were compared with eustataic sea level changes, suggesting net post-Miocene vertical uplift rates in the outer Coastal Plain of the Carolinas of 1 to 3 cm/ 1000 years. Holocene tectonic movement of the arch has been implied by leveling and survey data (Reference 2.5.1-266). Crone and Wheeler (Reference 2.5.1-258) classify the Cape Fear Arch as a Class C feature, based on lack of evidence for Quaternary faulting.

North of the Cape Fear Arch, the North Carolina Coastal Plain consists of two blocks, the Onslow block and, farther north, the Albermarle block, which are separated by the northwest-southeast-trending Neuse hinge (Figure 2.5.1-213), a basement flexure zone which borders the southern part of the Graingers basin and has persisted since the Mesozoic (Reference 2.5.1-255). The Neuse hinge separates the Onslow block to the south and Albemarle block to the north, delineating the boundary between two crustal blocks that have behaved differently throughout the Mesozoic and Cenozoic, and have at times uplifted or subsided relative to each other. At the present time, the Albemarle block is down relative to the Onslow block, creating the Albemarle embayment. (Reference 2.5.1-255) The Neuse hinge has affected the spatial distribution of Paleogene and perhaps Neogene sediments (Reference 2.5.1-255)." The Neuse hinge is not included as a Quaternary structure by Crone and Wheeler or Wheeler (References 2.5.1-258 and 2.5.1-259)."

Attachments/Enclosures:

Attachment 02.05.01-01A: Figure 2.5.1-202 (Revised)

Attachment 02.05.01-01B: Figure 2.5.1-213 (Revised)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-2

Text of NRC RAI:

FSAR Section 2.5.1.1.2. provides a discussion about the geologic history of the region with respect to opening and closing of oceans and multiple episodes of metamorphism and accretion of exotic terranes.

a) There are only 2 figures that are map views only and no cross-sections illustrating the geologic history and regional evolution of structures in the region. A sequence of conceptual cross-sections is needed to help illustrate the complex history of opening and closing tectonic systems.

b) A large portion of this section is heavily based on Faill 1997a, 1997b and 1998. However, Faill's work is focused on the North Central Appalachian Orogen and does not specifically address tectonic evolution of the southern Appalachians. Please provide discussion on the geologic history and references specific to the Southern Appalachians.

c) Discussion in the texts repeatedly cites Figure 2.5.1-203 and 2.5.1-204. The figures do not correspond with each other with respect to labels used on each map. Please add terrane names from the map view to the column view so that NRC staff can connect the features in space and time, such as Carolina Magmatic arc and Laurentian rift and drift cover.

d) FSAR Section 2.5.1.1.2.2 cites Figure 2.5.1-206. The 5 cross-sections sections are not located on the map views of the same figure. Illustrate how the 5 x-sections on this figure fall out onto the 3 map views on the same figure.

PGN RAI ID #: H-0139

PGN Response to NRC RAI:

a) A figure showing the tectonic evolution of the Southern and Central Appalachian Orogen from Hatcher (1989) (RAI 02.05.01-02 Figure 1) (Attachment 02.05.01-02A) will be added to the FSAR in a future revision.

b) The discussion will be expanded in a future revision to include information specific to the southern Appalachians based on Horton et al. (Reference RAI 02.05.01-02 01), Horton and Zullo (Reference RAI 02.05.01-02 02), and White (Reference RAI 02.05.01-02 03).

c) FSAR Figure 2.5.1-203 will be deleted and replaced with a figure from Hatcher (RAI 02.05.01-02 Figure 2) (Attachment 02.05.01-02B) that is applicable to the entire Appalachians, not only to the central Appalachians. Text will be added to clarify the relationship of the age and timing of deformation recorded by the lithotectonic terranes in the region and a figure will be added to illustrate the tectonic evolution of the Southern and Central Appalachian Orogen (RAI 02.05.01-02 Figure 1) (Attachment 02.05.01-02A) to help clarify the timing of events in the site region.

d) FSAR Figure 2.5.1-206 is taken directly from Withjack et al. (Reference 2.5.1-219). The general locations of the cross sections are explained in the figure caption as either going from Southeastern Canada to Morocco (X-X') or from Southeastern United States to Mauritania (Y-Y'). Approximate locations of the cross sections and links to the stages of development (b and c map insets) will be added to revised Figure 2.5.1-206 for clarification in a future revision.

Associated HAR COL Application Revisions:

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

1. Revise FSAR Section 2.5.1.1.2.1 from:

"In the Mesoproterozoic, several continental masses, including the proto-North American (Laurentia) and proto-African continents, were assembled into a supercontinent (Rodinia) as a result of the Grenville orogeny (Reference 2.5.1-212). Grenvillian crystalline rocks are found as basement underlying most of the Appalachians (Reference 2.5.1-215). These billion-year-old rocks crop out in northeast-southwest-trending bands in north-central North Carolina (in the Raleigh belt, described in Subsection 2.5.1.1.3) and in Virginia, where the rocks are referred to as the Goochland terrane (Reference 2.5.1-211, Reference 2.5.1-217). Crustal extension and rifting began in the Proterozoic and continued into the Paleozoic (earliest Cambrian), separating the North American and African continents and forming the intervening proto-Atlantic Ocean (the Iapetus, Theic, and Rheic oceans) (Reference 2.5.1-212). During rifting, the newly formed passive continental margin began to subside and accumulate siliclastic sediments, which subsequently were overlain by a thick and wide carbonate shelf (Reference 2.5.1-212). Nearly 3 km (10,000 ft.) of sediments accumulated on the shallow platform edge as the North American continent drifted in tropical seas throughout approximately 30 million years during the early Cambrian (Reference 2.5.1-211).

The subsequent closing of the proto-Atlantic to form a late Paleozoic supercontinent (Pangea) occurred during a period of about 250 million years (Reference 2.5.1-212). As the ocean was closing, numerous microcontinents and oceanic terranes formed and were accreted as exotic or suspect terranes onto the eastern margin of North America; these recently have been recognized throughout the present Appalachian region. Differences in lithostratigraphy and deformational history, as well as fossils such as Cambrian trilobite faunas, have been used to identify some terranes as probably having originated in Europe or Africa before being accreted to North America (Reference 2.5.1-216). The amalgamation of these terranes to North America, combined with the final collision of North America with the West African continent, created the Appalachian orogen. Four or more major collisions, resulting in widely recognized orogenic events (e.g., the Potomac, Taconic, Acadian, and Alleghany orogenies shown on Figure 2.5.1-203, or the equivalent Penobscottian, Taconic, Acadian, and Alleghanian orogenies of Hatcher,[1] have been interpreted from the Paleozoic record (Reference 2.5.1-207). Orogenic episodes, however, appear to have occurred nearly continuously throughout the Paleozoic in various parts of the Appalachian orogen. (Reference 2.5.1-212)

At the beginning of the convergent phase in the early Paleozoic, the Potomac orogeny occurred offshore of the future central Appalachians when magmatic arcs converged toward

[1]. Different authors use different spellings for similar terms (e.g., the Carolinia or Carolina terrane and the Allegheny or Alleghanian orogeny). In this document the terminology established by the author whose work is being described is followed.

and accreted onto microcontinents a considerable distance away from the margin of North America (Reference 2.5.1-212). During this time, the microcontinent Carolinia was being formed as a magmatic arc above a subduction zone (Reference 2.5.1-211). About 600 million years before present (Ma), the Virgilina orogeny began, folding and faulting the older volcanic sequence during the next 50 million years (m.y.), as the ocean between Carolinia and North America began to close. Collision of Carolinia with North America occurred during the Middle Cambrian to Middle Ordivician (between about 520 and 490 Ma) (Reference 2.5.1-211). The margin of North America was deformed and metamorphosed by this collision, then cooled during subsequent thrust-driven uplift over the Piedmont and Blue Ridge areas (at about 480 Ma) (Reference 2.5.1-211). Figure 2.5.1-204 shows the current location of the Carolinia (magmatic arc) terrane with respect to the site. This figure also shows the large uplift of the 1-billion-year-old Grenville basement and the early Taconic (Cambrian to Late Ordivician) suture that separates the Carolinia terrane from the Laurentian (proto-North American continent) passive margin (Reference 2.5.1-211).

The Taconic orogeny is represented by the first accretion of assembled terranes onto the North American continental margin from the Middle to Late Ordovician. This orogeny, which extended from Newfoundland to Alabama, profoundly affected the tectonic framework of the existing carbonate shelf, creating a Taconic mountain system of unknown dimension on the east and a vast intracontinental basin, the Appalachian basin, on the west. The newly uplifted Taconic highland on the east created a regional drainage having a dominant northwestward flow that transported erosional debris (clastic sediments) into the basin during the Early Silurian. (Reference 2.5.1-212) As the siliciclastic input from the southeast waned, carbonate deposition was dominant in most of the north-central region of the basin into the Early Devonian (Reference 2.5.1-213).

In the Early to Middle Devonian, the Acadian orogeny began, and siliciclastic materials were re-introduced into the eastern part of the Appalachian basin (Reference 2.5.1-213). The Acadian orogeny is most clearly recorded in the northern Appalachians, where deformed and metamorphosed sedimentary and volcanic rocks, a clastic delta wedge, and abundant plutons provide evidence of this event. Evidence for the extent of the orogeny in the central and southern Appalachians is provided primarily by Acadian plutons and discontinuous local zones of medium- to high-grade metamorphism. (Reference 2.5.1-218)

The convergence of North America and Africa and their subsequent suturing during a continent-to-continent collision produced the Alleghany orogeny during the Late Carboniferous and earliest Permian. This, the last major compressive tectonism to affect the Appalachian orogen, affected a larger area of the presently exposed central and southern Appalachians than any previous Paleozoic tectonic event. (Reference 2.5.1-212) The Alleghany orogeny in the central and southern Appalachians involved a very low-angle thrust (décollement) that originated in the mid-crust east of the presently exposed Appalachians, then rose toward the west to progressively higher levels in the upper crust. The youngest (and thus best-preserved) manifestations of the Alleghany orogeny are northeast-southwest-trending strike-slip faults and dextral shear zones in the Piedmont region. Metamorphism and magmatism were significant events during the earlier phase of the Alleghany orogeny in the southern Appalachians. (Reference 2.5.1-214)

The Alleghanian orogeny produced the classic Appalachian folds and faults of the southern and central Appalachians (Reference 2.5.1-218). During this orogeny, the southern and central Appalachians were transported westward toward the North American craton in the form of a huge composite crystalline thrust sheet called the Blue Ridge – Piedmont thrust sheet (Reference 2.5.1-210). Evidence for a master detachment beneath the Blue Ridge and Piedmont regions is derived from both geophysical and structural data

(Reference 2.5.1-218). Alleghanian deformation and uplift produced a thick, clastic sedimentary sequence of conglomerates, sandstones, shales, and marls that were deposited following erosion of the mountain ranges uplifted during the orogen. These deposits, which constitute a molasse, are found today from Alabama to Pennsylvania. (Reference 2.5.1-218) Zones within the site region where metamorphism and ductile deformation associated with Paleozoic orogenic events have been recognized are shown on Figure 2.5.1-205."

To read:

"In the Mesoproterozoic, several continental masses, including the proto-North American (Laurentia) and proto-African continents, were assembled into a supercontinent (Rodinia) as a result of the Grenville orogeny (Reference 2.5.1-212). Grenvillian crystalline rocks are found as basement underlying most of the Appalachians (Reference 2.5.1-215). These billion-year-old rocks crop out in northeast-southwest-trending bands in north-central North Carolina (in the Raleigh belt, described in Subsection 2.5.1.1.3) and in Virginia, where the rocks are referred to as the Goochland terrane (Reference 2.5.1-211; Reference 2.5.1-217). Grenvillian rocks are also exposed as an internal massif in the Sauratown Mountains window (Figure 2.5.1-213; Reference RAI 02.05.01-02 04). Crustal extension and rifting began in the Proterozoic and continued into the Paleozoic (earliest Cambrian), separating the North American and African continents and forming the intervening proto-Atlantic Ocean (the lapetus, Theic, and Rheic oceans) (Reference 2.5.1-212). During rifting, the newly formed passive continental margin began to subside and accumulate siliclastic sediments, which subsequently were overlain by a thick and wide carbonate shelf (Reference 2.5.1-212). Nearly 3 km (10,000 ft.) of sediments accumulated on the shallow platform edge as the North American continent drifted in tropical seas throughout approximately 30 million years during the early Cambrian (Reference 2.5.1-211).

The subsequent closing of the proto-Atlantic to form a late Paleozoic supercontinent (Pangea) occurred during a period of about 250 million years (Reference 2.5.1-212). As the ocean was closing, numerous microcontinents and oceanic terranes formed and were accreted as exotic or suspect terranes onto the eastern margin of North America; these recently have been recognized throughout the present Appalachian region. Differences in lithostratigraphy and deformational history, as well as fossils such as Cambrian trilobite faunas, have been used to identify some terranes as probably having originated in Europe or Africa before being accreted to North America (Reference 2.5.1-216; Reference 2.5.1-249). The amalgamation of these terranes to North America, combined with the final collision of North America with the West African continent, created the Appalachian orogen. Four or more major collisions, resulting in widely recognized orogenic events (e.g., the Potomac, Taconic, Acadian, and Alleghany orogenies shown on RAI 02.05.01-02 Figures 1 and 2, or the equivalent Penobscottian, Taconic, Acadian, and Alleghanian orogenies of Hatcher,[2] have been interpreted from the Paleozoic record (Reference 2.5.1-207 and Reference RAI 02.05.01-02 03). Orogenic episodes, however, appear to have occurred nearly continuously throughout the Paleozoic in various parts of the Appalachian orogen. (Reference 2.5.1-212)

At the beginning of the convergent phase in the early Paleozoic, the Potomac orogeny occurred offshore of the future central Appalachians when magmatic arcs converged toward

[2]. Different authors use different spellings for similar terms (e.g., the Carolinia or Carolina terrane and the Allegheny or Alleghanian orogeny). In this document the terminology established by the author whose work is being described is followed.

and accreted onto microcontinents a considerable distance away from the margin of North America (Reference 2.5.1-212). During this time, the microcontinent Carolinia was being formed as a magmatic arc above a subduction zone (Reference 2.5.1-211). About 600 million years before present (Ma), the Virgilina orogeny began, folding and faulting the older volcanic sequence during the next 50 million years (m.y.), as the ocean between Carolinia and North America began to close. The Penobscottian event, between about 550 and 490 Ma, is the earliest major orogeny recognized in the Appalachian belt and primarily is expressed in the northern Appalachians. Evidence for the Penobscottian orogeny has not been observed south of Virginia, where the orogeny is bracketed in age between Late Cambrian metavolcanic rocks and an Early Ordovician pluton (Reference RAI 02.05.01-02 01).Collision of Carolinia with North America occurred during the Middle Cambrian to Middle Ordivician (between about 520 and 490 Ma) (Reference 2.5.1-211). The margin of North America was deformed and metamorphosed by this collision, then cooled during subsequent thrust-driven uplift over the Piedmont and Blue Ridge areas (at about 480 Ma) (Reference 2.5.1-211). Figure 2.5.1-204 shows the current location of the Carolinia (magmatic arc) terrane with respect to the site. This figure also shows the large uplift of the 1-billion-year-old Grenville basement and the early Taconic (Cambrian to Late Ordovician) suture that separates the Carolinia terrane from the Laurentian (proto-North American continent) passive margin (Reference 2.5.1-211).

The Taconic orogeny is represented by the first accretion of assembled terranes onto the North American continental margin from the Middle to Late Ordovician. This orogeny, which extended from Newfoundland to Alabama, profoundly affected the tectonic framework of the existing carbonate shelf, creating a Taconic mountain system of unknown dimension on the east and a vast intracontinental basin, the Appalachian basin, on the west. The newly uplifted Taconic highland on the east created a regional drainage having a dominant northwestward flow that transported erosional debris (clastic sediments) into the basin during the Early Silurian. (Reference 2.5.1-212) As the siliciclastic input from the southeast waned, carbonate deposition was dominant in most of the north-central region of the basin into the Early Devonian (Reference 2.5.1-213). The onset of the Taconian event is marked regionally throughout much of the Appalachian belt by an unconformity in the passive-margin sequence and deposition of clastic sediments derived from an uplifted source area or areas to the east. Rocks of the eastern Blue Ridge and Inner Piedmont are interpreted to have originated east of the Laurentian passive margin in Middle Ordovician time and, thus, were possibly formed during the Taconic collision(s). (Reference 2.5.1-249)

In the Early to Middle Devonian, the Acadian orogeny began, and siliciclastic materials were re-introduced into the eastern part of the Appalachian basin (Reference 2.5.1-213). The Acadian orogeny is most clearly recorded in the northern Appalachians, where deformed and metamorphosed sedimentary and volcanic rocks, a clastic delta wedge, and abundant plutons provide evidence of this event (Reference 2.5.1-218). Evidence for the extent of the orogeny in the central and southern Appalachians is provided primarily by Acadian plutons, discontinuous local zones of medium- to high-grade metamorphism (Reference 2.5.1-218), unconformities in foreland stratigraphic succession, activity of several major faults, and possibly ductile folding in the southern Appalachians (e.g., Kings Mountain and Gold Hills, and Brevard fault zones) (Reference RAI 02.05.01-02 01).

The convergence of North America and Africa and their subsequent suturing during a continent-to-continent collision produced the Alleghany orogeny during the Late Carboniferous and earliest Permian. This, the last major compressive tectonism to affect the Appalachian orogen, affected a larger area of the presently exposed central and southern Appalachians than any previous Paleozoic tectonic event. (Reference 2.5.1-212)

The Alleghany orogeny in the central and southern Appalachians involved a very low-angle thrust (décollement) that originated in the mid-crust east of the presently exposed Appalachians, then rose toward the west to progressively higher levels in the upper crust. The youngest (and thus best-preserved) manifestations of the Alleghany orogeny are northeast-southwest-trending strike-slip faults and dextral shear zones in the Piedmont region (i.e., the Nutbush Creek and Hollister faults). Metamorphism and magmatism were significant events during the earlier phase of the Alleghany orogeny in the southern Appalachians. (Reference 2.5.1-214)

The Alleghanian orogeny produced the classic Appalachian folds and faults of the southern and central Appalachians (Reference 2.5.1-218). During this orogeny, the southern and central Appalachians were transported westward toward the North American craton in the form of a huge composite crystalline thrust sheet called the Blue Ridge – Piedmont thrust sheet (Reference 2.5.1-210). Evidence for a master detachment beneath the Blue Ridge and Piedmont regions is derived from both geophysical and structural data (Reference 2.5.1-218). Alleghanian deformation and uplift produced a thick, clastic sedimentary sequence of conglomerates, sandstones, shales, and marls that were deposited following erosion of the mountain ranges uplifted during the orogen. These deposits, which constitute a molasse, are found today from Alabama to Pennsylvania. (Reference 2.5.1-218) Zones within the site region where metamorphism and ductile deformation associated with Paleozoic orogenic events have been recognized are shown on Figure 2.5.1-205. Some of the effects of the Alleghanian orogeny in the Carolinas include: numerous granitoid plutons southeast of the Brevard fault zone; amphibolite-facies regional metamorphism and deformation in the Kiokee and Raleigh metamorphic belts of the eastern Piedmont; strike-slip movement, along major faults from the Brevard fault zone southeastward to the eastern Piedmont fault system; westward transport of a composite stack of crystalline thrust sheets which now constitutes the western Piedmont and Blue Ridge. Imbricate thrusting and folding in the Valley and Ridge province. (Reference RAI 02.05.01-02 02)"

References:

Reference RAI 02.05.01-02 01

Horton, J.W., Drake, A.A., and Rankin, D.W., *Tectonostratigraphic Terranes and Their Paleozoic Boundaries in the Central and Southern Appalachians,* Geological Society of America, Special Paper 230:213-245, 1989.

Reference RAI 02.05.01-02 02

Horton, J.W., and Zullo, V.A., "An Introduction to the Geology of the Carolinas," in *The Geology of the Carolinas: Carolina Geological Society Fiftieth Anniversary Volume*, eds. J.W. Horton, Jr., and V.A. Zullo, pp. 1 – 10,1991, University of Tennessee Press, Knoxville, Tennessee.

Reference RAI 02.05.01-02 03

White, T.S., Witzke, B.J., and Ludvingson, G.A., "Evidence for an Albian Hudson Arm Connection Between the Cretaceous Western Interior Seaway of North American and the Labrador Sea," *Bulletin of the Geological Society of America* 112 (9):1,342-1,355, 2000.

Reference RAI 02.05.01-02 04

Horton, J.W., and McConnell, K.I., "The Western Piedmont," in *The Geology of the Carolinas: Carolina Geological Society Fiftieth Anniversary Volume*, eds. J.W. Horton, Jr., and V.A. Zullo, pp. 36 – 58,1991, University of Tennessee Press, Knoxville, Tennessee.

Attachments/Enclosures:

Attachment 02.05.01-02A: RAI 02.05.01-02 Figure 1

Attachment 02.05.01-02B: RAI 02.05.01-02 Figure 2 (Replaces Figure 2.5.1-203)

Attachment 02.05.01-02C: Figure 2.5.1-206 (Revised)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-3

Text of NRC RAI:

FSAR Section 2.5.1.1.3 discusses the complex, regional stratigraphy of the 200 mile regional boundary of the site.

a)The stratigraphic relationships within and between each tectonic regime is not provided, and terrane boundaries are not identified. Rock type is mixed in with rock age and is based on physiographic areas. Please provide a description of the regional stratigraphy by lithotectonic provinces or geologic belts and update the FSAR accordingly. Provide the boundaries for each lithotectonic province (fault systems) and then the internal stratigraphic relationships. Revise FSAR as needed.

b) FSAR Section 2.5.1.1.3.1 is a discussion of the Piedmont. There is no description of the northwestern and southeastern boundary of the Piedmont terrane. Please provide a clear discussion of stratigraphic relationships within the Piedmont litho-tectonic terrane and between other bordering litho-tectonic terranes.

c) The Mesozoic rift basins are discussed in the Piedmont section. Rift basins formed under a different tectonic regime. Please provide a discussion of the litho-tectonic terrane responsible for the development of extended crust and the Mesozoic rift basins and related rock.

d) The FSAR cites Figure 2.5.1-210. The explanation on the figure does not correspond to patterns on map. Please revise the explanation on the figure to match the map.

e) FSAR section 2.5.1.1.3.1.2.4 discusses Coastal Plain sediments in the Piedmont section. Coastal Plain and other Cenozoic rock formed under a completely different tectonic regime than the Piedmont. Please provide a discussion of the Coastal Plain section with boundaries and internal stratigraphic relationships.

PGN RAI ID #: H-0140

PGN Response to NRC RAI:

a) Additional text will be added in a future revision to clarify the distinction between physiographic provinces and provinces defined on the basis of lithotectonic terrane boundaries. Maps showing interpreted lithotectonic terrane boundaries within the site region are shown on Figures RAI 02.05.01-03 Figures 1 and 2. A map showing lithotectonic units within the Appalachian orogen published by Hibbard et al. (Reference RAI 02.05.01-03 01) (RAI 02.05.01-03 Figure 3) will be referenced and added in a future revision to clarify the ages of various rock units in the Appalachian orogen. As outlined in the following revisions, the stratigraphic relationships and terrane boundaries will be added to the discussion of the five provinces within the site region. Text modifications have been made for Sections 2.5.1.1.3.1, 2.5.1.1.3.2, 2.5.1.1.3.3, 2.5.1.1.3.4, and 2.5.1.1.3.5. The boundaries include any fault system juxtaposing the terranes and the stratigraphic change across these boundaries. The first paragraph of each section will be modified to clarify these associations.

b) FSAR Section 2.5.1.1.3.1 text as outlined in the following revision will be modified in a future revision to provide a discussion of the stratigraphic relationship within the Piedmont lithotectonic terrane and bordering terranes.

c) FSAR Section 2.5.1.1.3.1.2 text as provided below will be updated in a future revision to clarify the association of the Mesozoic basin sediments as part of a Triassic-Jurassic rift basin lithotectonic unit. Rift basins formed in a post-Paleozoic extensional tectonic environment related to rifting associated with the opening of the Atlantic. These are included as features superimposed on the significantly broader Piedmont province.

d) Figure 2.5.1-210 has been revised so that the explanation matches the patterns on the map.

e) The Coastal Plain sediments are referred to in FSAR Section 2.5.1.1.3.1.2.4 in order to define the borders of the Piedmont Province. The first two paragraphs of this section will be modified in a future revision to clarify this insertion.

Associated HAR COL Application Revisions:

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

1. Revise the 1st paragraph of FSAR Section 2.5.1.1.3 from:

"The complex stratigraphy and lithology of the HAR site region reflects the long and complex geologic history of this region (described in Subsection 2.5.1.2). The geologic units within a 320-km (200-mi.) radius of the HAR site are shown on Figure 2.5.1-207. A regional stratigraphic column is presented on Figure 2.5.1-208. The geologic units tend to be distributed in northeast-southwest-trending parallel-sided zones throughout the site region. A comparison of Figures 2.5.1-207 and 2.5.1-201, which shows the physiographic provinces of the site region, indicates that the northeast-southwest-trending linear physiographic provinces have similar stratigraphies, reflecting the similar geologic histories within each zone. Subdividing the broad physiographic units, therefore, provides a basis for the discussion of regional stratigraphy in this report subsection. The discussion in the following subsections is focused on the stratigraphy of North Carolina and the geologic belts recognized in the state, as shown on Figure 2.5.1-209. These geologic belts have similar rock types and geologic histories in the parts of the site region that lie in the adjacent states of Virginia, West Virginia, Kentucky, Tennessee, and South Carolina."

To read:

"The complex stratigraphy and lithology of the HAR site region reflects the long and complex geologic history of this region (described in Subsection 2.5.1.2). The geologic units within a 320-km (200-mi.) radius of the HAR site are shown on Figure 2.5.1-207. The geologic units tend to be distributed in northeast-southwest-trending parallel-sided zones throughout the site region. A comparison of Figures 2.5.1-207 and 2.5.1-201, which shows the physiographic provinces of the site region, indicates that the northeast-southwest-trending linear physiographic provinces have similar stratigraphies, reflecting the similar geologic histories within each zone. The broad northeast-southwest-trending lithotectonic belts include the Piedmont Province, the Blue Ridge Province, the Coastal Plain Province, the Valley and Ridge Province, and the Appalachian Plateau Province. With the exception of the Coastal Plain that unconformably overlies the Piedmont, these provinces are bounded by fault systems related to Paleozoic folding and faulting. Subdividing the broad physiographic units provides a basis for the discussion of regional stratigraphy in this report subsection. The discussion in the following subsections is focused on the stratigraphy of North Carolina and the geologic belts recognized in the state, as shown on Figure 2.5.1-209. Maps showing interpreted lithotectonic terrane boundaries within the site region are shown on RAI 02.05.01-03 Figures 1 and 2. A lithotectonic map of the Appalachian orogen that reflects current concepts regarding the age and tectonic associations of lithologic units within the study region is presented on RAI 02.05.01-03 Figure 3."

2. Revise the 1st paragraph of FSAR Section 2.5.1.1.3.1 from:

"The Piedmont region in North Carolina is underlain by predominantly crystalline and volcaniclastic rocks of Precambrian and Paleozoic age (Reference 2.5.1-202). These rocks can be divided into several broad northeast-southwest-trending belts on the basis of differences in metamorphic grade (Figure 2.5.1-209). Metamorphic grade is highest in the westernmost Piedmont belt and the Inner Piedmont, which contains high-grade amphibolite gneisses and schists. To the east, the Charlotte belt and the Raleigh belt contain rocks of lower amphibolite grade. Metavolcanic rocks and metasediments of mostly greenschist grade characterize the Carolina slate belt and the Eastern slate belt. The Triassic Deep River basin, in which the HAR site is located, is a sediment-filled trough. Cretaceous sediments overlap the southern margins of the Eastern slate belt and the Raleigh belt and the southeastern margin of the Deep River basin. Scattered small deposits of Eocene age locally overlie Cretaceous sediments and crystalline rocks of the Raleigh belt (Figure 2.5.1-207). (Reference 2.5.1-202) The description of stratigraphic units provided in the following subsections comes from the HNP FSAR, unless otherwise noted."

To read:

"The Piedmont region in North Carolina is underlain by predominantly crystalline and volcaniclastic rocks of Precambrian and Paleozoic age (Reference 2.5.1-202). These rocks can be divided into several broad northeast-southwest-trending belts on the basis of differences in metamorphic grade (Figure 2.5.1-209). To the northwest the Piedmont is separated from the Blue Ridge province by the Brevard fault zone. To the southeast the physiographic province extends to the Fall Line where it is unconformably overlain by Cretaceous and Tertiary sedimentary rocks of the Atlantic Coastal Plain. The eastern boundary of the Piedmont lithotectonic province is thought to extend southeastwards beneath the Atlantic Coastal Plain to the East Coast magnetic anomaly (Reference RAI 02.05.01-03 01). The Piedmont province can be subdivided into the Piedmont zone and the Carolina zone based on tectonothermal histories. The two are separated by the central Piedmont shear zone that is interpreted to be a late Paleozoic thrust fault, previously believed to be a suture zone (Reference RAI 02.05.01-03 01). In the Piedmont zone, metamorphic grade is highest in the westernmost Piedmont belt and the Inner Piedmont, which contains high-grade amphibolite gneisses and schists. To the east in the Carolina zone, the Charlotte belt and the Raleigh belt contain rocks of lower amphibolite grade. Metavolcanic rocks and metasediments of mostly greenschist grade characterize the Carolina slate belt and the Eastern slate belt. The Triassic Deep River basin, in which the HAR site is located, is a sediment-filled trough at the eastern margin of the Piedmont physiographic province that is part of a Triassic basins lithotectonic terrane. Cretaceous sediments overlap the southern margins of the Eastern slate belt and the Raleigh belt and the southeastern margin of the Deep River basin. Scattered small deposits of Eocene age locally overlie Cretaceous sediments and crystalline rocks of the Raleigh belt (Figure 2.5.1-207). (Reference 2.5.1-202) The description of stratigraphic units provided in the following subsections comes from the HNP FSAR, unless otherwise noted."

3. Revise the 1st paragraph of FSAR Section 2.5.1.1.3.2 from:

"The Blue Ridge physiographic province of the southern Appalachian orogen can be divided into western and eastern zones in westernmost North Carolina and the adjoining area of Tennessee. The Western Blue Ridge contains a succession of progressively younger Grenville and Neoproterozoic granitic rocks, mafic dikes and intrusions, and overlying metasedimentary rocks that experienced relatively low-grade Paleozoic metamorphism. The Eastern Blue Ridge sequence consists of Neoproterozoic-early Paleozoic clastic metasedimentary rocks and mafic to ultramafic bodies of higher metamorphic grade, plus felsic Paleozoic intrusions and sparse exposures of Grenville-age granitoid gneisses. The Western Blue Ridge generally is thought to be part of Laurentia (native North America), whereas the Eastern Blue Ridge, structurally and lithologically more complex than the western zone, is considered to comprise one or more exotic or suspect terranes (Reference 2.5.1-230)."

To read:

"The Blue Ridge physiographic province of the southern Appalachian orogen can be divided into western and eastern zones in westernmost North Carolina and the adjoining area of Tennessee (Reference 2.5.1-230). The province is positioned adjacent to the Valley and Ridge Province to the northwest and the Piedmont Province to the southeast, the boundary of which is the Brevard fault zone. An abrupt transition exists between the lower Paleozoic sedimentary and metasedimentary rocks involved in the adjacent Valley and Ridge thrust sheets to the late Precambrian sedimentary and metasedimentary rocks and some basement in the Blue Ridge (Reference 2.5.1-215). A major boundary fault with large displacements does not correspond to principal changes in metamorphic grade and therefore no single fault or fault zone can be identified as the contact between metamorphic core (Blue Ridge) and the relatively unmetamorphosed foreland (Valley and Ridge) (Reference 2.5.1-215). The Western Blue Ridge contains a succession of progressively younger Grenville and Neoproterozoic granitic rocks, mafic dikes and intrusions, and overlying metasedimentary rocks that experienced relatively low-grade Paleozoic metamorphism. The Eastern Blue Ridge sequence consists of Neoproterozoic-early Paleozoic clastic metasedimentary rocks and mafic to ultramafic bodies of higher metamorphic grade, plus felsic Paleozoic intrusions and sparse exposures of Grenville-age granitoid gneisses. The Western Blue Ridge generally is thought to be part of Laurentia (native North America), whereas the Eastern Blue Ridge, structurally and lithologically more complex than the western zone, is considered to comprise one or more exotic or suspect terranes (Reference 2.5.1-230). Locally separating the Western Blue Ridge and the Eastern Blue Ridge is the Mars Hill terrane that is considered to be a piece of Paleoproterozoic crust (Reference 2.5.1-230). This exposure is in the vicinity of Roan Mountain, Tennessee-North Carolina, to northwest of Asheville, North Carolina and has been included by some as part of the Western Blue Ridge (Figure 2.5.1-211) (Reference 2.5.1-230). The oldest rocks in the Blue Ridge province are of Middle Proterozoic age and occur in the middle of the zone. These rocks are felsic gneiss derived from sedimentary and igneous rocks, which locally and variably are interlayered with amphibolites, calc-silicate granofels, and rare marble. (Reference 2.5.1-208)"

4. Revise the 1st paragraph of FSAR Section 2.5.1.1.3.3 from:

"In the southeastern part of the site region, the Coastal Plain province lies as a northeast-southwest-trending band. Paleozoic rocks exposed in the Appalachian Mountains to the west can be traced beneath the cover of post-orogenic Mesozoic-Cenozoic Coastal Plain strata (Reference 2.5.1-217). Three subdivisions, or belts, that parallel the Atlantic Coast have been identified: Upper (Inner), Middle, and Lower (Outer) Coastal Plains. These subdivisions, typically separated by escarpments, have distinctive surficial stratigraphies. The Upper Coastal Plain is underlain by Cretaceous and Tertiary sediments that unconformably onlap Mesozoic to Precambrian rocks. The Middle Coastal Plain is underlain by Pliocene marine sediments that have local overlays of Quaternary eolian, lacustrine, colluvial, and alluvial deposits. The Lower Coastal Plain, which is of Quaternary age, is underlain by a repetitive, cyclic sequence of Pleistocene and Holocene marine, estuarine, fluvial, and local eolian deposits. (Reference 2.5.1-233)"

To read:

"In the southeastern part of the site region, the Coastal Plain province lies as a northeast-southwest-trending band (Figure 2.5.1-209). Paleozoic rocks exposed in the Appalachian Mountains to the west can be traced beneath the cover of post-orogenic Mesozoic-Cenozoic Coastal Plain strata (Reference 2.5.1-217). The sediments of the Carolina Coastal Plain were deposited during transgressive-regressive cycles caused by eustatic sea level fluctuations. Sequences of deposits from successive transgressive-regressive cycles are preserved along the Coastal Plain, with progressively younger sequences lying nearer the modern coast and topographically lower than older sequences. (Reference 2.5.1-209)

The Cretaceous rocks of the Carolinas consist primarily of a succession of sands and clays deposited in delta to marine shelf environments during the late Cretaceous (Reference 2.5.1-234). From oldest to youngest, these eastward-dipping map units are the Cape Fear, Middendorf, Black Creek, and Peedee formations (RAI 02.05.01-05 Figure1) (Reference 2.5.1-235). Generally the Cape Fear and Middendorf units are fluvial, the Blackcreek is mostly back barrier, estuarine to tidal flat, and the Peedee is open shelf in environment (Reference 2.5.1-235).

Several post-Cretaceous units overlie the Cretaceous formations, and the surficial stratigraphies and ages of the deposits and associated geomorphic features, such as wave-cut shorelines, have been used to define geomorphic subdivisions. In South Carolina, three subdivisions are recognized, an Upper, Middle, and Outer Coastal Plain; in North Carolina the Middle Coastal Plain has been included in the Outer Coastal Plain (RAI 02.05.01-05 Figure 2).

In general the Upper Coastal Plain is underlain by Cretaceous and dissected remnants of Tertiary sediments that unconformably onlap Mesozoic to Precambrian rocks. The Cretaceous and Tertiary units that crop out on the Upper Coastal Plain are highly dissected, and all original, constructional topography has been deeply eroded (Reference 2.5.1-209). Remnants of old and formerly more continuous fluvial deposits of probable Pliocene age occur on drainage divides in Wake County inland from the contiguous Coastal Plain deposits, suggesting that the Coastal Plain margin extended farther inland prior to erosion (Reference 2.5.1-228).

Seaward of the Orangeburg scarp, which marks the outer boundary of the Upper Coastal Plain, constructional topography generally is preserved, and the land surface is underlain by younger sediments of several transgressive-regressive cycles. (Reference 2.5.1-209).The Middle Coastal Plain (the western part of the Outer Coastal Plain in North Carolina) is underlain by Pliocene marine sediments that have local overlays of Quaternary eolian, lacustrine, colluvial, and alluvial deposits (Reference 2.5.1-233).

The Lower Coastal Plain, which is of Quaternary age, is underlain by a repetitive, cyclic sequence of Pleistocene and Holocene marine, estuarine, fluvial, and local eolian deposits, including the Waccamaw, Penholoway, Socastee, and Wando Formations (RAI 02.05.01-05 Figure 3). (Reference 2.5.1-233) Erosion and deposition, similar to that which formed the Pliocene Bear Bluff Formation, occurred in younger early Pleistocene sequences (1.9 to 1.5

Ma), resulting in deposition of the Waccamaw Formation directly on Cretaceous units (Reference 2.5.1-235).

Within 80 km (50 mi.) of the HAR site, several post-Cretaceous units overlie the Cretaceous formations along the Cape Fear River and its immediate vicinity, including: (1) remnants of the middle Eocene Castle Hayne Formation; (2) lag deposits that indicate deposition during the late Miocene or early Pliocene; (3) the upper Pliocene Duplin and Bear Bluff formations; and (4) the lower Pleistocene (?)[3] Waccamaw Formation (RAI 02.05.01-03 Figure 4 and RAI 02.05.01-05 Figure 3) (Reference 2.5.1-235). The late Tertiary through early Pleistocene beds on Cape Fear occur in successive, step-wise order, with the oldest unit, the Duplin Formation (3.0 Ma), farthest updip and directly overlying the Cretaceous beds (Reference 2.5.1-235). Downdip of that is the Bear Bluff Formation (2.5 Ma), which was deposited during a subsequent transgression in which the sea beveled off the Duplin sediments and deposited the Bear Bluff sediments directly on Cretaceous beds. (Reference 2.5.1-235)."

5. Revise the 1st paragraph of FSAR Section 2.5.1.1.3.4 from:

"The Valley and Ridge province contains 9000 – 12,000 m (30,000 – 40,000 ft.) of Paleozoic sedimentary rocks of predominantly early Paleozoic age; the province is called "Ridge and Valley" in this reference. Folding and faulting is extensive in the province; topographic forms are strongly influenced by alternating stratigraphic layers of resistant and nonresistant rocks. (Reference 2.5.1-206) Most of the province consists of alternating ridges and valleys. The valleys typically are underlain by carbonates, and the ridges are composed chiefly of orthoquartzite (Reference 2.5.1-236)."

To read:

"The Ridge and Valley province contains 9,000 – 12,000 m (30,000 – 40,000 ft.) of Paleozoic sedimentary rocks of predominantly early Paleozoic age. The province is the leading edge of the Paleozoic fold and thrust belt and is thought to have deformed last in the southern and central Appalachians along with the western Blue Ridge (Reference 2.5.1-215). The lithotectonic province is between the Blue Ridge province to the southeast and the Appalachian Plateau province to the northwest. The eastern boundary of the province defines a change from lesser deformed Paleozoic sedimentary rocks to highly folded and faulted Precambrian rocks in the Blue Ridge province. Folding and faulting is extensive in the province; topographic forms are strongly influenced by alternating stratigraphic layers of resistant and nonresistant rocks. (Reference 2.5.1-206) Most of the province consists of alternating ridges and valleys. The valleys typically are underlain by carbonates, and the ridges are composed chiefly of orthoquartzite (Reference 2.5.1-236)."

6. Revise the 1st paragraph of FSAR Section 2.5.1.1.3.5 from:

"The Appalachian Plateaus province is underlain predominantly by clastic rocks, including conglomerate, sandstone, and shale with some interbedded coal. These rocks are predominantly Mississippian and Pennsylvanian in age, and thus are younger than those of other Appalachian provinces. Rocks of the Appalachian Plateaus province were not subjected to the intense deformation that affected the other Appalachian provinces.
(Reference 2.5.1-206)"

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3. Indicates uncertainty in age or type of fault.

To read:

"The Appalachian Plateaus province is underlain predominantly by clastic rocks, including conglomerate, sandstone, and shale with some interbedded coal. The Appalachian Plateau is bounded by the Ridge and Valley province to the east and the Interior Low Plateaus to the west. The rocks within the Appalachian Plateaus province are predominantly Mississippian and Pennsylvanian in age, and thus are younger than those of other Appalachian provinces. Rocks of the Appalachian Plateaus province were not subjected to the intense deformation that affected the other Appalachian provinces. (Reference 2.5.1-206) The deposits overlie Permian to Cambrian age sedimentary rocks that exhibit little to no deformation."

7. Revise FSAR Section 2.5.1.1.3.1.2 from:

"Mesozoic sedimentary and igneous rocks in the part of the site region that is located in the Piedmont province are found primarily in exposed rift basins. In North Carolina, these Mesozoic rift basins occur in two subparallel belts that strike northeasterly: the eastern belt includes the Deep River basin and the western belt includes the Dan River basin. Other Mesozoic basins, both exposed and buried, occur within the adjoining states of Virginia and South Carolina (Reference 2.5.1-220, Figure 2.5.1-210). Mesozoic rift basins are described in more detail in Subsection 2.5.1.1.4.2.3."

To read:

"Mesozoic sedimentary and igneous rocks in the part of the site region that is located in the Piedmont physiographic province are found primarily in exposed rift basins. The basins were superimposed along Paleozoic structures that were reactivated within the Piedmont province (Reference 2.5.1-220). In North Carolina, these Mesozoic rift basins occur in two subparallel belts that strike northeasterly: the eastern belt includes the Deep River basin and the western belt includes the Dan River basin. Other Mesozoic basins, both exposed and buried, occur within the adjoining states of Virginia and South Carolina (Reference 2.5.1-220, Figure 2.5.1-210). Tectonic origin and deposition of the Mesozoic rift basins are described in more detail in Subsection 2.5.1.1.4.2.3."

8. Revise FSAR Section 2.5.1.1.3.1.2.4 from:

Post-rift rocks in the Piedmont province are limited in extent. Cretaceous and Tertiary units that crop out on the Upper Coastal Plain to the east are highly dissected. The western margin of the Coastal Plain is very ragged and in places not well defined (Reference 2.5.1-209). Within the site region, the Eocene Castle Hayne Limestone occurs as scattered deposits lying unconformably on crystalline rocks of the Raleigh belt. The formation consists of light gray fossiliferous limestone and light gray marl. (Reference 2.5.1-202) In the eastern part of the site region, the Yorktown Formation of Miocene age locally overlaps Eastern slate belt rocks. This unit reveals primarily clay, sand, and shell marl in surface exposures. At one time, these Tertiary marine deposits evidently covered much of the Coastal Plain and extended onto the Piedmont Plateau. (Reference 2.5.1-202)

Upland terrace sediments of unknown age are mapped along the inner edge of the Coastal Plain and in the Piedmont. Small patches of undifferentiated upland gravel and sand of probable Pliocene age are observed on the highest areas of drainage divides in Wake County. The sediment is described as deeply weathered, poorly sorted, and containing subangular to rounded pebbles. Upland gravel units are identified primarily by the rounded quartz pebbles in the soil. The origin of these deposits is interpreted to be primarily fluvial, although locally colluvial. (Reference 2.5.1-228)

To read:

"Post-rift rocks in the Piedmont province are limited in extent. The eastern margin of the Piedmont and the western margin of the Coastal Plain are very ragged and in places not well defined (Reference 2.5.1-209). Within the site region, the Eocene Castle Hayne Limestone occurs as scattered deposits lying unconformably on crystalline rocks of the Raleigh belt. The formation consists of light gray fossiliferous limestone and light gray marl. (Reference 2.5.1-202) In the eastern part of the site region, the Yorktown Formation of Miocene age locally overlaps Eastern slate belt rocks. This unit reveals primarily clay, sand, and shell marl in surface exposures. At one time, these Tertiary marine deposits evidently covered much of the neighboring Coastal Plain and extended onto the Piedmont Plateau. (Reference 2.5.1-202)

Upland terrace sediments of unknown age are mapped in the Piedmont and along the inner edge of the Coastal Plain. Small patches of undifferentiated upland gravel and sand of probable Pliocene age are observed on the highest areas of drainage divides in Wake County. The sediment is described as deeply weathered, poorly sorted, and containing subangular to rounded pebbles. Upland gravel units are identified primarily by the rounded quartz pebbles in the soil. The origin of these deposits is interpreted to be primarily fluvial, although locally colluvial. (Reference 2.5.1-228)"

References:

Reference RAI 02.05.01-03 01

Hibbard, J.P., E.F. Stoddard, D.T. Secor, and A.J. Dennis, "The Carolina Zone: overview of Neoproterozoic to Early Paleozoic peri-Gondwanan terranes along the eastern Flank of the southern Appalachians," *Earth-Science Reviews*, Vol. 57, pp. 299-339, 2002.

Attachments/Enclosures:

Attachment 02.05.01-03A: RAI 02.05.01-03 Figure 1

Attachment 02.05.01-03B: RAI 02.05.01-03 Figure 2

Attachment 02.05.01-03C: RAI 02.05.01-03 Figure 3

Attachment 02.05.01-03D: Figure 2.5.1-210 (Revised)

Attachment 02.05.01-03E: Figure 2.5.1-211 (Revised)

Attachment 02.05.01-03F: RAI 02.05.01-03 Figure 4

Attachment 02.05.01-05A: RAI 02.05.01-05 Figure 1

Attachment 02.05.01-05B: RAI 02.05.01-05 Figure 2

Attachment 02.05.01-05C: RAI 02.05.01-05 Figure 3

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-4

Text of NRC RAI:

FSAR Section 2.5.1.1.3.2 provides a discussion of the stratigraphy of the Blue Ridge.

a) The tectonic boundaries for the Blue Ridge are not provided. There are no maps or figures illustrating these relationships. Please provide a description of regional stratigraphic relationships within the lithotectonic terrane of the Blue Ridge province. Provide a figure or map illustrating these relationships. Provide a concise description of the northwest and southeast boundaries to the Blue Ridge.

b) The FSAR cites Reference 2.5.1-208. This is a WEB site of the Maryland Geological survey. The FSAR must reference official agency (NCGS) records. If the WEB site is the official agency record, then it must be preserved and retrievable if the WEB site changes at a later date.

c) The interpretation statements are very wide reaching throughout this section and there is little attribution to the original source of investigation and information. Please provide the reference to the scientists who did the original work.

d) FSAR section 2.5.1.1.3.2.1, discusses the Geochronology of Blue Ridge. There are three sentences presented about southern Appalachian basement rocks in general with no relationship to the preceding discussion of Blue Ridge stratigraphy. Please define these basement rocks with respect to the rocks discussed in previous section.

e) FSAR section 2.5.1.1.3.2.1, introduces the Mars Hill terrane for the first time. There is no geologic map to locate this feature. Please provide a geologic map to illustrate the location of the terrane and a discussion to explain the field relations and geochronology that leads to the age estimate of this terrane.

PGN RAI ID #: H-0141

PGN Response to NRC RAI:

a) The general boundaries of the Blue Ridge province are shown on FSAR Figure 2.5.1-201. The Blue Ridge province includes Late Proterozoic and early Paleozoic and basement massifs between the Brevard fault to the east and the eastern boundary of the North American Paleozoic platform sediments to the west that underlie the Valley and Ridge province as shown on Figures 2.5.1-211 and Figure 2.5.1-212. Cross sections shown on FSAR Figure 2.5.1-212 illustrate the general structures associated with the eastern and western margins of the Blue Ridge province. As shown in the following revision, additional text will be added to Section 2.5.1.1.3.2 to discuss the northwest and southeast boundaries of the Blue Ridge province and to describe the regional stratigraphic relationships across these boundaries.

b) Reference 2.5.1-208 has been preserved and is retrievable as a (.PDF) document.

c) As shown in the following revision, Section 2.5.1.1.3.2 will be updated to include citations to References 2.5.1-215, 2.5.1-230, 2.5.1-208, and 2.5.1-231 and additional references based on supplemental discussion added to the text.

d) As shown in the following revision, the update to FSAR Section 2.5.1.1.3.2.1 will include additional discussion of the structural process associated with the emplacement of the basement massif in the Blue Ridge province. Additional references will be added to describe the tectonic environment associated with the formation of stratigraphy within the Blue Ridge province.

e) As shown in the following revision, FSAR Section 2.5.1.1.3.2.1 will be updated to clarify the lithologic diversity and field relations in the Mars Hills terrane used for dating. The terrane will be labeled on an updated Figure 2.5.1-211 in a future revision.

Associated HAR COL Application Revisions:

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

1. Revise FSAR Section 2.5.1.1.3.2 from:

   "The Blue Ridge physiographic province of the southern Appalachian orogen can be divided into western and eastern zones in westernmost North Carolina and the adjoining area of Tennessee. The Western Blue Ridge contains a succession of progressively younger Grenville and Neoproterozoic granitic rocks, mafic dikes and intrusions, and overlying metasedimentary rocks that experienced relatively low-grade Paleozoic metamorphism. The Eastern Blue Ridge sequence consists of Neoproterozoic-early Paleozoic clastic metasedimentary rocks and mafic to ultramafic bodies of higher metamorphic grade, plus felsic Paleozoic intrusions and sparse exposures of Grenville-age granitoid gneisses. The Western Blue Ridge generally is thought to be part of Laurentia (native North America), whereas the Eastern Blue Ridge, structurally and lithologically more complex than the western zone, is considered to comprise one or more exotic or suspect terranes. (Reference 2.5.1-230)"

   To read:

   "The Blue Ridge physiographic province of the southern Appalachian orogen can be divided into western and eastern zones in westernmost North Carolina and the adjoining area of Tennessee (Reference 2.5.1-230). The province is positioned adjacent to the Valley and Ridge Province to the northwest and the Piedmont Province to the southeast, the boundary of which is the Brevard fault zone. An abrupt transition exists between the lower Paleozoic sedimentary and metasedimentary rocks involved in the adjacent Valley and Ridge thrust sheets to the late Precambrian sedimentary and metasedimentary rocks and some basement in the Blue Ridge (Reference 2.5.1-215). A major boundary fault with large displacements does not correspond to principal changes in metamorphic grade and therefore no single fault or fault zone can be identified as the contact between metamorphic core (Blue Ridge) and the relatively unmetamorphosed foreland (Valley and Ridge) (Reference 2.5.1-215). The Western Blue Ridge contains a succession of progressively younger Grenville and Neoproterozoic granitic rocks, mafic dikes and intrusions, and overlying metasedimentary rocks that experienced relatively low-grade Paleozoic metamorphism. The Eastern Blue Ridge sequence consists of Neoproterozoic-early Paleozoic clastic metasedimentary rocks and mafic to ultramafic bodies of higher metamorphic grade, plus felsic Paleozoic intrusions and sparse exposures of Grenville-age granitoid gneisses. The Western Blue Ridge generally is thought to be part of Laurentia (native North America), whereas the Eastern Blue Ridge, structurally and lithologically more complex than the western zone, is considered to comprise one or more exotic or suspect terranes (Reference 2.5.1-230). Locally separating the Western Blue Ridge and the Eastern Blue Ridge is the Mars Hill terrane that is considered to be a piece of Paleoproterozoic crust (Reference 2.5.1-230). This exposure is in the vicinity of Roan Mountain, Tennessee-North Carolina, to northwest of Asheville, North Carolina and has been included by some as part of the Western Blue Ridge, but has no counterpart (Figure 2.5.1-211) (Reference 2.5.1-230). The oldest rocks in the Blue Ridge province are of Middle Proterozoic age and occur in the middle of the zone. These rocks are felsic gneiss derived from sedimentary and igneous rocks, which locally and variably are interlayered with amphibolites, calc-silicate granofels, and rare marble. (Reference 2.5.1-208)"

2. Revise the 1st paragraph of FSAR Section 2.5.1.1.3.2.1 from:

   "Basement rocks in the southern Appalachians are believed to be virtually all of Grenville age (1000 to 1250 Ma), based on whole-rock rubidium-strontium (Rb-Sr) isochrons and conventional uranium-lead (U-Pb) dating methods (Reference 2.5.1-232). Ages of basement rocks in the southern Appalachians also may be documented in younger plutonic rocks and metasedimentary rocks as inherited or detrital zircon (Reference 2.5.1-232). Analyses of zircons from southern Appalachian basement rocks (sampled in a northeast-southwest-trending zone that includes western North Carolina) have delineated a granitic magmatic pulse from about 1165 to 1150 Ma (Reference 2.5.1-232)."

   To read:

   "The Proterozoic Grenvillian crystalline rocks serve as the basement upon which late Precambrian and younger stratigraphic packages that ultimately became involved in the Appalachian oregenies were deposited (Reference 2.5.1-215).The Blue Ridge is an elongate external basement massif along which late Precambrian syn-rift sedimentary and volcanic rocks, as well as older basement rocks, have been translated and deformed by younger Appalachian compressional structures, especially large-scale Alleghanian (late Paleozoic) thrust faults (Reference RAI 02.05.01-04 01).The rocks within the Blue Ridge province make up most of the basement rocks in the southern Appalachians and are considered to be uniformly broadly granitic in composition (Reference 2.5.1-230) In the northwestern Blue Ridge, rift-related rocks are laterally discontinuous and overlie Precambrian (~1000 Ma) crystalline basement. In the southeastern Blue Ridge, rift-related rocks and continental basement rocks are truncated by thrust faults (Reference RAI 02.05.01-04 01). Basement rocks in the southern Appalachian are believed to be Grenville age (1000 to 1250 Ma), based on whole-rock rubidium-strontium (Rb-Sr) isochrons and conventional uranium-lead (U-Pb) dating methods (Reference 2.5.1-232). Ages of basement rocks in the southern Appalachians also may be documented in younger plutonic rocks and metasedimentary rocks as inherited or detrital zircon (Reference 2.5.1-232). Analyses of zircons from southern Appalachian basement rocks (sampled in a northeast-southwest-trending zone that includes western North Carolina) have delineated a granitic magmatic pulse from about 1165 to 1150 Ma (Reference 2.5.1-232)."

3. Revise the 2nd paragraph of FSAR Section 2.5.1.1.3.2.1 from:

   "The Mars Hill terrane in northwestern North Carolina and southeastern Tennessee is a lithologically diverse basement exposure that is distinct in age and metamorphic history from structurally adjacent sections of the Blue Ridge province (Reference 2.5.1-230). Basement of the adjacent Eastern and Western Blue Ridge comprises relatively homogeneous granitic rocks, 1100 to 1200 Ma. Field relations and geochronology suggest that the lithologically diverse Mars Hill terrane may have an age of about 1900 Ma, thus containing the oldest rocks in the southern Appalachians (Reference 2.5.1-230). These rocks, as well as those in the adjoining Eastern and Western Blue Ridge, experienced a profound metamorphic event shortly before 1000 Ma (Reference 2.5.1-230)."

To read:

"The Mars Hill terrane in northwestern North Carolina and southeastern Tennessee is a lithologically diverse basement exposure that is distinct in age and metamorphic history from structurally adjacent sections of the Blue Ridge province (Reference 2.5.1-230). The Mars Hill terrane is interpreted as a continental fragment that may represent a portion of lower crust that underlies the more juvenile rocks of the Western Blue Ridge and possibly the Eastern Blue Ridge basement during Grenville time (Reference 2.5.1-230). The Mars Hills terrane is characterized by a great diversity of lithologies interspersed on all scales (Reference 2.5.1-230). Much of the Mars Hill terrane can be characterized by block-in-matrix mélange. This lithology is cut by dikes of the 730-Ma Neoproterozoic Bakersville dike swarm (Reference 2.5.1-230). Basement of the adjacent Eastern and Western Blue Ridge comprises relatively homogeneous granitic rocks, 1100 to 1200 Ma in age. Field relations and geochronology suggest that the lithologically diverse Mars Hill terrane may have an age of about 1900 Ma, thus containing the oldest rocks in the southern Appalachians; the terrane lacks Phanerozoic rocks (Reference 2.5.1-230). These rocks, as well as those in the adjoining Eastern and Western Blue Ridge, experienced a profound metamorphic event shortly before 1000 Ma (Reference 2.5.1-230)."

References:

Reference RAI 02.05.01-04 01

Thomas, W. A., "The Appalachian-Ouachita Rifted Margin of Southeastern North America." *Geological Society of America Bulletin*. Vol. 103. pp. 215-431, 1991.

Attachments/Enclosures:

Attachment 02.05.01-03E: Figure 2.5.1-211 (Revised)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-5

Text of NRC RAI:

FSAR Section 2.5.1.1.3.3 provides a discussion of the coastal Plain stratigraphy. There is no stratigraphic column illustrating relationships. The text begins by breaking out the upper, middle and lower Coastal Plain, however, the following text does not break out the formations according to those introduced categories. Provide a stratigraphic column and define what is meant by "constructional topography".

PGN RAI ID #: H-0142

PGN Response to NRC RAI:

As shown below, the discussion of Coastal Plain stratigraphy will be reorganized in a future revision. References to geomorphic provinces (upper, middle, and lower Coastal Plain) has been eliminated. These terms are not used systematically throughout the Coastal Plain region. For example, Soller and Mills (1991) subdivide the Coastal Plain into two parts: an area of erosional topography near the Fall Zone (inner Coastal Plain), and an area to seaward where constructional topography is evident or dominant (Outer Coastal Plain). Additional figures and stratigraphic columns have been added to illustrate stratigraphic relationships in the Triassic, Cretaceous, and Upper Cenozoic-Quaternary.

"Constructional topography" refers to topography that resulted from deposition of sediments. In this case, this is the topography that would have been present during the Cretaceous and Tertiary.

Associated HAR COL Application Revisions:

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

1. Revise FSAR Section 2.5.1.1.3.3 from:

   "In the southeastern part of the site region, the Coastal Plain province lies as a northeast-southwest-trending band. Paleozoic rocks exposed in the Appalachian Mountains to the west can be traced beneath the cover of post-orogenic Mesozoic-Cenozoic Coastal Plain strata (Reference 2.5.1-217). Three subdivisions, or belts, that parallel the Atlantic Coast have been identified: Upper (Inner), Middle, and Lower (Outer) Coastal Plains. These subdivisions, typically separated by escarpments, have distinctive surficial stratigraphies. The Upper Coastal Plain is underlain by Cretaceous and Tertiary sediments that unconformably onlap Mesozoic to Precambrian rocks. The Middle Coastal Plain is underlain by Pliocene marine sediments that have local overlays of Quaternary eolian, lacustrine, colluvial, and alluvial deposits. The Lower Coastal Plain, which is of Quaternary age, is underlain by a repetitive, cyclic sequence of Pleistocene and Holocene marine, estuarine, fluvial, and local eolian deposits. (Reference 2.5.1-233)

The Cretaceous rocks of the Carolinas consist primarily of a succession of sands and clays deposited in delta to marine shelf environments during the late Cretaceous (Reference 2.5.1-234). From oldest to youngest, these eastward-dipping map units are the Cape Fear, Middendorf, Black Creek, and Peedee formations (Reference 2.5.1-235).

Cenozoic stratigraphic units in the Coastal Plain province within the site region include Tertiary marine deposits and marine through nonmarine Quaternary sediments. Several post-Cretaceous units overlie the Cretaceous formations along the Cape Fear River and its immediate vicinity, including: (1) remnants of the middle Eocene Castle Hayne Formation; (2) lag deposits that indicate deposition during the late Miocene or early Pliocene; (3) the upper Pliocene Duplin and Bear Bluff formations; and (4) the lower Pleistocene (?)[4] Waccamaw Formation (Reference 2.5.1-235).

The late Tertiary through early Pleistocene beds on Cape Fear occur in successive, step-wise order, with the oldest unit, the Duplin Formation (3.0 Ma), farthest updip and directly overlying the Cretaceous beds (Reference 2.5.1-235). Downdip of that is the Bear Bluff Formation (2.5 Ma), which was deposited during a subsequent transgression in which the sea beveled off the Duplin sediments and deposited the Bear Bluff sediments directly on Cretaceous beds. Similar erosion and deposition occurred in younger early Pleistocene sequences (1.9 to 1.5 Ma), resulting in deposition of the Waccamaw Formation directly on Cretaceous units (Reference 2.5.1-235).

The Cretaceous and Tertiary units that crop out on the Upper Coastal Plain are highly dissected, and all original, constructional topography has been deeply eroded (Reference 2.5.1-209). Remnants of old and formerly more continuous fluvial deposits of probable Pliocene age occur on drainage divides in Wake County inland from the contiguous Coastal Plain deposits, suggesting that the Coastal Plain margin extended farther inland prior to erosion (Reference 2.5.1-228). Seaward of the Orangeburg scarp, which marks the outer boundary of the Upper Coastal Plain, constructional topography generally is preserved, and the land surface is underlain by younger sediments of several transgressive-regressive cycles, as described previously (Reference 2.5.1-209)."

To read:

"In the southeastern part of the site region, the Coastal Plain province lies as a northeast-southwest-trending band (Figure 2.5.1-209). Paleozoic rocks exposed in the Appalachian Mountains to the west can be traced beneath the cover of post-orogenic Mesozoic-Cenozoic Coastal Plain strata (Reference 2.5.1-217). The sediments of the Carolina Coastal Plain were deposited during transgressive-regressive cycles caused by eustatic sea level flucuations. Sequences of deposits from successive transgressive-regressive cycles are preserved along the Coastal Plain, with progressively younger sequences lying nearer the modern coast and topographically lower than older sequences. (Reference 2.5.1-209)

The Cretaceous rocks of the Carolinas consist primarily of a succession of sands and clays deposited in delta to marine shelf environments during the late Cretaceous (Reference 2.5.1-234). From oldest to youngest, these eastward-dipping map units are the Cape Fear, Middendorf, Black Creek, and Peedee formations (RAI 2.5.1-05 Figure1) (Reference 2.5.1-235). Generally the Cape Fear and Middendorf units are fluvial, the Blackcreek is mostly back barrier, estuarine to tidal flat, and the Peedee is open shelf in environment (Reference 2.5.1-235).

4. Indicates uncertainty in age or type of fault.

Several post-Cretaceous units overlie the Cretaceous formations, and the surficial stratigraphies and ages of the deposits and associated geomorphic features, such as wave-cut shorelines, have been used to define geomorphic subdivisions. In South Carolina, three subdivisions are recognized, an Upper, Middle, and Outer Coastal Plain; in North Carolina the Middle Coastal Plain has been included in the Outer Coastal Plain (Reference 2.5.1-209) (RAI 2.5.1-05 Figure 2).

In general the Upper Coastal Plain is underlain by Cretaceous and dissected remnants of Tertiary sediments that unconformably onlap Mesozoic to Precambrian rocks. The Cretaceous and Tertiary units that crop out on the Upper Coastal Plain are highly dissected, and all original, constructional topography has been deeply eroded (Reference 2.5.1-209). Remnants of old and formerly more continuous fluvial deposits of probable Pliocene age occur on drainage divides in Wake County inland from the contiguous Coastal Plain deposits, suggesting that the Coastal Plain margin extended farther inland prior to erosion (Reference 2.5.1-228).

Seaward of the Orangeburg scarp, which marks the outer boundary of the Upper Coastal Plain, constructional topography generally is preserved, and the land surface is underlain by younger sediments of several transgressive-regressive cycles. (Reference 2.5.1-209).The Middle Coastal Plain (the western part of the Outer Coastal Plain in North Carolina) is underlain by Pliocene marine sediments that have local overlays of Quaternary eolian, lacustrine, colluvial, and alluvial deposits.

The Lower Coastal Plain, which is of Quaternary age, is underlain by a repetitive, cyclic sequence of Pleistocene and Holocene marine, estuarine, fluvial, and local eolian deposits, including the Waccamaw, Penholoway, Socastee, and Wando Formations (RAI 2.5.1-05 Figure 3). (Reference 2.5.1-233) Erosion and deposition, similar to that which formed the Pliocene Bear Bluff Formation, occurred in younger early Pleistocene sequences (1.9 to 1.5 Ma), resulting in deposition of the Waccamaw Formation directly on Cretaceous units (Reference 2.5.1-235).

Several post-Cretaceous units overlie the Cretaceous formations along the Cape Fear River and its immediate vicinity, including: (1) remnants of the middle Eocene Castle Hayne Formation; (2) lag deposits that indicate deposition during the late Miocene or early Pliocene; (3) the upper Pliocene Duplin and Bear Bluff formations; and (4) the lower Pleistocene (?)[5] Waccamaw Formation (RAI 2.5.1-05 Figure 3) (Reference 2.5.1-235). The late Tertiary through early Pleistocene beds on Cape Fear occur in successive, step-wise order, with the oldest unit, the Duplin Formation (3.0 Ma), farthest updip and directly overlying the Cretaceous beds (RAI 02.05.01-03 Figure 4) (Reference 2.5.1-235). Downdip of that is the Bear Bluff Formation (2.5 Ma), which was deposited during a subsequent transgression in which the sea beveled off the Duplin sediments and deposited the Bear Bluff sediments directly on Cretaceous beds. (Reference 2.5.1-235)

Attachments/Enclosures:

Attachment 02.05.01-05A: RAI 02.05.01-5 Figure 1

Attachment 02.05.01-05B: RAI 02.05.01-5 Figure 2

Attachment 02.05.01-05C: RAI 02.05.01-5 Figure 3

Attachment 02.05.01-03F: RAI 02.05.01-3 Figure 4

5. Indicates uncertainty in age or type of fault.

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-6

Text of NRC RAI:

FSAR Section 2.5.1.1.4.2.1. provides a discussion of late Proterozoic to early Paleozoic basement structures.

a) The text does not provide a well defined northwest boundary to the Iapetan normal fault zone of Wheeler. Because of the potential for location of seismic sources, both the northwest and southeast boundary of this zone needs to be illustrated with the location of HAR site included.

b) The text discusses the findings of Hatcher & Lemiszki, 1998 and Hatcher et al, 1998 with respect to faults formed beneath the Blue Ridge thrust. However, there is no indication where these faults are with respect to Wheeler's southeast or northwest boundary of intact Iapetan faults. There is no illustration of the locations of the faults and boundaries. Please provide a map of features discussed in text.

c) The faults defined by the Lawrence and Hoffman paper are Paleozoic-age faults. They seem to be located incorrectly in this section? Please explain this discrepancy.

PGN RAI ID #: H-0143

PGN Response to NRC RAI:

a) The northwestern boundary of the Iapetan normal fault zone will be added to Figure 2.5.1-213 in a future revision.
b) Hatcher et al. (Reference RAI 02.05.01-06 01) provided an updated interpretation of the basement faults. The current location of these faults will be added to the revised Figure 2.5.1-213 in a future revision. Text in section 2.5.1.1.4.2.1 will be revised as indicated below based on Hatcher et al., (Reference RAI 02.05.01-06 01).
c) The discussion of Paleozoic-age faults defined in the Lawrence and Hoffman will be moved in a future revision to revised FSAR Subsection 2.5.1.1.4.2.2 Paleozoic Tectonic Structures that includes a summary of the significant Paleozoic structures in the site region.

Associated HAR COL Application Revisions:

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

1. Revise the 3rd paragraph of FSAR Section 2.5.1.1.4.2.1 from:

   "Hatcher and Lemiszki in Hatcher et al. present a regional structure contour map of the basement surface beneath the Valley and Ridge and Blue Ridge and Piedmont region of Alabama, Georgia, Tennessee, the Carolinas, and southwest Virginia (Reference 2.5.1-249, Reference 2.5.1-250). The basement surface is inferred from seismic reflection and surface geologic data obtained by industry, academia, and U.S. and state geological surveys, along with crustal seismic lines in the more internal parts of the orogen. The basement surface in this reconstruction, which dips gently southeast in the Tennessee embayment from Virginia to Georgia, contains several previously unrecognized rift-related normal faults that formed in the latest Proterozoic to earliest Cambrian (Reference 2.5.1-250). Additionally, Lawrence and Hoffman show five major basement faults underlying the Coastal Plain: the Nutbush Creek fault, the Hollister fault zone, the Roanoke Island-Goldsboro fault, the Pender fault, and an unnamed fault (Figure 2.5.1-213) (Reference 2.5.1-251). The southern extensions of several of the north-south-trending faults are truncated by the Pender fault (Reference 2.5.1-251). Movement on the Nutbush Creek fault is estimated to be 160 km (100 mi.) of dextral offset between 312 and 285 Ma. Dextral faulting on the Hollister fault zone is estimated to be 25 km (15.5 mi.) between 251 and 292 Ma. (Reference 2.5.1-251)"

To read:

"Hatcher et al. (Reference RAI 02.05.01-06 01) present a regional structure contour map of the basement surface beneath the Valley and Ridge and Blue Ridge and Piedmont region of Alabama, Georgia, Tennessee, the Carolinas, and southwest Virginia. The basement surface is inferred from seismic reflection and surface geologic data obtained by industry, academia, and U.S. and state geological surveys, along with crustal seismic lines in the more internal parts of the orogen. The basement surface in this reconstruction, which dips gently southeast in the Tennessee embayment from Virginia to Georgia, contains several previously unrecognized rift-related normal faults that formed in the latest Proterozoic to earliest Cambrian (Reference 2.5.1-250)."

2. The following paragraphs will be added to FSAR Section 2.5.1.1.4.2.2:

   The central and southern Appalachians were collectively assembled into various terranes by a series of Paleozoic orogenies. All suspect terranes west of the Carolina and Albermarle volcanic arcs, including those amalgamated during the Penobscottian event, were accreted to the Laurentian native terranes and initially deformed and metamorphosed together during the Taconian orogeny. The significance of the Acadian orogeny in the southern and central Appalachians is uncertain and preceded the late Paleozoic Alleghanian orogeny (Figure 2.5.1-205).The collision of Laurentia and Gondwanaland marked the final stage of accretionary history in the Appalachians, and is responsible for the reactivation of earlier Paleozoic structures and the formation of folding and thrusting in the Blue Ridge and Ridge and Valley provinces (Reference RAI 02.05.01-06 02).

   Numerous tectonic structures that experienced Alleghanian deformation are exposed in the western half of the 320-km (200-mi.) radius around the HAR site region. These include the Brevard fault, Central Piedmont shear zone, Nutbrush Creek, Gold Hill/Hollister, and Augusta faults, In the eastern half of the site region, similar structures underlie the post-orogenic Mesozoic-Cenozoic sediments of the Coastal Plain. These structures, including the sub-Coastal Plain sediment extensions of the Nutbush Creek and Hollister faults, Roanoke Island-Goldsboro fault and inferred Pender fault, have been recognized using data sources that include exploration wells and geophysical techniques (Reference 2.5.1-217). The Alleghanian orogeny in the central and southern Appalachians is known as a thrust-dominated orogen (Reference 2.5.1-218). Alternating weak and strong horizons that assisted in the propagation of Alleghanian thrusts were provided by Paleozoic foreland basins and clastic wedges. The Blue-Ridge Piedmont (BRP) composite crystalline thrust sheet had a major role in Alleghanian deformation. (Reference 2.5.1-218)

The BRP thrust sheet is one of the largest intact composite crystalline thrust sheets in the world, extending from Alabama to Pennsylvania throughout the southern and central Appalachians. The BRP thrust sheet is bounded on the west by the Blue Ridge fault system. The eastern boundary probably is buried beneath the Coastal Plain. (Reference 2.5.1-207) Formed during the collision of North America with Africa, the thrust sheet drove the foreland deformation in front of it. Accordingly, the BRP thrust sheet is composed of Paleozoic basement made up of intact, complexly deformed Late Proterozoic and early Paleozoic sedimentary sequences. (Reference 2.5.1-207) Several overprinted episodes of faulting are recognized in southern Virginia and western North Carolina.

Evidence for the extent of the Alleghanian BRP thrust sheet beneath the Blue Ridge and Piedmont provinces is derived from both geophysical and structural data. The acquisition and interpretation of seismic reflection profiles developed across the southern Appalachians by the Consortium for Continental Reflection Profiling (COCORP) in the late 1970s to early 1980s and subsequent interpretation of industry seismic data provided significant subsurface information to support a model for the development of the Appalachian thrust belt above a master décollement or detachment (Reference 2.5.1-252, Reference 2.5.1-253).

"The Brevard fault zone is widely considered to be one of the most fundamental tectonic features of the southern Appalachian orogen (Reference Horton and McConnell,1991). The Brevard fault zone is described in detail by Horton and McConnell as a linear, southeast-dipping belt of mylonitic and cataclastic rocks, typically 1 to 2 km wide, that extends more than 600 km from the Gulf Coastal Plain onlap in Alabama almost to the North Carolina-Virginia border, where it apparently continues into Virginia as the Bowens Creek fault..The Brevard fault is a complex fault zone that is recognized as a major Alleghanian structure within the BRP thrust sheet (Reference 2.5.1-207). The fault zone has had a complex history that includes Alleghanian dip- and strike-slip motion preceded by a history of dip-slip motion. A summary of earlier studies and models for the origin and structure of the Brevard fault zone is provided in Hatcher (Reference 2.5.1-207; Reference 2.5.1-215; Reference RAI 02.05.01-06 02). In a summary of literature from the 1970s and early 1980s Horton and McConnell (Reference RAI 02.05.01-06 02) conclude that the Brevard fault zone has experienced a long and complex Paleozoic history, including Taconic, Acadian (debated), and Alleghanian deformation, in which thrusting played an important role. An additional summary of work published on the Brevard fault zone from 1983-1988 by Horton and McConnell, contributed to the understanding and importance of the recognition and documentation of late Paleozoic (Alleghanian) dextral strike-slip along the fault zone. Hatcher (Reference 2.5.1-215) credits work done in the 1950s through 1970s as recognizing that the Brevard fault is a major crustal break that was therefore speculated to be a continental suture. Hatcher (Reference 2.1.5-215) recognized that as the understanding of the fault system has improved, the similarity of stratigraphic assemblages on both sides of the fault clearly indicates that it is not a suture. Whereas the multiple deformation histories of the fault zone are extensive and controversial, diabase dikes preclude post Jurassic slip on the Brevard fault and cooling age histories indicate that no slip has occurred on the Brevard fault since the late Paleozoic (Reference RAI 02.05.01-06 02).

The Central Piedmont shear zone, previously referred to as the central Piedmont suture, (Figure 2.5.1-211) is exposed from near the Georgia-Alabama boundary northward into central Virginia. From central South Carolina to the north, the fault is traceable to and folded into the Kings Mountain belt along the North Carolina-South Carolina border. The Central Piedmont shear zone separates the volcanic island-arc association of the Avalon-Carolina exotic terrane from the rocks of the Inner Piedmont and eastern Blue Ridge block, which have North American plate affinities. (Reference 2.5.1-215) This tectonic boundary was originally viewed as a cryptic suture involving late Paleozoic tectonothermal overprinting of an older fundamental structure and consequently was termed the central Piedmont suture, recently however, this contact has been shown to be a Paleozoic shear zone along most of its length without evidence of earlier activity (Reference RAI 02.05.01-06 03). The structure has been interpreted to be a major late Paleozoic ductile thrust that decapitated the original suture and marks the final emplacement of Carolina Zone against Laurentian rocks during the Alleghanian orogeny. Consequently, the name was modified to the Central Piedmont shear zone (Reference RAI 02.05.01-06 03).

The Eastern Piedmont fault system (Figure 2.5.1-213) , which includes the Nutbush Creek fault and Modoc shear zone, extends from Alabama to Virginia and is described by Hatcher et al. (Reference 2.5.1-327) as a series of linear cataclastic zones that coincide with magnetic anomalies and parallel the trend of the Appalachians. These magnetic anomalies coincide with cataclastic rocks and also with a low velocity zone likely due to fracturing of the crystalline rocks during recurrent faulting. (Reference 2.5.1-327) The timing of movement on the fault system is constrained by faulted granites that are estimated to have formed approximately 400 Ma; the faults are intruded by Mesozoic dikes, and the faults do not offset Coastal Plain deposits. The Eastern Piedmont fault system may have been initiated within the slate-belt island arc as it collapsed and was accreted to North America during the early to middle Paleozoic (Reference 2.5.1-327).

The Nutbush Creek fault crops out in the Piedmont west of Raleigh (Reference 2.5.1-231). Based on apparent truncations of magnetic anomalies the Nutbush Creek fault is inferred to extend south and southwest under the North Carolina Coastal Plain into South Carolina where it may connect with the Modoc fault of Hatcher and others (Reference 2.5.1-327). Movement on this fault is estimated to be 160 km (100 mi.) of dextral offset between 312 and 285 Ma

The Modoc shear zone is a region of high ductile strain that can be traced through the Piedmont province of South Carolina and Georgia. The ductile zone marks the approximate northwestern limit of penetrative deformation and amphibolite-facies metamorphism. The zone trends northeast and can be invariably characterized by a deformed intrusive contact between upper Paleozoic plutonic orthogneiss in the Kiokee belt and older metamorphic and igneous rocks in the Carolina slate belt. The curving of lithologic contacts and structural elements in the zone along with a very steep surface dip to the northwest, is evidence for a zone of flattening or right-lateral strike-slip displacement. Within the Modoc zone there are limited amounts of brittle faulting that postdate the ductile shearing, but have displacements too small to interrupt the continuity of major lithologic units (Reference RAI 02.05.01-06 04).

The Augusta fault zone is concealed under the sediments of the Atlantic Coastal Plains for much of its length, and in the vicinity of its exposure in Augusta, Georgia, forms the northwest trending boundary between the Kiokee belt and the Belair belt. The fault zone is evident as a magnetic anomaly for much of its covered length. The fault zone shows evidence of an early ductile shear history with minor postmetamorphic brittle faulting similar to the Modoc shear zone. The Augusta fault zone is a thrust fault, displacing low-grade rocks of the Belair belt over high-grade rocks of the Kiokee belt. The fault has a surface dip of about 40 degrees SE, traceable by geophysical data to where the dip flattens to less than 8 degrees about 60 km to the south of the surface trace. (Reference RAI 02.05.01-06 04)

The Gold Hill-Silver Hill shear zone records dextral strike-slip motion in the Carolina terrane of North Carolina. Geologic similarities and along strike position of the Deal Creek shear zone (Figure 2.5.1-213) to the southwest suggest that it is an extension of the Gold Hill-Silver Hill shear zone. The two are separated by Inner Piedmont terrane rocks. The age of dextral strike-slip movement along the Gold Hill-Silver Hill fault is constrained between ~400 and ~325 Ma. (Reference RAI 02.05.01-06 05)

The Sauratown Mountains anticlinorium is a structural window in western North Carolina and southwestern Virginia. The anticlinorium is made up of four stacked thrust sheets each containing middle Proterozoic basement and an overlying sequence of late Paleozoic to early Cambrian metasedimentary and metaigneous rocks (Reference RAI 02.05.01-06 02).

Major thrusting and imbrication is thought to have occurred coincident with and following middle Paleozoic metamorphism. A thrust fault that borders the anticlinorium is thought to be coincident with the Inner Piedmont thrust stack that is related to the Taconic oregeny that occurred at about 440 to 470 Ma in the southern Appalachians (Reference RAI 02.05.01-06 02).

Lawrence and Hoffman (Reference 2.5.1-251) show four other major basement faults underlying the Coastal Plain: the Hollister fault zone, the Roanoke Island-Goldsboro fault and unnamed southwest-trending splay, and the inferred Pender fault. (Figure 2.5.1-213).The locations of these structures are inferred by Lawrence and Hoffman from cuttings and cores from 124 boreholes to basement, combined with Bouguer gravity and magnetic maps. The Hollister fault, crops out in the Piedmont and is mappable as magnetic lineaments to the south under the Coastal Plain cover. Dextral faulting on the Hollister fault zone is estimated to be 25 km (15.5 mi.) between 251 and 292 Ma. (Reference 2.5.1-251)

The Roanoke Island-Goldsboro fault, which is totally concealed by the Coastal Plain cover, is inferred primarily from truncated magnetic anomalies. Possible offsets suggest dextral displacement. The eastern end of the fault is on trend with a high-angle, south-wall-down-thrown fault that cuts the basement surface as well as the lower part of the Cretaceous section, suggesting possible later reactivation of an earlier basement fault. (Reference 2.5.1-251)

The inferred Pender fault is defined by an east-west discontinuity in the magnetic data. If this discontinuity is a fault, it would probably merge with the northeast-trending Piedmont fault system. The southern extensions of several of the north-south-trending faults, including the Hollister fault traces are truncated by the inferred Pender fault (Reference 2.5.1-251)."

Reference:

Reference RAI 02.05.01-06 01

Hatcher, R.D., P.J. Lemiszki, J.B. Whisner, "Character of rigid boundaries and internal deformation of the southern Appalachians foreland fold-thrust belt, " *The Geological Society of America*, Special Paper 433, pp. 243-276, 2007.

Reference RAI 02.05.01-06 02

Horton, J.W. Jr., and McConnell, K.I., "The Western Piedmont," in The Geology of the Carolinas - Carolina Geological Society 50th Anniversary Volume, ed. J.W. Horton, Jr. and V.A. Zullo, University of Tennessee Press, 1991.

Reference RAI 02.05.01-06 03

Hibbard, J.P., E.F. Stoddard, D.T.Secor, and A.J. Dennis, "The Carolina Zone: overview of Neoproterozoic to Early Paleozoic peri-Gondwanan terranes along the eastern Flank of the southern Appalachians," *Earth-Science Reviews*, Vol. 57, pp. 299-339, 2002.

Reference RAI 02.05.01-06 04

Bramlett, K.W., Secor, D.T., and Prowell, D.C., "The Belair Fault: A Cenozoic Reactivation Structure in the Eastern Piedmont," Geological Society of America Bulletin 93:1,109-1,117, 1982.

Reference RAI 02.05.01-06 05

West Jr., T.E., "Structural Analysis of the Carolina-Inner Piedmont Terrane Boundary: Implications for the Age and Kinematics of the Central Piedmont Suture, a Terrane Boundary that Records Paleozoic Laurentia-Gondwana Interactions," Tectonics 17 (3):379-394, 1998.

Attachments/Enclosures:

Attachment 02.05.01-01B: Figure 2.5.1-213 (Revised)

Attachment 02.05.01-03E: Figure 2.5.1-211 (Revised)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-7

Text of NRC RAI:

FSAR Section 2.5.1.1.4.2.2 provides a discussion about Paleozoic tectonic structures. Figure 2.5.1-214 shows that the Piedmont suture is closer to HAR than either the Brevard fault zone or the BRT. The Brevard fault essentially terminates against this fault. In addition this fault is shown to truncate against the Nutbush Creek fault.

a) The discussion of the Piedmont suture is limited to the geographic location and does not address the timing of movement or how it relates to other large fault systems with the 200 mile radius of the SHNPP. Please provide more information about this fault system from the most recent literature. Explain how it relates to the Nutbush Creek fault and to the Brevard fault zone.

b) The Brevard fault zone is a major tectonic feature in the 200 mile radius for the site and the FSAR refers the reader to the work of others for summaries of the geologic models of the Brevard Fault zone. However, the FSAR does not actually provide any review or summary of Brevard Fault zone models. Please provide a summary of current conceptual models for the Brevard Fault zone in the FSAR.

c) Figure 2.5.1-211 shows several regional faults located within the 200 mile radius of the site whose age of movement are not indicated on the figure legend nor are there discussions of these faults provided in the text. Please provide discussion of these faults and the likely age of movement. These faults include: Nubush Creek fault, Augusta fault, Modoc zone, faults in the vicinity of the Sauratown Mtn Window, the Gold Hill and Silver Hill faults.

d) The FSAR states that most of the HAR site is located within the Atlantic Coast tectonic province. Zoback and Zoback, 1989 indicate that there is no separate stress province for the Atlantic Coastal plain. Please define this tectonic province and cite recent literature.

PGN RAI ID #: H-0144

PGN Response to NRC RAI:

The discussion of Paleozoic structures will be expanded in a future revision to provide a more detailed discussion of the structural relationships and ages of structures in the HAR site region.

a) The last paragraph of Section 2.5.1.1.4.2.2 will be modified in a future revision as shown below to further evaluate the central Piedmont suture in terms of recent literature.

b) The fourth paragraph in Section 2.5.1.1.4.2.2 will be modified in a future revision as shown below to further describe the Brevard fault zone in terms of recent literature. The Brevard fault zone is an important Appalachian orogen structure and has been interpreted and modeled in many ways. Text will be modified to explain the history of thought involving the fault zone.

c) Various sections related to the discussion of tectonic features will be modified in a future revision as shown below to provide additional discussion of regional faults within the HAR site region. The discussion of Paleozoic-age faults from FSAR Section 2.5.1.1.4.2.1

mapped by Lawrence and Hoffman (Reference 2.5.1-251) will be moved to FSAR Subsection 2.5.1.1.4.2.2 Paleozoic Tectonic Structures. In addition to the expanded discussion of the Brevard fault zone and the Central Piedmont shear zone (suture), and the Eastern Piedmont fault system, additional discussion of specific faults will be added, including : Nutbush Creek fault, Augusta fault, Modoc shear zone, faults in the vicinity of the Sauratown Mountain Window, the Gold Hill and Silver Hill faults, faults underlying the Coastal Plain sediments east of the HAR site (i.e.,: the Roanoke Island-Goldsboro fault, the inferred Pender fault, and the Hollister fault)

d) The discussion of contemporary stress in the study region outlined in FSAR section 2.5.1.1.4.1 also noted that the Atlantic Coastal Plain stress province characterized by northwest compression, inferred in part from the orientations of post-Cretaceous reverse faults in the Coastal Plain region was not supported by updated stress maps. Reference to the Atlantic Coast tectonic province will be deleted from FSAR section 2.5.1.1.4.2.2 in a future revision. As outlined in the Response to RAI 02.05.01-6, a revised section 2.5.1.1.4.2.2 will focus on structural details associated with faults in the HAR site region. Contemporary tectonic stresses are examined in detail in section 2.5.1.1.4.1.

Associated HAR COL Application Revisions:

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

1. Revise the last two paragraphs of FSAR Section 2.5.1.4.2.2 from:

"The Brevard fault, a complex fault zone, is recognized as a major Alleghanian structure within the BRP thrust sheet (Reference 2.5.1-207). The Brevard fault defines the western boundary of the Piedmont physiographic province. The fault zone has had a complex history that includes Alleghanian dip- and strike-slip motion preceded by a history of dip-slip motion. A summary of earlier studies and models for the origin and structure of the Brevard fault zone is provided in Hatcher (Reference 2.5.1-207).

The Central Piedmont suture (Figure 2.5.1-211) is exposed from near the Georgia-Alabama boundary northward into central Virginia. From central South Carolina to the north, the fault is traceable to and folded into the Kings Mountain belt along the North Carolina-South Carolina border. The Central Piedmont suture separates the volcanic island-arc association of the Avalon-Carolina exotic terrane from the rocks of the Inner Piedmont and eastern Blue Ridge block, which have North American plate affinities. (Reference 2.5.1-215)"

To read:

"The Brevard fault zone is widely considered to be one of the most fundamental tectonic features of the southern Appalachian orogen (Reference RAI 02.05.01-07 01). The Brevard fault zone is described in detail by Horton and McConnell as a linear, southeast-dipping belt of mylonitic and cataclastic rocks, typically 1 to 2 km wide, that extends more than 600 km from the Gulf Coastal Plain onlap in Alabama almost to the North Carolina-Virginia border, where it apparently continues into Virginia as the Bowens Creek fault..The Brevard fault is a complex fault zone that is recognized as a major Alleghanian structure within the BRP thrust sheet (Reference 2.5.1-207). The fault zone has had a complex history that includes Alleghanian dip- and strike-slip motion preceded by a history of dip-slip motion. A summary of earlier studies and models for the origin and structure of the Brevard fault zone is provided in Hatcher (Reference 2.5.1-207; Reference 2.5.1-215; Reference RAI 02.05.01-07 01). In a summary of literature from the 1970s and early 1980s Horton and McConnell

(Reference RAI 02.05.01-07 01) conclude that the Brevard fault zone has experienced a long and complex Paleozoic history, including Taconic, Acadian (debated), and Alleghanian deformation, in which thrusting played an important role. An additional summary of work published on the Brevard fault zone from 1983-1988 by Horton and McConnell, contributed to the understanding and importance of the recognition and documentation of late Paleozoic (Alleghanian) dextral strike-slip along the fault zone. Hatcher (Reference 2.5.1-215) credits work done in the 1950s through 1970s as recognizing that the Brevard fault is a major crustal break that was therefore speculated to be a continental suture. Hatcher (Reference 2.1.5-215) recognized that as the understanding of the fault system has improved, the similarity of stratigraphic assemblages on both sides of the fault clearly indicates that it is not a suture. Whereas the multiple deformation histories of the fault zone are extensive and controversial, diabase dikes preclude post Jurassic slip on the Brevard fault and cooling age histories indicate that no slip has occurred on the Brevard fault since the late Paleozoic (Reference RAI 02.05.01-07 01).

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The Eastern Piedmont fault system (Figure 2.5.1-213) , which includes the Nutbush Creek fault and Modoc shear zone, extends from Alabama to Virginia and is described by Hatcher et al. (Reference 2.5.1-327) as a series of linear cataclastic zones that coincide with magnetic anomalies and parallel the trend of the Appalachians. These magnetic anomalies coincide with cataclastic rocks and also with a low velocity zone likely due to fracturing of the crystalline rocks during recurrent faulting. (Reference 2.5.1-327) The timing of movement on the fault system is constrained by faulted granites that are estimated to have formed approximately 400 Ma; the faults are intruded by Mesozoic dikes, and the faults do not offset Coastal Plain deposits. The Eastern Piedmont fault system may have been initiated within the slate-belt island arc as it collapsed and was accreted to North America during the early to middle Paleozoic (Reference 2.5.1-327).

The Nutbush Creek fault crops out in the Piedmont west of Raleigh (Reference 2.5.1-231). Based on apparent truncations of magnetic anomalies the Nutbush Creek fault is inferred to extend south and southwest under the North Carolina Coastal Plain into South Carolina where it may connect with the Modoc fault of Hatcher and others (Reference 2.5.1-327). Movement on this fault is estimated to be 160 km (100 mi.) of dextral offset between 312 and 285 Ma

The Modoc shear zone is a region of high ductile strain that can be traced through the Piedmont province of South Carolina and Georgia. The ductile zone marks the approximate northwestern limit of penetrative deformation and amphibolite-facies metamorphism. The zone trends northeast and can be invariably characterized by a deformed intrusive contact between upper Paleozoic plutonic orthogneiss in the Kiokee belt and older metamorphic and igneous rocks in the Carolina slate belt. The curving of lithologic contacts and structural elements in the zone along with a very steep surface dip to the northwest, is evidence for a zone of flattening or right-lateral strike-slip displacement. Within the Modoc zone there are limited amounts of brittle faulting that postdate the ductile shearing, but have displacements too small to interrupt the continuity of major lithologic units (Reference RAI 02.05.01-07 03).

The Augusta fault zone is concealed under the sediments of the Atlantic Coastal Plains for much of its length, and in the vicinity of its exposure in Augusta, Georgia, forms the northwest trending boundary between the Kiokee belt and the Belair belt. The fault zone is evident as a magnetic anomaly for much of its covered length. The fault zone shows evidence of an early ductile shear history with minor postmetamorphic brittle faulting similar to the Modoc shear zone. The Augusta fault zone is a thrust fault, displacing low-grade rocks of the Belair belt over high-grade rocks of the Kiokee belt. The fault has a surface dip of about 40 degrees SE, traceable by geophysical data to where the dip flattens to less than 8 degrees about 60 km to the south of the surface trace. (Reference RAI 02.05.01-07 03)

The Gold Hill-Silver Hill shear zone records dextral strike-slip motion in the Carolina terrane of North Carolina. Geologic similarities and along strike position of the Deal Creek shear zone (Figure 2.5.1-213) to the southwest suggest that it is an extension of the Gold Hill-Silver Hill shear zone. The two are separated by Inner Piedmont terrane rocks. The age of dextral strike-slip movement along the Gold Hill-Silver Hill fault is constrained between ~400 and ~325 Ma. (Reference RAI 02.05.01-07 04)

The Sauratown Mountains anticlinorium is a structural window in western North Carolina and southwestern Virginia. The anticlinorium is made up of four stacked thrust sheets each containing middle Proterozoic basement and an overlying sequence of late Paleozoic to early Cambrian metasedimentary and metaigneous rocks (Reference RAI 02.05.01-07 01).

Major thrusting and imbrication is thought to have occurred coincident with and following middle Paleozoic metamorphism. A thrust fault that borders the anticlinorium is thought to be coincident with the Inner Piedmont thrust stack that is related to the Taconic oregeny that occurred at about 440 to 470 Ma in the southern Appalachians (Reference RAI 02.05.01-07 01).

Lawrence and Hoffman (Reference 2.5.1-251) show four other major basement faults underlying the Coastal Plain: the Hollister fault zone, the Roanoke Island-Goldsboro fault and unnamed southwest-trending splay, and the inferred Pender fault.(Figure 2.5.1-213).The locations of these structures are inferred by Lawrence and Hoffman from cuttings and cores from 124 boreholes to basement, combined with Bouguer gravity and magnetic maps. The Hollister fault, crops out in the Piedmont and is mappable as magnetic lineaments to the south under the Coastal Plain cover. Dextral faulting on the Hollister fault zone is estimated to be 25 km (15.5 mi.) between 251 and 292 Ma. (Reference 2.5.1-251)

The Roanoke Island-Goldsboro fault, which is totally concealed by the Coastal Plain cover, is inferred primarily from truncated magnetic anomalies. Possible offsets suggest dextral displacement. The eastern end of the fault is on trend with a high-angle, south-wall-down-thrown fault that cuts the basement surface as well as the lower part of the Cretaceous section, suggesting possible later reactivation of an earlier basement fault. (Reference 2.5.1-251)

The inferred Pender fault is defined by an east-west discontinuity in the magnetic data. If this discontinuity is a fault, it would probably merge with the northeast-trending Piedmont fault system. The southern extensions of several of the north-south-trending faults, including the Hollister fault traces are truncated by the inferred Pender fault (Reference 2.5.1-251)."

2. Revise FSAR Section 2.5.1.1.4.2 from:

   "A tectonic map of the important structures within the Appalachian orogen in the HAR site region is shown on Figure 2.5.1-211; cross sections are shown on Figure 2.5.1-212. Regional tectonism in the Appalachians is expressed by uplift, subsidence, geomorphic features, seismicity, and faulting that has been occurring in response to long-term compression since the Early Cretaceous (Reference 2.5.1-242, Reference 2.5.1-233). Faulting typically is considered the most definitive evidence of crustal deformation. The entire state of North Carolina and most of the site region are located within the Atlantic Coast tectonic province characterized by Prowell (Reference 2.5.1-225). A small northwestern section of the site region is within the interior tectonic province. The Atlantic Coast province is characterized by Cretaceous and younger northeast-southwest-trending reverse fault zones and fault systems that may be as long as 100 km (60 mi.) (Prowell in Reference 2.5.1-225) (Figure 2.5.1-213). Although a component of lateral slip has been reported for many reverse faults, Prowell reports that dip-slip reverse motion is dominant (Reference 2.5.1-225). Fault strikes typically are within 45 degrees of north, and dips typically range from 40 to 85 degrees.

   The large Cretaceous and Cenozoic fault zones in the Appalachians have trends that are subparallel to the inner margin of the Coastal Plain. These similar orientations indicate the strong influence of the regional fabric of the Appalachian crystalline basement rocks, as well as the presence of preexisting structural features. (Prowell in Reference 2.5.1-225) Some researchers speculate that reactivation of faults associated with early Mesozoic rift basins and sutures between suspect and exotic terranes emplaced during the pre-Mesozoic may be responsible for much of the recent seismicity recorded in the eastern United States. Presumably, these faults have been reactivated in the present stress field, in which the maximum horizontal compressive stress is oriented east-northeast to west-southwest. (Reference 2.5.1-243)

   The primary source of the thick sediment layer deposited on the coastal margin is the uplift and subsequent erosion of exposed Appalachian crystalline rock. Over geologic time, rates of uplift in the Appalachians have been approximately 40 m (131 ft.) per m.y. (Prowell in Reference 2.5.1-225).

   Principal tectonic features in the site region 320-km (200-mi.) radius are shown on Figure 2.5.1-213. The principal tectonic structures within the HAR site region can be divided into five categories based on their age of formation or reactivation: Late Proterozoic to early Paleozoic, Paleozoic, Mesozoic, Cenozoic, or Quaternary time. These categories provide the framework for the discussion that follows."

   To read:

   The concepts of suspect (allochthons) and exotic terranes, which were recognized at the time of the EPRI-SOG study (Reference 2.5.1-203), have been more widely employed to decipher the accretionary history and tectonic evolution of the Appalachian orogen (see discussion in Subsection 2.5.1.1.2) and to define lithotectonic units (Reference 2.5.1-207;

Reference RAI 02.05.01-07 01; Reference RAI 02.05.01-07 05). A tectonic map of the important structures within the Appalachian orogen in the HAR site region as defined by Hatcher et al. (Reference 2.5.1-207) is shown on Figure 2.5.1-211; related regional cross sections are shown on Figure 2.5.1-212. A more recent lithotectonic map of the site region is shown on RAI 02.05.01-03 Figure 3.

Principal tectonic features in the site region 320-km (200-mi.) radius are shown on Figure 2.5.1-213. The principal tectonic structures within the HAR site region can be divided into five categories based on their age of formation or reactivation: Late Proterozoic to early Paleozoic, Paleozoic, Mesozoic, Cenozoic, or Quaternary time. These categories provide the framework for the discussion that follows.

References:

Reference RAI 02.05.01-07 01

Horton, J.W. Jr., and McConnell, K.I., "The Western Piedmont," in The Geology of the Carolinas - Carolina Geological Society 50th Anniversary Volume, ed. J.W. Horton, Jr. and V.A. Zullo, University of Tennessee Press, 1991.

Reference RAI 02.05.01-07 02

Hibbard, J.P., E.F. Stoddard, D.T.Secor, and A.J. Dennis, "The Carolina Zone: overview of Neoproterozoic to Early Paleozoic peri-Gondwanan terranes along the eastern Flank of the southern Appalachians," *Earth-Science Reviews*, Vol. 57, pp. 299-339, 2002.

Reference RAI 02.05.01-07 03

Bramlett, K.W., Secor, D.T., and Prowell, D.C., "The Belair Fault: A Cenozoic Reactivation Structure in the Eastern Piedmont," Geological Society of America Bulletin 93:1,109-1,117, 1982.

Reference RAI 02.05.01-07 04

West Jr., T.E., "Structural Analysis of the Carolina-Inner Piedmont Terrane Boundary: Implications for the Age and Kinematics of the Central Piedmont Suture, a Terrane Boundary that Records Paleozoic Laurentia-Gondwana Interactions," Tectonics 17 (3):379-394, 1998.

Reference RAI 02.05.01-07 05

Hibbard, J.P., van Staal, C.R., Rankin, D.W., and Williams, H. 2006: Lithotectonic map of the Appalachian Orogen, Canada-United States of America; Geological Survey of Canada, Map 2096A, scale 1:1 500 000.

Attachments/Enclosures:

Attachment 02.05.01-03E: Figure 2.5.1-211 (Revised)

Attachment 02.05.01-01B: Figure 2.5.1-213 (Revised)

Attachment 02.05.01-03C: RAI 02.05.01-03 Figure 3

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-8

Text of NRC RAI:

FSAR section 2.5.1.1.4.2.3 discusses Mesozoic tectonic structures and cites several figures.

a) Figure 2.5.1-209 does not label the Dan River, Wadesboro, Sanford and Durham basins. Please revise figure and label appropriately.

b) Figure 2.5.1-213 shows faults associated with the Triassic basins incorrectly colored. These faults should be color/labeled as Mesozoic because that is when the adjacent and associated basins were formed.

c) The Pembroke faults are discussed in text and are not included in any figure. The Eastern Piedmont fault system is included in Figure 2.5.1-213, but there is no discussion in the text about the Eastern Piedmont fault system. Please revise figure and text appropriately.

d) The Chatham fault is called out in text. However, in Figure 2.5.1-215, the Chatham fault is not identified. Please revise figure and include label.

e) The Colon cross structure and the Peking cross structures are not defined or described in the text. Define and describe these structures.

f) The FSAR states that the Jonesboro fault was probably seismologically similar to modern-day segmented, active basin-bounding normal faults in extensional tectonic settings. Please provide the basis for that statement and provide a discussion of the relevance to the HAR and any evidence for historic seismicity on this structure.

PGN RAI ID #: H-0145

PGN Response to NRC RAI:

a) Figure 2.5.1-209 is not cited in this section, and is a regional figure that is not appropriate for labeling of the subbasins of the Deep River Basin. Subbasins are identified on Figures 2.5.1-202 and 2.5.1-215.

b) The color of faults bounding Triassic basins will be changed on Figure 2.5.1-213 in a future revision to more clearly indicate latest known activity during the Mesozoic.

c) The general location of the Pembroke faults is shown on Figure 2.5.1-216, as cited in Subsection 2.5.1.1.4.2.5 (p. 2.5-37 of the FSAR). Further discussion of the evaluation of postulated Pembroke faults is provided in the Response to RAI 02.05.01-15. Discussion of the Eastern Piedmont fault system will be added to FSAR Subsection 2.5.1.1.4.2.2 in a future revision (See Response to RAI 02.05.01-6). The Brevard fault was shown on Figure 2.5.1-213 as part of the Eastern Piedmont fault system- Figures 2.5.1-213 and 2.5.1-229 will be modified in a future revision to correct this. Note: Figure 2.5.1-213 will be revised to include faults shown in RAI 02.05.01-03 Figure 3.

d) The Chatham fault zone borders the west edge of the Dan River Basin. It was mistakenly cited as bordering the west edge of the Deep River Basin. Text in FSAR section 2.5.1.1.4.2.3 will be corrected in a future revision.

e) The Colon and Pekin cross structures are described in the first paragraph of Subsection 2.5.1.2.4 and are areas that separate the three subbasins of the Deep River basin. The Deep River basin is divided into three subbasins, from north to south, the Durham, Sanford, and Wadesboro basins. The width of the Deep River Basin dramatically narrows at the Colon and Pekin cross structures (Reference 2.5.1-204). The Colon cross structure is a basement uplift and constriction that separates the Durham and Sanford basins (Reference 2.5.1-220).The Pekin cross structure separates the Sanford and Wadesboro basins, and is less well defined due to coastal plain sediment cover and limited subsurface data (Reference 2.5.1-220). The first paragraph of Subsection 2.5.1.2.4 will be revised in a future revision to better describe the Colon and Pekin cross structures.

f) Various authors including Bain and Harvey (Reference RAI 02.05.01-08 01), Bartholemew et al. (Reference 2.5.1-339), and Wooten et al. (Reference 2.5.1-254) have cited the Basin and Range faults and associated basins as an analogy for the structural and depositional environments of the Jonesboro fault and adjacent Durham basin during their development in Mesozoic time. Wooten et al. (Reference 2.5.1-254) used the Basin and Range and other modern normal faults as an analog to understand the complexity and structure of the Deep River Basin, and to subdivide the Jonesboro fault into four segments. The implication was not to suggest that the Jonesboro fault is structurally active. As illustrated in RAI 02.05.01-08 Figure 1 there is essentially no seismicity in the vicinity of the Deep River basin and there are no moderate to large magnitude earthquakes or alignments of seismicity associated with the Jonesboro fault to suggest it is a capable tectonic source.

Associated HAR COL Application Revisions:

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

1. Revise paragraph 3 of FSAR Section 2.5.1.1.4.2.3 from:

   "More than a dozen Mesozoic rift basins lie within the region (320-km [200-mi.] radius) of the site. The HAR site area is located within the Deep River basin, the southernmost exposed rift basin; to the south are large buried basins. In North Carolina, the exposed rift basins form two bands: the eastern band includes the Deep River basin and associated outlier Ellerbe and Crowburg basins and the western band includes the Dan River basin and the smaller outlier Davie County basin. Both the Deep River basin, in which the HAR site is located (Figure 2.5.1-215), and the Dan River basin are half-graben flanked by major normal fault zones toward which the basin strata dip. The Jonesboro fault system is on the eastern border of the Deep River basin, and the Chatham fault zone borders the western edge. Both basins exhibit stratigraphy common to most of the Newark Supergroup, that is, a sequence of three distinct stratigraphic units that are interpreted to have been deposited in an extensional basin, the areal extent of which increased through time.
   (Reference 2.5.1-220)"

   To read:

   "More than a dozen Mesozoic rift basins lie within the region (320-km [200-mi.] radius) of the site. The HAR site area is located within the Deep River basin, the southernmost exposed rift basin; to the south are large buried basins. In North Carolina, the exposed rift basins form two bands: the eastern band includes the Deep River basin and associated outlier Ellerbe and Crowburg basins and the western band includes the Dan River basin and the smaller outlier Davie County basin. Both the Deep River basin, in which the HAR site is located (Figure 2.5.1-215), and the Dan River basin are half-graben flanked by major normal fault zones toward which the basin strata dip. The Jonesboro fault system is on the eastern border of the Deep River basin. Both basins exhibit stratigraphy common to most of the Newark Supergroup, that is, a sequence of three distinct stratigraphic units that are interpreted to have been deposited in an extensional basin, the areal extent of which increased through time. (Reference 2.5.1-220)"

2. Revise paragraph 1 of FSAR Section 2.5.1.2.4 from:

   "The HAR site lies within the approximately 230-km- (144-mi.-) long Deep River basin (Figure 2.5.1-215), which traditionally is divided into three subbasins (from north to south): the Durham, Sanford, and Wadesboro basins (e.g., Reference 2.5.1-334, Reference 2.5.1-220). The Durham and Sanford basins are separated by a constriction and basement uplift called the Colon cross structure. Here the Deep River basin narrows appreciably (Figure 2.5.1-215). (Reference 2.5.1-220) The basement high represented by the Colon cross structure likely formed from differential subsidence between the Durham and Sanford basins (Reference 2.5.1-204). The eastern border of the Durham basin is step-faulted, and the basin is cut by north 45-degree-east-trending faults, parallel to the borders of the Sanford and Wadesboro basins. The Sanford and Wadesboro basins are separated by the Pekin cross structure and Coastal Plain overlap (Figure 2.5.1-215). (Reference 2.5.1-220) The Sanford and Wadesboro subbasins have been rotated by faulting, forming horst and graben structures within the basin (Reference 2.5.1-334). Two main sets of faults cut the Deep River basin. The major set strikes northeast (paralleling the Jonesboro fault) and includes faults both synthetic and antithetic to the Jonesboro that cut the basin into a series of largely post-depositional fault blocks that show differential subsidence (Reference 2.5.1-220). The other set of faults is roughly perpendicular to these, striking northwest. These faults are nearly vertical and are characterized by much smaller vertical displacements. Many of these northwest-striking faults have been intruded by diabase dikes. (Reference 2.5.1-220)"

   To read:

   "Pre-Mesozoic structures in the site vicinity include late Paleozoic fault zones that crop out in the Piedmont, the Nutbush Creek and Hollister faults, which are discussed in Subsection 2.5.1.1.4.2.2. These faults are characterized as late Paleozoic ductile mylonite zones having dominantly right-lateral strike-slip displacement (Reference 2.5.1-251). The site area and much of the surrounding site vicinity lie within the Deep River basin and the most recent deformation in the site area (within an 8-km- [5-mi.-] radius) is primarily related to Mesozoic rifting (see Subsection 2.5.1.2.4.1). Minor faults exposed in the foundation exposures of the Main Dam occur in crystalline rock within approximately 1 km (0.6 mi.) of the Jonesboro fault, the main eastern boundary fault of the Mesozoic basin. These are described in Subsection 2.5.1.2.4.2. Evidence for local, small faults in Cretaceous and post-Cretaceous faulting in the site vicinity beyond the site area is discussed in Subsection 2.5.1.2.4.3.

2.5.1.2.4.1 Mesozoic Structures

2.5.1.2.4.1.1 Deep River Basin Structures

The HAR site lies within the approximately 230-km- (144-mi.-) long Mesozoic Deep River basin (Figure 2.5.1-215), which traditionally is divided into three subbasins (from north to south): the Durham, Sanford, and Wadesboro basins (e.g., Reference 2.5.1-334, Reference 2.5.1-220). The Durham and Sanford basins are separated by a constriction and basement high called the Colon cross structure. Here the Deep River basin narrows appreciably (Figure 2.5.1-215). (Reference 2.5.1-220) The Colon cross-structure is constrained in part by field mapping. Slightly different lithologies occur on either side of the Colon cross-structure suggesting that the Colon structure may have acted as a barrier to sedimentation. (Reference 2.5.1-204) The basement high represented by the Colon cross structure likely formed from differential subsidence between the Durham and Sanford basins, but the details of the extent, structural components, and evolution of the Colon cross-structure are not well known (Reference 2.5.1-204, Reference 2.5.1-254). Gravity and aeromagnetic maps of the Durham basin provided by Bain and Brown (Reference 2.5.1-334) and Bain and Harvey (Reference RAI 02.05.01-08 01) as discussed in Subsection 2.5.1.2.4.4 suggest that basement is shallower where the basin narrows. The HAR site lies in the transition between the southern end of the Durham basin and the northern end of the Colon cross-structure.

Regional geologic mapping and fault investigations in the Durham basin north of the Colon cross structure conducted as part of a major study to characterize its waste storage potential provide additional data on the structural features in the Durham basin (Reference 2.5.1-334). In the Durham basin, northeast-trending faults and fracture zones are cross-faulted along north-northwest-tending faults and fracture zones to produce diamond and triangular shaped fault blocks in map view. The eastern border of the Durham basin is step-faulted and the basin is cut into a series of southeasterly rotated, post-depositional slices that trend parallel to the borders of the Sanford and Wadesboro basins (Reference 2.5.1-334).

The Sanford and Wadesboro basins are separated by the Pekin cross structure and Coastal Plain overlap (Figure 2.5.1-215). (Reference 2.5.1-220) The Sanford and Wadesboro subbasins have been rotated by faulting, forming horst and graben structures within the basin (Reference 2.5.1-334).

Two main sets of faults cut the Deep River basin. The major set strikes northeast (paralleling the Jonesboro fault) and includes faults both synthetic and antithetic to the Jonesboro that cut the basin into a series of largely post-depositional fault blocks that show differential subsidence (Reference 2.5.1-220). The other set of faults is roughly perpendicular to these, striking northwest. These faults are nearly vertical and are characterized by much smaller vertical displacements. Many of these northwest-striking faults have been intruded by diabase dikes. (Reference 2.5.1-220)

The most prominent faults of Mesozoic age mapped within the site vicinity (within a 40-km [25-mi.] radius) are the Jonesboro and Bonsal-Morrisville faults (Figure 2.5.1-230). Faults mapped in the site area (within an 8-km [5-mi.] radius) include the Jonesboro fault; the Harris fault (HF); the South Borrow Pit fault (SBPF); three smaller faults (faults FA, FB, and FC) at the borrow pits; the W8 and W82 faults; and two small, unnamed faults (Reference 2.5.1-275, Figure 2.5.1-230). Based on detailed studies that are discussed in the following sections, none of these faults is considered to be a capable tectonic source, as defined in Regulatory Guide 1.208, Appendix A (see discussion in Subsection 2.5.3.6)."

References:

Reference RAI 02.05.01-08 01

Bain, G.L and B.W. Harvey, "Field Guide to the Geology of the Durham Triassic Basin," Carolina Geological Society Fortieth Anniversary Meeting, October 7-9, 1977

Attachments/Enclosures:

Attachment 02.05.01-01B: Figure 2.5.1-213 (Revised)

Attachment 02.05.01-03C: RAI 02.05.01-03 Figure 3

Attachment 02.05.01-08A: Figure 2.5.1-216 (Sheets 1 and 2) (Revised)

Attachment 02.05.01-08B: Figure 2.5.1-229 (Revised)

Attachment 02.05.01-08C: RAI 02.05.01-08 Figure 1

Attachment 02.05.01-08D: Figure 2.5.1-230 (Sheet 1 of 2) (Revised)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-13

Text of NRC RAI:

FSAR Ref 2.5.1-208 and Ref 2.5.1-275 cite the NCGS web site for geologic map of NC and electronic communication.

a) The web site URL as stated in the FSAR document does not actually work when typed into the URL line of a browser application. Also, the NCGS web site presents several geologic maps on the final page. Which geologic map is being referenced in the FSAR? These maps have been digitized from the original to be served up on the internet. The original and official agency document needs to be referenced. In addition the web site has a disclaimer page that states: "These images are used for internal purposes by NCDENR. We assume no responsibility to maintain the data for the recipient in any manner or form." A WEB reference for a government agency must include a reference to the official agency record. If the WEB site is the official agency record, then it must be preserved and retrievable if the WEB site changes at some later date. Explain how you will meet this requirement.

b) What does "electronic communication" mean? How do we see or examine this information? Who is responsible for the content of this information?

PGN RAI ID #: H-0150

PGN Response to NRC RAI:

a) The web site URL for the state geologic maps of North Carolina is correct as listed in Reference 2.5.1-208. If there is difficulty accessing this site, it can be accessed by going to http://gis.enr.state.nc.us/sid/bin/ and clicking on State Geologic Maps. The geologic map legend and the lithotectonic map and explanations were used in the FSAR. These data were downloaded and saved as pdfs to preserve the information as downloaded. Digital data for the Geologic Map of North Carolina (geology, faults, and dikes) was obtained from the North Carolina Geological Survey as electronic GIS shapefiles. These shapefiles can also be downloaded from http://www.nconemap.com/Default.aspx?tabid=286. These shapefiles were digitized by the NCGS from the 1985 Geologic Map of North Carolina. The reference for 2.5.1-208 will be revised in Section 2.5.7 in a future revision.

b) Reference 2.5.1-275 refers to electronic GIS shapefiles of unpublished geologic mapping by the NCGS for the New Hill and Cokesbury quadrangles and the Raleigh 100k Quadrangle, and accompanying explanations, that were emailed to us by the NCGS on three different dates. Shapefiles are preserved as sent, and copies of the emails were saved. The reference for 2.5.1-275 will be revised in a future revision to include the Raleigh 100k Quadrangle in Section 2.5.7. As confirmed by recent communication with the NCGS, the final versions of the maps have not yet been released. The current preliminary draft of the Raleigh 100k map dated 10/10/08 is attached. It is also available through the National Geologic Map Database at http://ngmdb.usgs.gov/Prodesc/proddesc_82610.htm.

Associated HAR COL Application Revisions:

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

1. Reference 2.5.1-208 will be revised from:

   2.5.1-208 North Carolina Geological Society (NCGS), "Geologic Map of North Carolina (including Generalized Geologic Map, Map Showing Major Litho-Tectonic Features, Map Showing Geologic Belts from West to East, and Explanations)," 1985, Website, www.gis.enr.state.nc.us/sid/bin/index.plx?client=zGeologic_Maps&site=9AM, accessed March 27, 2006; and electronic communication March 27, 2006.

   To read:

   2.5.1-208 North Carolina Geological Society (NCGS), "Geologic Map of North Carolina (including Generalized Geologic Map, Map Showing Major Litho-Tectonic Features, Map Showing Geologic Belts from West to East, and Explanations)," 1985, Website, www.gis.enr.state.nc.us/sid/bin/index.plx?client=zGeologic_Maps&site=9AM, accessed March 27, 2006; digital GIS files for geology, faults, and dikes obtained by electronic communication March 27, 2006 and available at http://www.nconemap.com/Default.aspx?tabid=286.

2. Reference 2.5.1-275 will be revised from:

   2.5.1-275 North Carolina Geological Survey (NCGS), Unpublished Geologic Data for the New Hill and Cokesbury 7.5-minute Quadrangles via Electronic Communications of May 25, September 8, and October 10, 2006.

   To read:

   2.5.1-275 North Carolina Geological Survey (NCGS), Unpublished Geologic Data for the New Hill and Cokesbury 7.5-minute Quadrangles and the Raleigh 100k Quadrangle via Electronic Communications of May 25, September 8, and October 10, 2006.

Attachments/Enclosures:

See attached file:

Attachment 02.05.01-13A.pdf Preliminary Bedrock Geologic Map of the Raleigh Quadrangle, North Carolina

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-14

Text of NRC RAI:

FSAR section 2.5.1.1.4.2.5.6 (p. 2.5-46) refers to a Paleozoic mylonitic shear zone in the discussion of the Nutbush fall line along with Parker's (1979) reverse fault. The mylonite zone is not marked on the map. Please locate this feature on a map and explain the significance of Parker's reverse fault.

PGN RAI ID #: H-0151

PGN Response to NRC RAI:

The Paleozoic mylonitic shear zone will be labeled on Figure 2.5.1-219 as the Nutbush Creek Fault Zone based on the draft version of the Raleigh 100k quadrangle dated 10/10/08.

The reverse fault mapped by Parker (Reference 2.5.1-228) is a southward-dipping, low-angle reverse fault that displaces layering in fine-grained gneiss and quartz veins as well as the overlying pebbly sand terrace deposits, likely of Pliocene or Pleistocene age (RAI 02.05.01-14 Figure 1; fault number 150 on Figure 2.5.1-219). Minimum dip-slip displacement in the gneiss is 8 ft (2.4 m). Fault number 49 from the Prowell compilation, which has a reported attitude of N15°W, 39°SW may be the same feature as the Parker fault. Although the fault(s) are generally coincident with the Nutbush Creek fault zone, the general attitude of the faults relative to the Nutbush Creek fault, which trends N15°E in this region and the small displacement in deposits of Pliocene-early Quaternary age does not suggest that the Nutbush Creek fault or Nutbush fall zone are significant tectonic sources.

An updated discussion of the fall lines of Weems (FSAR section 2.5.1.1.4.2.5.6) is provided in RAI 02.05.01-12. Longitudinal stream profiles that accompany Figure 2.5.1-219 are included in RAI 02.05.01-12 as Figure 2.5.1-220. A more complete discussion of the Parker fault is included in RAI 02.05.01-18. A discussion of the mylonite shear zone associated with the Nutbush Creek fault zone is included in revised text in RAIs 02.05.01-08 and -20.

Associated HAR COL Application Revisions:

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

1. Figure 2.5.1-219 will be revised as described above.

Attachments/Enclosures:

Attachment 02.05.01-14A: Figure 2.5.1-219 (revised)

Attachment 02.05.01-14B: RAI 02.05.01-14 Figure 1

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-20

Text of NRC RAI:

FSAR Section 2.5.1.2.4 provides a discussion of the structural geology at the site area scale. Several faults near the HAR are covered in this section.

a) FSAR (p. 2.5-77) states that the eastern boundary of the Deep river basin is step faulted. Do you mean the western boundary of the basin?

b) FSAR (p. 2.5-78) states: "West/northwest-east/southeast-trending faults east of the Jonesboro fault are brittle faults that dip 60 to 70 degrees to the north or south and commonly are characterized by quartz breccia zones. These faults are associated with extension and opening of Mesozoic basins". Provide a reference for the stated interpretation.

c) FSAR (p. 2.5-79) states: "Vertically aligned cobbles and clastic dikes and pillar structures in the Durham basin suggest that ground shaking and liquefaction accompanied some large paleoseismic events along the Jonesboro fault during deposition of Triassic sediments in the adjacent basin (Reference 2.5.1-339)". Provide further explanation of why this is evidence of paleoliquefaction.

d) The FSAR (p. 2.5-80) provides a discussion of fracture and joints in the site area with respect to the local faults. The numerous sets of joint orientations are described in difficult to understand manner. Please provide rose diagrams or stereo net projection diagrams for the joint and fracture data discussed in the text. Keep the data separated/segregated per study area, such as the Low Level Radiological Waste site (LLRW), the Borrow pits, auxiliary dam, etc. Some of these data need to be added to the geologic maps to enable examination of the relationship to the local geology and to each group of joints.

f) FSAR (p. 2.5-80) states: "Faulting and fault-related folding were revealed in the south borrow pit by changes in the orientation of bedding." Is the fault seen in field exposure or is it inferred from analysis of bedding plane attitude? Please provide more details along with structural measurements (strike and dip on a geologic map).

g) FSAR states: "The South Borrow Pit fault (SBPF) is characterized by breccia, foliated breccia, and clay gouge." Are there photographs available to show the fault in the field setting along with the location of the breccias and gouge within the rock?

h) FSAR states: "Map units in the hanging wall of the SBPF form an outcrop-scale syncline having an east/southeast-plunging axis parallel to the SBPF." Please explain further by providing structural data on a map to illustrate the syncline.

i) FSAR (p. 2.5-82) states: "Examination of the strata adjacent to the W8 fault, regional relations, and seismic reflection data suggest that the W8 fault and other nearby, smaller north-south trending faults were last active in the Triassic, but did not produce surface rupture". Please explain how these data were used to constrain age of movement.

j) FSAR states: "Drag along the fault is revealed as a change in the orientation of bedding from easterly to westerly across the fault within the fault zone". Provide further explanation about what this statement means including and illustration of structural measurements on a geologic map.

k) FSAR (p. 2.5-82) states: "Figure 2.5.1-236 presents a schematic block diagram showing a conceptual structural model of the faults discussed previously". Please revise this figure so that it can be related the discussion in the text. Specifically the 'A' panel is not legible and doesn't have the HAR located for orientation and the 'B' panel is confusing and it is unclear what it is attempting to illustrate.

PGN RAI ID #: H-0157

PGN Response to NRC RAI:

a) No. This statement does apply to the Jonesboro fault. Based on detailed studies of the Durham basin, Bain and Brown (Reference 2.5.1-334) suggest that the Jonesboro fault is actually a fault zone characterized by step faulting along numerous individual faults. This is illustrated in the schematic block diagram illustrating the conceptual model of the distribution of lithofacies associations in the central Durham basin (Figure 2.5.1-233) and profile AA' on Figure 2.5.1-240. The text will be modified in a future revision for clarity and to provide a reference for the statement.

b) The reference for this statement is Heller et al., (Reference RAI 02.05.01-20 01). The text will be modified in a future revision to cite this reference.

c) The features interpreted to be related to strong ground shaking and liquefaction were observed in 1993 by M. Bartholomew, K. Fleischmann, and J. Wilson (Reference 2.5.1-339) in new road construction that provided temporary exposures at a location (referred to as the Angus Barn locality) close to the Jonesboro fault where it crosses U. S. Highway 70 midway between Raleigh and Durham. Bartholomew et al. (1994) in a Carolina Geological Survey guidebook that describes these exposures note that inferred paleoliquefaction features also are observed elsewhere in the basin:

> "Severe seismic shaking of nonindurated sediment during Triassic deposition is suggested by pillar structures (*e.g.,*Geer Street and U.S. 70, Durham) and numerous, locally abundant, sediment-filled (clastic) dikes (e.g., quarries near SE Durham, Bethesda, and Genlee) throughout the basin from Creedmoor to Sanford. At the Angus Barn locality, however, we observed (localities A and C, Figure 2) a less common type of soft-sediment deformation features associated with liquefaction that has not been noted elsewhere in the basin before. ....At the Angus Barn locality, the effect of soft-sediment deformation is most apparent in vertically oriented cobbles in beds of Triassic alluvial fan gravels (Figure 3A; locality C). Such re-orientation, which occurs as large cobbles rapidly gravitate downward through finer material, is common in gravel deposits adjacent to active faults ...and is attributed to severe shaking of unconsolidated gravels. Vertically oriented cobbles also occur in a nearby deformed channel deposits just west of locality A. "

Observations of the orientations, lengths, and relative ages of the older joint sets combined with the rapid, fluidized injection of clay and sand into some joints suggests that these features are related to syndepositional paleoseismic events (i.e., the clastic and clay dikes are consistent with their formation during large paleo-earthquakes associated with displacement on the adjacent Durham segment of the Jonesboro fault during Triassic-Jurassic development of the basin) (Reference RAI 02.05.01-20 02).

d) Section 2.5.1.2.4 will be revised to clarify the discussion of the structural features including fractures observed in the different study areas. Field measurements from the Auxilliary Dam, north and south borrow pit areas, rose diagrams and lower hemisphere equal-area stereonet projections of structure data from the north and south borrow pits and a summary table of fracture properties for fracture sets A and B in the hanging wall of the South Borrow Pit fault (SBPF) are shown on RAI 02.05.01-26 Figure 1. This figure will be added to the FSAR in a future revision. Fracture orientations in map view also are provided for the Low Level Radiological Waste site (LLRW) site study area (RAI 02.05.01-20 Figure 1). There are no summary rose diagrams or stereonet projection diagrams available for the fracture mapping completed at the HNP Unit 1 or Main Dam study areas. The text provided in the HAR FSAR summarizes the information as provided in the detailed studies for these areas.

f) Excavations made in the late-1970's for material to construct the Auxiliary Dam for the HNP Unit 1 (referred to as the north and south borrow pits) provided a well-exposed sequence of Triassic age sedimentary rocks the could be used to delineate major structures and structural trends at these locations. RAI 02.05.01-26 Figure 1illustrates the structural data and relationships between faulting and folding observed in the borrow pit areas.

g) Illustrations of the various structural features observed in the borrow pit area are shown in RAI 02.05.01-20 Figures 2-8. Locations of these features are shown on RAI 02.05.01-26 Figure 1.

h) The map units that define the plunging syncline in the hanging wall of the SBPF and related structural data are shown on RAI 02.05.01-26 Figure 1.

i) This statement was from Wooten et al. (Reference 2.5.1-251), which was illustrated in part by an east-west trending seismic reflection profile across the LLRW study area (RAI 02.05.01-20 Figures 9 and 10). Wooten et al. (2001) (Reference 2.5.1-251) conclude that the reflection data represent intrabasinal expressions of basin-scale, half-graben sedimentation and concomitant faulting in the Mesozoic Deep River rift basin. As illustrated in RAI 05.02.01-20 Figure 10, some of the faults interpreted from the reflection data are truncated by overlying subhorizontal reflective horizons suggesting that the faults were not active throughout the entire period of Mesozoic time represented by strata imaged in this profile. Wooten et al. (Reference 2.5.1-254) noted that correlation to core and geophysical logs in several wells along the E-W profile were used to interpret many of the observed reflective horizons as transitions from mudstone to sandstone, which may be the result of a series of upward-fining sequences. From the interpretation of this profile, it is suggested that the statement that these faults did not produce surface rupture was meant to imply that the faults died out during the Mesozoic and did not have surface expression during the period represented by the youngest strata imaged in the seismic profile.

The W8 fault, which is described as being listric at depth, is interpreted to have initially developed as a normal fault during normal movement on the Durham segment of the Jonesboro fault. It was subsequently reactivated as a right-lateral, strike-slip fault during normal displacements on the Holly Springs segment. (Reference 2.5.1-254). The fault is offset by younger east-west-trending faults, such as the W-82 and SBPF faults, suggesting the faults were last active in the Triassic (Figure 2.5.1-236).

FSAR Section 2.5.1.2.4 will be revised in a future revision to state that the W8 fault and other nearby, smaller north-south-trending faults are listric faults at depth that are displaced by later movement on east-west trending faults such as the SBPF; these north trending faults are therefore judged to have been last active in the Triassic (Reference 2.5.1-254).

j) Harding Lawson Associates (1997) (Reference 2.5.1-332) made the following observations that indicate drag along the W8. The changes in dip are also illustrated in RAI 02.05.01-20 Figure 1.

"Downhole imaging provides oriented bedding directions throughout each boring, so that variations in bedding orientation due to changes in depositional environment or structural deformation can be recognized. Dips west of the W8 fault are on the order of 20 degrees to the east, increasing to about 40 degrees approaching the fault. Immediately east of the W8 fault, a gentle anticline has been mapped, with nearly horizontal beds at the surface near the fault and dips systematically increasing to about 20 degrees NE both with depth near the fault and eastward."

k) The model shown in Figure 2.5.1-236A represents structural relationships for faults in the borrow pit and LLRW study areas. The HAR site is located approximately 2 km to the east of the borrow pits and therefore is not depicted on this figure. To better clarify the sequence of deformational events that resulted in the structural relationships depicted in Figure 2.5.1-236A, additional block diagram figures illustrating the different stages of structural development have been added to the figure (Figure 2.5.1-236C). The schematic diagram shown in Figure 2.5.1-236 B illustrates how movement on different segments of the Jonesboro fault likely influenced the direction of slip on the faults in the LLRW study and borrow pit areas. This is further illustrated and described in Figure 2.5.1-236C.

Associated HAR COL Application Revisions:

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

1. Revise FSAR Section 2.5.1.2.4 from:

"The HAR site lies within the approximately 230-km- (144-mi.-) long Deep River basin (Figure 2.5.1-215), which traditionally is divided into three subbasins (from north to south): the Durham, Sanford, and Wadesboro basins (e.g., Reference 2.5.1-334, Reference 2.5.1-220). The Durham and Sanford basins are separated by a constriction and basement uplift called the Colon cross structure. Here the Deep River basin narrows appreciably (Figure 2.5.1-215). (Reference 2.5.1-220) The basement high represented by the Colon cross structure likely formed from differential subsidence between the Durham and Sanford basins (Reference 2.5.1-204). The eastern border of the Durham basin is step-faulted, and the basin is cut by north 45-degree-east-trending faults, parallel to the borders of the Sanford and Wadesboro basins. The Sanford and Wadesboro basins are separated by the Pekin cross structure and Coastal Plain overlap (Figure 2.5.1-215). (Reference 2.5.1-220) The Sanford and Wadesboro subbasins have been rotated by faulting, forming horst and graben structures within the basin (Reference 2.5.1-334). Two main sets of faults cut the Deep River basin. The major set strikes northeast (paralleling the Jonesboro fault) and includes faults both synthetic and antithetic to the Jonesboro that cut the basin into a series of largely post-depositional fault blocks that show differential subsidence (Reference 2.5.1-220). The other set of faults is roughly perpendicular to these, striking northwest. These faults are nearly vertical and are characterized by much smaller vertical displacements. Many of these northwest-striking faults have been intruded by diabase dikes. (Reference 2.5.1-220)

The most prominent faults mapped within the site vicinity (within a 40-km [25-mi.] radius) are the Jonesboro and Bonsal-Morrisville faults (Figure 2.5.1-230). Many smaller faults also have been mapped within the site vicinity; several of these are associated with the Jonesboro fault. Additionally, faults that trend approximately north 10 degrees east, observed east of the Jonesboro fault within Paleozoic igneous and metamorphic rocks (Figure 2.5.1-230), are late Paleozoic ductile mylonite zones having dominantly right-lateral strike-slip displacement. West/northwest-east/southeast-trending faults east of the Jonesboro fault (Figure 2.5.1-230) are brittle faults that dip 60 to 70 degrees to the north or south and commonly are characterized by quartz breccia zones. These faults are associated with extension and opening of Mesozoic basins. Similarly, northwest-southeast-trending folds located west of the bend in the Jonesboro fault are either syndepositional fault-bend folds or were formed from differential movement along the Jonesboro fault. Most faults in the site vicinity are pre-Cretaceous, but a few cut Cretaceous sediments; one cuts Pliocene/Pleistocene terrace deposits (Figure 2.5.1-230, Reference 2.5.1-228, Reference 2.5.1-256). A southward-dipping, low-angle thrust fault formerly exposed in a railroad cut near the town of Banks (approximately 23 km [14 mi.] east of the HAR site) displaces pebbly sand terrace deposits of probable Pliocene or Pleistocene age, having produced approximately 2.5 m (8 ft.) of dip-slip displacement (Reference 2.5.1-228) (Feature 150, Figure 2.5.1-230). Another reverse fault, found approximately 80 km (50 mi.) southeast of the site, offsets Pliocene-Pleistocene sand and clay of the Coharie formation by up to 3 m (9 ft.), and appears to have large lateral offset (Table 2.5.1-201, Number 46).

Faults mapped in the site area (within an 8-km [5-mi.] radius) include the Jonesboro fault; the Harris fault; the South Borrow Pit fault; three smaller faults (faults A, B, and C) at the borrow pits; the W8 and W82 faults; and two small, unnamed faults (Reference 2.5.1-275, Figure 2.5.1-230). Based on detailed studies, none of these faults is considered to be a capable tectonic source, as defined in Regulatory Guide 1.208, Appendix A (see discussion in Subsection 2.5.3.6).

The Jonesboro fault, part of which is located approximately 6.5 km (4 mi.) south of the site, is more than 160 km (100 mi.) long. It trends northeast-southwest, dips northwest, and forms the southeastern side of the Deep River basin (Figure 2.5.1-215). It marks the contact between Triassic sedimentary rocks to the west and Paleozoic volcaniclastic and crystalline rocks to the east (Figure 2.5.1-230). The Jonesboro fault and other associated faults probably were reactivated along older structural trends in the basement rock (Reference 2.5.1-202). Reactivation or initiation of tensional, normal-type movement along the Jonesboro fault was followed by deposition of Triassic sediments. The fault was last active between the intrusion of Late Triassic – Jurassic dikes and deposition of the overlying, unfaulted Cretaceous marine sediments (Reference 2.5.1-202). Southwest of the Main Dam, the fault is covered by unbroken Cretaceous sediments (Reference 2.5.1-202). The estimated total displacement along the Jonesboro fault is 3000 to 4500 m (9840 to 14,760 ft.) of dip-slip displacement (e.g., Reference 2.5.1-204); the amount of lateral displacement is unknown. The Jonesboro fault can be divided into four segments, which are marked by abrupt, 30- to 60-degree changes in trend of the main fault surface: the Creedmoor segment (CS), the Durham segment (DS), the Holly Springs segment (HSS), and the Sanford composite segment (SCS) (Figure 2.5.1-215, Reference 2.5.1-339, Reference 2.5.1-254). Recurring displacement on the Holly Springs and Durham segments of the Jonesboro fault during the Triassic account for the development of most of the structural features in the site area (Reference 2.5.1-254). The approximately 55-km- (34-mi.-) long Durham segment extends from the abrupt (east/northeast to north/northeast) deflection point near Holly Springs to the abrupt (northeast to north/northwest) deflection point approximately 10.6 km (6.6 mi.) east of Creedmoor (Reference 2.5.1-339, Figure 2.5.1-215). Vertically aligned cobbles and clastic dikes and pillar structures in the Durham basin suggest that ground shaking and liquefaction accompanied some large paleoseismic events along the Jonesboro fault during deposition of Triassic sediments in the adjacent basin (Reference 2.5.1-339). In contrast, sheared cobbles and gouge zones indicate subsequent brittle fracturing of indurated rock at depth. Triassic movement on the central part of the Durham segment of the Jonesboro fault was primarily sinistral-oblique normal, as indicated by slip directions on nearby smaller faults. The overall direction of Triassic extension, inferred from these slip directions, was approximately east-west. (Reference 2.5.1-339)

Faults identified during a comprehensive study for siting of the HNP site and studies of the foundation excavations for the Main Dam include the Harris (or Site) fault and minor faults at the Main Dam. Subsequent detailed investigations that included drilling, trenching, geophysical surveys, and detailed mapping of exposures in the south borrow pit were conducted to evaluate a potential site for a low-level waste repository approximately 2.4 km (1.5 mi.) west of the HAR site (Reference 2.5.1-332, Reference 2.5.1-254). The deformation and timing of the most recent movement on the Harris fault is described in detail in Subsection 2.5.3. The Harris fault, along with faults identified at a potential LLRW disposal facility site and two borrow pit sites west and south of the HAR site, are minor faults associated with the Jonesboro fault. These faults generally trend either approximately east-west or north-south (Figure 2.5.1-231). The Harris fault, where exposed in sedimentary beds, exhibits an approximately east strike, has a southerly dip between 55 and 90 degrees, always exhibits drag folding on the hanging wall, and seldom exhibits any disturbance of bedding planes on the northern or "foot" wall. The Harris fault tends to become oversteepened in coarser-grained sandstones and is nearly vertical adjacent to diabase dikes that it offsets. (Reference 2.5.1-202) Based on borehole data, vertical offset in Triassic sediments along the fault in the vicinity of the HNP site is between 25 and 30 m (80 and 100 ft.) (Reference 2.5.1-202). Bedding in the Triassic bedrock underlying the HNP site and adjacent areas strikes north 5 degrees to 15 degrees east and dips 9 to 17 degrees to the southeast (Reference 2.5.1-202).

Three prominent joint sets were observed at the HNP site; the two dominant sets are vertical. One set strikes north 40 degrees to 50 degrees east; the other strikes north 20 degrees to 30 degrees west. The third joint set trends north/northwest-south/southeast and dips 55 to 70 degrees to the southwest (Reference 2.5.1-202). Joints are irregularly spaced every few feet and are mostly vertical (Reference 2.5.1-202).

High-angle joints and fractures were observed in oriented acoustic soundings in Boreholes BPA-5, BPA-47, and BPA-48 at HAR 2, and Boreholes BPA-25, BPA-49, and BPA-50 at HAR 3, as discussed in Subsection 2.5.4.4.2.2. These features predominantly dip between 60 to 70 degrees to the west to northwest. Isolated high-angle joints are also oriented in other directions.

At the auxiliary dam (Figure 2.5.1-232), two dominant, high-angle fracture sets are seen in muddy, sandy conglomerate and muddy conglomeratic sandstone beds. The first strikes east/northeast and dips 75 to 90 degrees south; the second strikes south/southeast and dips 60 to 90 degrees west (Reference 2.5.1-254). The east/northeast-striking set is parallel to the Harris fault and is interpreted to represent extensional fractures developed during normal, dip-slip movement on the Harris fault. Locally, pinnate fractures show evidence for a component of left-lateral movement on the fault (Reference 2.5.1-254). South/southeast-striking fractures likely predate intrusion of dikes and are related to generally east-west extension along the Jonesboro fault and related structures (Reference 2.5.1-254). Termination relationships among the fracture sets indicate that the east/northeast-striking fractures are younger than the south/southeast-striking fractures (Reference 2.5.1-254).

Twenty-four minor faults having lengths measured in meters to tens of meters (tens of feet) and displacements measured in centimeters (inches), all judged to be noncapable, were mapped in pre-Triassic crystalline rocks in the foundation of the Main Dam (Reference 2.5.1-202, Reference 2.5.1-331). The Main Dam is located approximately 900 m (3000 ft.) southeast of the Jonesboro fault in an area of pre-Triassic igneous and metamorphic rocks consisting of granite, hornblende-mica gneiss, layered quartz-feldspar gneiss, and mica schist (Reference 2.5.1-331, Figure 2.5.1-230). The dominant joint set in the crystalline rocks at the Main Dam strikes approximately north 60 degrees to 70 degrees east and dips 50 to 70 degrees southeast. Another set strikes north 20 degrees to 35 degrees west and dips 70 to 90 degrees southwest. (Reference 2.5.1-331) The foliation in this area generally strikes approximately north 55 degrees east and dips 60 degrees northwest. Joints typically are spaced approximately 1 m (2 – 3 ft.) apart and strike northeast and northwest (Reference 2.5.1-331). Folding in the site area is most common in gneisses and schists exposed in the foundation of the Main Dam. These rocks appear to have undergone several periods of folding, predominately isoclinal folding (Reference 2.5.1-331). The magnitude of this folding could not be determined because of the limited area of exposure of the crystalline rocks.

Faulting and fault-related folding were revealed in the south borrow pit by changes in the orientation of bedding. In the borrow pit, the South Borrow Pit fault (SBPF) strikes north 72 degrees west, dips 30 to 70 degrees south, has a minimum trace length of approximately 430 m (1400 ft.) based on known exposures, and exhibits a right-stepping pattern across the borrow pit (Reference 2.5.1-226). In the westernmost part of the borrow pit, the strike of the SBPF ranges from north 80 degrees east to north 50 degrees west over 60 m (200 ft.) along strike, and dip ranges from 40 degrees to vertical. The SBPF is characterized by breccia, foliated breccia, and clay gouge (Reference 2.5.1-226). Map units in the hanging wall of the SBPF form an outcrop-scale syncline having an east/southeast-plunging axis parallel to the SBPF (Reference 2.5.1-254). The geometry of the syncline suggests it was formed by drag related to normal or right-lateral strike-slip movement along the SBPF (Reference 2.5.1-254).

Several dominant fracture orientations were seen in the north borrow pit. The oldest set of joints trend north/northwest-south/southeast, are bleached, and terminate against bedding. East/northeast-west/southwest-trending, bleached joints terminate against the oldest north/northwest-south/southeast set; younger east-west-trending joints abut both of the older sets. The east-striking set is subparallel to and genetically related to the SBPF. The other set, which strikes generally north, is interpreted to have formed prior to movement on the SBPF. Fracture spacing increases with distance from the SBPF; close to the SBPF fractures are 10 to 30 cm (4 to 12 in.) apart. (Reference 2.5.1-226) East/northeast-striking fractures exposed in the southern end of the south borrow pit are interpreted to be related to the W82 fault to the south (Reference 2.5.1-254). Older joints typically are 1 – 3 m (3 – 10 ft.) long; younger joints are less than 0.3 m (1 ft.) long (Reference 2.5.1-254). East/southeast-striking, nearly vertical fractures are dominant in the south borrow pit, especially in the hanging wall near the SBPF. These fractures have been interpreted to reflect extension orthogonal to the SBPF. (Reference 2.5.1-254) Bedding-parallel fractures that occur throughout the south borrow pit likely are related to east-west extension and basin-parallel faulting (Reference 2.5.1-254).

Three smaller faults (faults A, B, and C) also were mapped in the south borrow pit (Figure 2.5.1-232). Fault A is a northeast-striking, near-vertical to steeply east-dipping normal fault that terminates at its southern end against the SBPF. It is characterized by partly to completely decomposed, foliated breccia; random-fabric breccia; and contorted beds. The zone of contorted bedding and brecciated rock is 1 – 3 m (3 – 10 ft.) wide and can be traced approximately 35 m (110 ft.) along strike. The strike of the foliation and compositional layering within the fault zone generally is oblique to the strike of the fault, but drag-folding along the fault indicates a component of normal displacement. (Reference 2.5.1-226) Initial movement along fault A is interpreted as normal displacement antithetic to the Jonesboro fault and as predating movement on the SBPF (Reference 2.5.1-226). Kinematic indicators suggest a right-lateral component of movement on fault A, similar to the W8 fault (Reference 2.5.1-226). Fault B is a normal fault that strikes north 20 degrees to 25 degrees west, dips 85 to 90 degrees west, and can be traced approximately 24 m (80 ft.) along strike. The fault is characterized by less than 20 cm (8 in.) of foliated breccia and breccia, intense fracturing, and clay. Fault C generally strikes north 35 degrees east, dips 60 degrees south, and is characterized by a 25- to 33-cm- (10- to 13-in.-) wide foliated breccia. Folds in the hanging wall may indicate compressional, left-lateral, and possibly reverse components of movement on fault C. (Reference 2.5.1-226)

Three primary faults were identified at the LLRW disposal facility site: the W8 fault, the W82 fault, and the western extension of the SBPF (Figure 2.5.1-232). The east/southeast-west-northwest-trending SBPF and the W82 fault were mapped approximately 760 and 975 m (2500 and 3200 ft.) south of the Harris fault, respectively (Figures 2.5.1-231 and 2.5.1-232). The W8 fault strikes north/northeast and dips approximately 55 degrees west (Reference 2.5.1-332). The W82 fault strikes east/northeast, subparallel to the Harris fault, and dips toward the south (Reference 2.5.1-226). Identification of these faults was based on three primary stratigraphic marker units: conglomeratic sandstone, sandstone, and purple sandstone and mudstone, all of which could be traced over tens of meters (hundreds of feet). Bedding dips generally from 15 to 20 degrees east (Reference 2.5.1-332). Examination of the strata adjacent to the W8 fault, regional relations, and seismic reflection data suggest that the W8 fault and other nearby, smaller north-south-trending faults were last active in the Triassic, but did not produce surface rupture (Reference 2.5.1-254). Borehole W205CH1 intersected the W8 fault at a depth of approximately 100 m (330 ft.), indicating a dip of approximately 55 degrees. Borehole cores showed that the fault is expressed as a zone of numerous fractures extending approximately 3 m (10 ft.) above and approximately 9 m (30 ft.) below the fault. (Reference 2.5.1-332) Drag along the fault is revealed as a change in the orientation of bedding from easterly to westerly across the fault within the fault zone. Bedding dips increase from approximately 20 degrees east to the west of the W8 fault to approximately 40 degrees east approaching the fault (Reference 2.5.1-332). Because stratigraphy differs on either side of the fault, displacement could not be measured directly; therefore, the fault is assumed to have more than 275 m (900 ft.) of vertical displacement (Reference 2.5.1-332). Trench mapping that extended approximately 600 m (2000 ft.) east and west of the W8 fault revealed no other faults of this size (Reference 2.5.1-332). Approximately 20 smaller, low-angle, bedding-parallel faults, exhibiting little or no displacement, were observed in the trenches (Reference 2.5.1-332).

Two dominant fracture sets were observed during trenching, drilling (using electrical and optical imaging techniques), and mapping studies at the LLRW disposal facility site. One set is parallel to the bedding, strikes roughly north, and dips to the east. The other fracture set strikes generally north and dips steeply west, is orthogonal to the first, and is not bedding parallel. (Reference 2.5.1-332) High-angle fractures are most abundant in the hanging wall of the W8 fault, and fracture density also may increase near minor faults

(Reference 2.5.1-332). The bedding-parallel fractures tend to occur at the boundaries of units that have significantly different mechanical properties, such as coarse-grained sandstone in contact with mudstone. Many of these boundary areas have accommodated slip during ancient faulting and tilting episodes (Reference 2.5.1-332).

Figure 2.5.1-236 presents a schematic block diagram showing a conceptual structural model of the faults discussed previously. Wooten et al. discuss the structural development of these faults, relating them to the dominant directions of displacement on the Durham and Holly Springs segments of the Jonesboro fault (Figure 2.5.1-236) (Reference 2.5.1-254). Wooten et al. note that although the dominant displacement on all three east/southeast-west/northwest-trending faults was normal (down to the south or southeast), the steep dips (70 to 90 degrees) along parts of the fault suggest that the faults originated as strike-slip faults accommodating displacement at the southern end of the Durham segment (Reference 2.5.1-254)."

To read:

"2.5.1.2.4 Structural Geology of Site Area

Pre-Mesozoic structures in the site vicinity include late Paleozoic fault zones (e.g., the Nutbush Creek fault) that crop out in the Piedmont, which are discussed in Subsection 2.5.1.1.4.2.2. These faults are characterized as late Paleozoic ductile mylonite zones having dominantly right-lateral strike-slip displacement (Reference 2.5.1-251). The site area and much of the surrounding site vicinity lie within the Deep River basin and the most recent deformation in the site area (within an 8-km- [5-mi.-] radius) is primarily related to Mesozoic rifting (see Subsection 2.5.1.2.4.1). Minor faults exposed in the foundation exposures of the Main Dam occur in crystalline rock within approximately 1 km (0.6 mi.) of the Jonesboro fault, the main eastern boundary fault of the Mesozoic basin. These are described in Subsection 2.5.1.2.4.2. Evidence for local, small Cretaceous and post-Cretaceous faulting in the site vicinity beyond the site area is discussed in Subsection 2.5.1.2.4.3.

2.5.1.2.4.1 Mesozoic Structures

2.5.1.2.4.1.1 Deep River Basin Structures

The HAR site lies within the approximately 230-km- (144-mi.-) long Mesozoic Deep River basin (Figure 2.5.1-215), which traditionally is divided into three subbasins (from north to south): the Durham, Sanford, and Wadesboro basins (e.g., Reference 2.5.1-334, Reference 2.5.1-220). The Durham and Sanford basins are separated by a constriction and basement high called the Colon cross structure. Here the Deep River basin narrows appreciably (Figure 2.5.1-215). (Reference 2.5.1-220) The Colon cross-structure is constrained in part by field mapping. Slightly different lithologies occur on either side of the Colon cross-structure suggesting that the Colon structure may have acted as a barrier to sedimentation. (Reference 2.5.1-204) The basement high represented by the Colon cross structure likely formed from differential subsidence between the Durham and Sanford basins, but the details of the extent, structural components, and evolution of the Colon cross-structure are not well known (Reference 2.5.1-204, Reference 2.5.1-254). Gravity and aeromagnetic maps of the Durham basin provided by Bain and Brown (Reference 2.5.1-334) and Bain and Harvey (RAI Reference 02.05.01-20 03) as discussed in Subsection

2.5.1.2.4.4 suggest that basement is shallower where the basin narrows. The HAR site lies in the transition between the southern end of the Durham basin and the northern end of the Colon cross-structure.

Regional geologic mapping and fault investigations in the Durham basin north of the Colon cross structure conducted as part of a major study to characterize its waste storage potential provide additional data on the structural features in the Durham basin (Reference 2.5.1-334). In the Durham basin, northeast-trending faults and fracture zones are cross-faulted along north-northwest-tending faults and fracture zones to produce diamond and triangular shaped fault blocks in map view. The eastern border of the Durham basin is step-faulted and the basin is cut into a series of southeasterly rotated, post-depositional slices that trend parallel to the borders of the Sanford and Wadesboro basins (Reference 2.5.1-334).

The Sanford and Wadesboro basins are separated by the Pekin cross structure and Coastal Plain overlap (Figure 2.5.1-215). (Reference 2.5.1-220) The Sanford and Wadesboro subbasins have been rotated by faulting, forming horst and graben structures within the basin (Reference 2.5.1-334).

Two main sets of faults cut the Deep River basin. The major set strikes northeast (paralleling the Jonesboro fault) and includes faults both synthetic and antithetic to the Jonesboro that cut the basin into a series of largely post-depositional fault blocks that show differential subsidence (Reference 2.5.1-220). The other set of faults is roughly perpendicular to these, striking northwest. These faults are nearly vertical and are characterized by much smaller vertical displacements. Many of these northwest-striking faults have been intruded by diabase dikes. (Reference 2.5.1-220)

The most prominent faults of Mesozoic age mapped within the site vicinity (within a 40-km [25-mi.] radius) are the Jonesboro and Bonsal-Morrisville faults (Figure 2.5.1-230). Faults mapped in the site area (within an 8-km [5-mi.] radius) include the Jonesboro fault; the Harris fault (HF); the South Borrow Pit fault (SBPF); three smaller faults (faults FA, FB, and FC) at the borrow pits; the W8 and W82 faults; and two small, unnamed faults (Reference 2.5.1-275, Figure 2.5.1-230). Based on detailed studies that are discussed in the following sections, none of these faults is considered to be a capable tectonic source, as defined in Regulatory Guide 1.208, Appendix A (see discussion in Subsection 2.5.3.6).

Jonesboro Fault

The Jonesboro fault, part of which is located approximately 6.5 km (4 mi.) south of the site, is more than 160 km (100 mi.) long. It trends northeast-southwest, dips northwest, and forms the southeastern side of the Deep River basin (Figure 2.5.1-215). It marks the contact between Triassic sedimentary rocks to the west and Paleozoic volcaniclastic and crystalline rocks to the east (Figure 2.5.1-230). The Jonesboro fault and other associated faults probably were reactivated along older structural trends in the basement rock (Reference 2.5.1-202). Reactivation or initiation of tensional, normal-type movement along the Jonesboro fault was followed by deposition of Triassic sediments. The fault was last active between the intrusion of Late Triassic – Jurassic dikes and deposition of the overlying, unfaulted Cretaceous marine sediments (Reference 2.5.1-202). Southwest of the Main Dam, the fault is covered by unbroken Cretaceous sediments (Reference 2.5.1-202). The estimated total displacement along the Jonesboro fault is 3000 to 4500 m (9840 to 14,760 ft.) of dip-slip displacement (e.g., Reference 2.5.1-204); the amount of lateral displacement is unknown. The Jonesboro fault can be divided into four segments, which are marked by abrupt, 30- to 60-degree changes in trend of the main fault surface: the Creedmoor segment (CS), the Durham segment (DS), the Holly Springs segment (HSS), and the Sanford composite segment (SCS) (Figure 2.5.1-215, Reference 2.5.1-339, Reference 2.5.1-254). Recurring displacement on the Holly Springs and Durham segments of the Jonesboro fault during the Triassic account for the development of most of the structural features in the site area (Reference 2.5.1-254). The approximately 55-km- (34-mi.-) long Durham segment extends from the abrupt (east/northeast to north/northeast) deflection point near Holly Springs to the abrupt (northeast to north/northwest) deflection point approximately 10.6 km (6.6 mi.) east of Creedmoor (Reference 2.5.1-339, Figure 2.5.1-215). Reported vertically aligned cobbles and clastic dikes and pillar structures in the Durham basin observed in road construction exposures that are no longer visible suggest that ground shaking and liquefaction accompanied some large paleoseismic events along the Jonesboro fault during deposition of Triassic sediments in the adjacent basin (Reference 2.5.1-339). In contrast, sheared cobbles and gouge zones indicate subsequent brittle fracturing of indurated rock at depth. Triassic movement on the central part of the Durham segment of the Jonesboro fault was primarily sinistral-oblique normal, as indicated by slip directions on nearby smaller faults. The overall direction of Triassic extension, inferred from these slip directions, was approximately east-west. (Reference 2.5.1-339)

As part of the HNP Unit 1 FSAR investigations, magnetic and reconnaissance surveys were conducted on diabase dikes and "cross-faults" occurring along the Jonesboro fault in an effort to constrain the timing of faulting on the Harris fault. None of the dikes mapped at these locations are continuous across the Jonesboro fault, indicating that the amount of offset between dikes varies from 400 to 130 m (1300 to 420 ft.). (Reference 2.5.1-202) The age of last movement on the Jonesboro fault is bracketed between the intrusion of Late Triassic-Jurassic dikes and the deposition of the overlying unfaulted Cretaceous marine sediments, between 180 and 135 Ma (Reference 2.5.3-202; Reference 2.5.1-275). Existing exposures of the Jonesboro fault are rare. During a period of abnormally low lake level in 1995 a normally submerged exposure of the fault was observed by Tyler Clark (NCGS) along the Shearon Harris reservoir shoreline approximately 3 km southwest of where Buckhorn Creek enters the lake (Figure 2.5.1-231). At this location very saprolitic coarse grained Triassic sediment was observed to be juxtaposed against a saprolitic light-colored sandstone interpreted to be Buckhorn granite/granodiorite. The contact between the two units, the Jonesboro fault, was observed to be an approximately 0.5 m (1.6 ft.) wide zone of anatomosing fault surfaces and fault breccia. As observed at other locations along the Jonesboro fault, ductile deformation features overprinted by brittle deformation observed at this location suggest that the fault initiated at depth in the ductile realm and later experienced brittle deformation due to footwall uplift. A wave-cut scarp at the faulted contact was interpreted to be due to fault line erosion.

Additionally, no geomorphic features indicative of Quaternary reactivation of faulting (e.g., scarps in post-Mesozoic deposits, offset geomorphic features, vegetation lineaments) were noted during field and aerial reconnaissance conducted for this study. Based on the above observations, the Jonesboro fault was judged not to be a capable fault (Reference 2.5.1-202).

Bonsal Morrisville Fault

The Bonsal-Morrisville fault (Figure2.5.1-230) is located approximately 7.4 km (4.6 mi.) northwest of the site in the Durham basin. The Bonsal-Morrisville fault is approximately 26 km (16 mi.) long, trends ~N37E, and has 600 to 1800 m (2000 to 6000 ft.) of vertical down-on-the-northwest displacement (Figure 2.5.1-241, Reference 2.5.3-214). Based on seismic data (Reference 2.5.1-334), the Bonsal-Morrisville fault makes the Durham basin a double half graben (Figure 2.5.1-240). Both the Jonesboro and the Bonsal-Morriville faults dip to the northwest. The Bonsal-Morrisville fault appears to die out as it heads north towards Raleigh, but to the south, it may go through the Colon Cross Structure to the Sanford basin to the south (Figures 2.5.1-215 and 2.5.1-230). South of the Colon cross structure in the Sanford basin, the Bonsal-Morrisville fault may become the Deep River fault, also shown to be a major basin-internal fault (Figure 2.5.1-230). The Deep River fault continues south, disappearing under the Cretaceous Coastal Plain sediments covering the Pekin cross-structure, which separates the Sanford basin from the Wadesboro basin. Here the Deep River fault becomes the major bounding fault of the Wadesboro basin. (Tyler Clark, personal communication, 11/4/2008)

Harris Fault (Site Fault)

Extensive geologic investigations were performed to assess surface faulting at the HNP site during the construction and licensing of the HNP facilities. The Harris fault, a minor cross-basin fault within the basin, also referred to as the "Site fault" in the HNP FSAR and HNP FSER documents and NUREG-1038, was discovered in the foundation of the Plant Waste Processing Building during excavation (Reference 2.5.3-201, Reference 2.5.3-202). Preconstruction site characterization activities, which included 3700 m (12,125 ft.) of trenching (at depths of 0.6 to 3.6 m [2 to 12 ft.]), numerous geologic borings to depths of 15 to 76 m (50 to 250 ft.), and approximately 1500 linear m (5000 linear ft.) of magnetic survey lines (Figure 2.5.3-201), failed to show evidence of this fault or other surface faulting (Reference 2.5.3-201). The two trenches appear to have intersected each other and the fault at a location along the margin of a gully. At this location the trenches do not appear to have been excavated deep enough to provide sufficient exposure of unweathered bedrock in which the fault would have been more easily identified. After the Harris fault was discovered in the waste building excavation, a comprehensive fault investigation program was completed by Ebasco Services, Inc., to evaluate the location, style of faulting, and age of the most recent movement. The results of this study are well documented in a report by Ebasco Services, Inc. (Reference 2.5.3-202).

Detailed investigations conducted by Ebasco demonstrated that the Harris fault is a minor tensional normal fault whose last movement was prior to 150 Ma (Reference 2.5.3-202, Reference 2.5.3-201). Observations and conclusions from these studies regarding the location, style of faulting, and timing of deformation that demonstrate that the Harris fault is not a capable tectonic source are summarized in the following paragraphs.

After the Harris fault was discovered in the excavation for the HNP Waste Processing Building, it was traced some 2400 m (8000 ft.) east and west in a series of short trenches normal to the fault (Reference 2.5.3-201) (Figure 2.5.3-201). It was also exposed in excavations at the Auxiliary Dam (Reference 2.5.3-201). When exposed in sedimentary beds, the fault exhibits an approximately east-to-west strike, a southerly dip between 60° and 90°; always exhibits drag folding on the hanging wall and seldom exhibits any disturbance of bedding planes on the northern or "foot" wall (Reference 2.5.3-202). Bedding in the Triassic bedrock underlying the HNP site and adjacent areas strikes north 5 degrees to 15 degrees east and dips 9 to 17 degrees to the southeast (Reference 2.5.1-202).The fault-gouge zone varies from several centimeters (a few inches) to about 1 m (3 ft.) in width (Reference 2.5.3-201). The fault tends to become oversteepened in coarser-grained sandstones and is nearly vertical adjacent to diabase dikes offset by the fault. No additional faults were discovered in 1200 linear m (4000 linear ft.) of trenching. (Reference 2.5.3-202)

Nine core borings were completed in sedimentary rocks on either side of the Harris fault to determine the vertical component of offset. Correlation of marker beds in the site area proved to be extremely difficult because sediment lithology changes radically over short lateral distances. Based on borehole data, vertical offset in Triassic sediments along the Harris fault in the vicinity of the HNP site is between 24 and 30 m (80 and 100 ft.). (Reference 2.5.3-201) Near-vertical diabase dikes proved to be the best references for estimating horizontal displacement. It was noted, however, that the offset of dikes shows only post-intrusive movement, not necessarily the total offset of the sediments. The horizontal offset of diabase dikes as exposed in the trenches ranges from 0.1 to 4 m (0.5 to 13 ft.); a large horizontal component of movement is precluded in that the fault changes strike about every 90 m (300 ft.). (Reference 2.5.3-201) Prominent joint sets at the site and their relation to the Harris fault are discussed later in this subsection.

A number of secondary minerals observed in the fault gouge at the intersections of the fault with diabase dikes were used for determining age relationships between the dikes and faulting (Reference 2.5.3-202). Zeolite mineral assemblages, including harmotome, heulandite, and laumontite, that are related to hydrothermal and "burial" metamorphic events, were observed only in association with the diabase dikes; furthermore, analyses of strontium isotope ratios ($^{87}Sr/^{86}Sr$) suggest that the diabase and zeolites are genetically related. Evidence for this association can be found in their occurrence only in the dike-fault intersections or as small veins or amygdule fillings in the dikes, and in their absence from the fault zone away from the dikes. (Reference 2.5.3-201) The minimum age of the zeolite minerals has been determined from their potassium-argon (K/Ar) content as 35 Ma; however, these are spuriously low because zeolites tend to lose argon but not potassium. (Reference 2.5.3-202) The intact condition of some of the very brittle, delicate zeolites indicates that the zeolites were formed after faulting, suggesting that the last movement on the fault was more than 10 Ma, but most probably before the final cooling of the dike about 200 Ma or during a burial metamorphic event before 150 Ma (Reference 2.5.3-201). One laumontite vein has been cataclastically deformed, as evidenced by shearing, and also shows mechanical disaggregation and rotation of laumontite grains. This indicates that there was some movement on the fault after crystallization of at least some laumontite. Paleomagnetic dating showed that the diabase dikes underwent burial metamorphism about 20 million years after dike intrusion; therefore, the laumontite is likely associated with the original deuteric hydrothermal alteration of the dike shortly after its crystallization, whereas harmotome and heulandite were formed during the burial metamorphism some 20 million years later. Because the secondary minerals were emplaced prior to 150 Ma and have not been disturbed by subsequent faulting, the last movement on the fault was prior to that time. (Reference 2.5.3-202)

Soils were also used to help constrain the timing of faulting on the Harris fault. Based on trench exposures and outcrops, the fault has not moved during formation of existing soil and saprolite on Triassic sedimentary rocks. Below the uppermost soil horizon, the material is classified as saprolite, and weathering decreases with depth from 0.6 to 4.6 m (2 to 15 ft.). Clay mineralogy studies show this to be an in-place residual weathering profile. Although soils in this area have been variously estimated to be as old as Miocene, more rapid erosion has prevented the HNP site soils from developing a strong profile. (Reference 2.5.3-201) Based on analogy with depths of oxidation at a similar location, the formation of the saprolite may have started more than several million years ago (Reference 2.5.3-202), and the diabase has not been disturbed by movement on the fault for more than 500,000 years (Reference 2.5.3-201).

Based on search of current literature and discussions with researchers in the area, no more recent work on the Harris fault has been completed. Given the detailed level of investigation by Ebasco (Reference 2.5.3-202) that demonstrated that the fault is not a capable tectonic source, it was judged that no further work was needed to characterize the Harris fault."

Borrow Pit Faults

Detailed geologic mapping at scales of 1:12 to 1:3750 that was performed at both the north and south borrow pits to the west and southwest of the HNP site revealed four faults: the SBPF and faults A, B, and C (FA, FB, and FC). The Harris fault was exposed north of the north borrow pit (Figure 2.5.3-201). The borrow pits are partially located within the area of the proposed Wake/Chatham LLRW disposal facility site (Figure 2.5.3-201). (Reference 2.5.3-205) Different structural patterns were seen in the north and south borrow pits. Faulting and fault-related folding in the south borrow pit were inferred from changes in the orientation of bedding (Reference 2.5.3-205).

Faulting exposed in the borrow pits can be divided into two stages: Stage 1 faulting occurred on FA and is interpreted to be associated with longitudinal normal faulting and tilting of beds within the Triassic Deep River basin, antithetic to the Jonesboro fault; Stage 2 faulting represents a later stage of transverse faulting along the SBPF, involving both normal and dextral strike-slip components that produced map-scale folding in the hanging wall of the SBPF. Stage 2 also involved reactivation of FA and formation of east- and north-striking shear mode fractures. Based on exposures in the borrow pits, total displacement cannot be determined on any of the faults. (Reference 2.5.3-205)

The South Borrow Pit fault (SBPF) strikes north 72 degrees west, dips 30 to 70 degrees south, has a minimum trace length of approximately 430 m (1400 ft.) based on known exposures, and exhibits a right-stepping pattern across the borrow pit (Reference 2.5.1-226). In the westernmost part of the south borrow pit, the strike of the SBPF ranges from north 80 degrees east to north 50 degrees west over 60 m (200 ft.) along strike, and dip ranges from 40 degrees to vertical. The SBPF is characterized by breccia, foliated breccia, and clay gouge (Reference 2.5.1-226). Map units in the hanging wall of the SBPF form an outcrop-scale syncline having an east/southeast-plunging axis parallel to the SBPF (Reference 2.5.1-254). The geometry of the syncline suggests it was formed by drag related to normal or right-lateral strike-slip movement along the SBPF (Reference 2.5.1-254).

Three smaller faults (faults A, B, and C) also were mapped in the south borrow pit (Figure 2.5.1-232). Fault A is a northeast-striking, near-vertical to steeply east-dipping normal fault that terminates at its southern end against the SBPF. It is characterized by partly to completely decomposed, foliated breccia; random-fabric breccia; and contorted beds. The zone of contorted bedding and brecciated rock is 1 – 3 m (3 – 10 ft.) wide and can be traced approximately 35 m (110 ft.) along strike. The strike of the foliation and compositional layering within the fault zone generally is oblique to the strike of the fault, but drag-folding along the fault indicates a component of normal displacement. (Reference 2.5.1-226) Initial movement along fault A is interpreted as normal displacement antithetic to the Jonesboro fault and as predating movement on the SBPF (Reference 2.5.1-226). Kinematic indicators suggest a right-lateral component of movement on fault A, similar to the W8 fault (Reference 2.5.1-226). Fault B is a normal fault that strikes north 20 degrees to 25 degrees west, dips 85 to 90 degrees west, and can be traced approximately 24 m (80 ft.) along strike. The fault is characterized by less than 20 cm (8 in.)

of foliated breccia and breccia, intense fracturing, and clay. Fault C generally strikes north 35 degrees east, dips 60 degrees south, and is characterized by a 25- to 33-cm- (10- to 13-in.-) wide foliated breccia. Folds in the hanging wall may indicate compressional, left-lateral, and possibly reverse components of movement on fault C. (Reference 2.5.1-226)

Faults Exposed at the LLRW Disposal Facility Site

Chem-Nuclear Systems, Inc., conducted geologic and hydrogeologic investigations at the proposed LLRW disposal facility site, 300 to 450 m (1000 to 1500 ft.) west of the borrow pits (Reference 2.5.3-204). These investigations involved four trenches (GM-1 through GM-4) (Figure 2.5.3-201), totaling approximately 1219 m (4000 ft.) in length, and nine boreholes along the line of the GM-1 trench (Reference 2.5.3-204). Seismic reflection/refraction and vertical seismic profiling were performed at the site to provide correlation between boreholes, to evaluate faults, and to determine thickness of weathered bedrock (Reference 2.5.3-204).

Three primary faults were identified at the LLRW disposal facility site: the W8 fault, the W82 fault, and the western extension of the SBPF (Figure 2.5.1-232). The east/southeast-west-northwest-trending SBPF and the W82 fault were mapped approximately 760 and 975 m (2500 and 3200 ft.) south of the Harris fault, respectively (Figures 2.5.1-231 and 2.5.1-232). The W8 fault strikes north/northeast and dips approximately 55 degrees west (Reference 2.5.1-332). The W82 fault strikes east/northeast, subparallel to the Harris fault, and dips toward the south (Reference 2.5.1-226). Identification of these faults was based on three primary stratigraphic marker units: conglomeratic sandstone, sandstone, and purple sandstone and mudstone, all of which could be traced over tens of meters (hundreds of feet). Bedding dips generally from 15 to 20 degrees east (Reference 2.5.1-332). Examination of the strata adjacent to the W8 fault, regional relations, and seismic reflection data suggest that the W8 fault and other nearby, smaller north-south-trending faults are listric faults at depth that are displaced by later movement on east-west trending faults such as the SBFP; these north trending faults are therefore judged to have been last active in the Triassic (Reference 2.5.1-254).

Borehole W205CH1 intersected the W8 fault at a depth of approximately 100 m (330 ft.), indicating a dip of approximately 55 degrees. Borehole cores showed that the fault is expressed as a zone of numerous fractures extending approximately 3 m (10 ft.) above and approximately 9 m (30 ft.) below the fault. (Reference 2.5.1-332) Drag along the fault is revealed as a change in the orientation of bedding from easterly to westerly across the fault within the fault zone. Bedding dips increase from approximately 20 degrees east to the west of the W8 fault to approximately 40 degrees east approaching the fault (Reference 2.5.1-332). Because stratigraphy differs on either side of the fault, displacement could not be measured directly; therefore, the fault is assumed to have more than 275 m (900 ft.) of vertical displacement (Reference 2.5.1-332). Trench mapping that extended approximately 600 m (2000 ft.) east and west of the W8 fault revealed no other faults of this size (Reference 2.5.1-332). Approximately 20 smaller, low-angle, bedding-parallel faults, exhibiting little or no displacement, were observed in the trenches (Reference 2.5.1-332).

Figure 2.5.1-236 presents schematic block diagrams showing a conceptual structural model of the faults discussed previously. Wooten et al. discuss the structural development of these faults, relating them to the dominant directions of displacement on the Durham and Holly Springs segments of the Jonesboro fault (Figure 2.5.1-236) (Reference 2.5.1-254). Wooten et al. note that although the dominant displacement on all three east/southeast-west/northwest-trending faults was normal (down to the south or southeast), the steep dips (70 to 90 degrees) along parts of the fault suggest that the faults originated as strike-slip faults accommodating displacement at the southern end of the Durham segment of the Jonesboro fault (Reference 2.5.1-254).

A comparison was made between topographic lows and faulting at the LLRW disposal facility site. Many of the topographic lows appear to be controlled by stratigraphy rather than by structure. Saddles and strike-parallel drainages tend to be underlain by fine-grained units such as mudstones and ridges tend to be associated with sandstone units (Reference 2.5.3-204). On a more localized scale, isolated zones of deep weathering and minor topographic lows tend to correlate with small faults or zones of increased fracturing. Where linear drainages were associated with faults, the drainages were located slightly south of the actual fault in the hanging wall block, probably due to the presence of more fractured and deformed rock compared to the relatively undeformed rock on the footwall block. (Reference 2.5.3-204) Hydrologic tests also showed that groundwater was localized within the fractured sediments adjacent to the faults, similar in some cases to the localization of groundwater along the dikes (Reference 2.5.3-204).

Other Small Intrabasinal Faults in the Site Area

Several other faults and folds have been mapped within the site area (Figures 2.5.1-230 and 2.5.1-231). The most prominent is the Bonsal-Morrisville fault, which is discussed above. A smaller, approximately N70E trending fault that crosses the Bonsal-Morrisville fault was shown on the 1985 geologic map and is retained on more recent, more detailed unpublished mapping by the NCGS (Reference 2.5.3-208). Although more recent studies could not identify the fault in the field it was retained in more recent mapping because high-angle bedding measurements, "different"-looking strata than the rest of the basin (possibly Lithofacies Association I), and abundant fractures were seen in the area of the mapped fault. Additionally, seismic reflection studies by Bain and Harvey (RAI Reference 02.05.01-20 03) indicated anomalous seismic reflectors in that area.

A north-to-northwest-trending fault that was shown on the 1985 geologic map of North Carolina within approximately 185 m (600 ft.) northeast of the HAR 3 site (Reference 2.5.3-207) has been removed on more recent unpublished maps by the NCGS. Geophysical data and field reconnaissance show no indication of a fault in this location, but rather identify the presence of a diabase dike.

Two short faults were recognized during excavation along Highway 1. The easternmost of these two faults, which lies approximately 7.2 km (4.5 mi.) northeast of the HAR site (Figure 2.5.1-231) is an approximately 460 m [1500 ft.] long, high-angle normal fault (Reference 2.5.3-208). The fault displays drag in Triassic sediments and is located at the northwest end of the Holly Springs anticline, part of a zone of syndepositional, fault-bend folding in the hanging wall of the Jonesboro fault (Figure 2.5.1-231). The westernmost of these two faults is a northeast-trending (approximately 630 m [2067 ft.] long) fault that lies approximately 2 km (1.2 mi.) northwest of the HAR site (Figure 2.5.1-231) and was identified during the widening of US 1 in May 1997 (Figure 2.5.1-231, Reference 2.5.3-208). The exposure was in a storm water drain excavation that is now under the highway. The excavation showed a fault zone of disrupted Triassic sediments in which at least four slickensided fault surfaces all striking northeast-southwest, dipping moderately-steeply to the northwest were mapped. The fault zone could not be traced beyond the extent of the excavation. However, based on similar observations at the LLRW site to the south, NCGS staff felt the fault zone could be significant, and speculated that it could be a northward extension of the W8 fault. (Tyler Clark, pers. comm., 10/8/08)"

No evidence of post-Triassic movement on any of these structures is reported in the literature or has been documented by recent mapping by the NCGS. The faults are interpreted to have formed in the same tectonic stress field as the other better studied Mesozoic rift faults in the site area (e.g., the Jonesboro fault, the Harris fault, and the faults in the LLRW and borrow pit study areas). Based on the absence of evidence for post-Triassic deformation and the structural association with noncapable faults, these faults are judged not to be capable tectonic fault sources.

Fracture and Joints

Three prominent joint sets were observed at the HNP site; the two dominant sets are vertical. One set strikes north 40 degrees to 50 degrees east; the other strikes north 20 degrees to 30 degrees west. The third joint set trends north/northwest-south/southeast and dips 55 to 70 degrees to the southwest (Reference 2.5.1-202). Joints are irregularly spaced every few feet and are mostly vertical (Reference 2.5.1-202).

High-angle joints and fractures were observed in oriented acoustic soundings in Boreholes BPA-5, BPA-47, and BPA-48 at HAR 2, and Boreholes BPA-25, BPA-49, and BPA-50 at HAR 3, as discussed in Subsection 2.5.4.4.2.2. These features predominantly dip between 60 to 70 degrees to the west to northwest. Isolated high-angle joints are also oriented in other directions.

At the Auxiliary Dam (Figure 2.5.1-232), two dominant, high-angle fracture sets are seen in muddy, sandy conglomerate and muddy conglomeratic sandstone beds. The first strikes east/northeast and dips 75 to 90 degrees south; the second strikes south/southeast and dips 60 to 90 degrees west (Reference 2.5.1-254). The east/northeast-striking set is parallel to the Harris fault and is interpreted to represent extensional fractures developed during normal, dip-slip movement on the Harris fault. Locally, pinnate fractures show evidence for a component of left-lateral movement on the fault (Reference 2.5.1-254). South/southeast-striking fractures likely predate intrusion of dikes and are related to generally east-west extension along the Jonesboro fault and related structures (Reference 2.5.1-254). Termination relationships among the fracture sets indicate that the east/northeast-striking fractures are younger than the south/southeast-striking fractures (Reference 2.5.1-254).

Several dominant fracture orientations were seen in the north borrow pit. The oldest set of joints trend north/northwest-south/southeast, are bleached, and terminate against bedding. East/northeast-west/southwest-trending, bleached joints terminate against the oldest north/northwest-south/southeast set; younger east-west-trending joints abut both of the older sets. The east-striking set is subparallel to and genetically related to the SBPF. The other set, which strikes generally north, is interpreted to have formed prior to movement on the SBPF. Fracture spacing increases with distance from the SBPF; close to the SBPF fractures are 10 to 30 cm (4 to 12 in.) apart. (Reference 2.5.1-226) East/northeast-striking fractures exposed in the southern end of the south borrow pit are interpreted to be related to the W82 fault to the south (Reference 2.5.1-254). Older joints typically are 1 – 3 m (3 – 10 ft.) long; younger joints are less than 0.3 m (1 ft.) long (Reference 2.5.1-254). East/southeast-striking, nearly vertical fractures are dominant in the south borrow pit, especially in the hanging wall near the SBPF. These fractures have been interpreted to reflect extension orthogonal to the SBPF. (Reference 2.5.1-254) Bedding-parallel fractures that occur throughout the south borrow pit likely are related to east-west extension and basin-parallel faulting (Reference 2.5.1-254).

Two dominant fracture sets were observed during trenching, drilling (using electrical and optical imaging techniques), and mapping studies at the LLRW disposal facility site. One set is parallel to the bedding, strikes roughly north, and dips to the east. The other fracture set strikes generally north and dips steeply west, is orthogonal to the first, and is not bedding parallel. (Reference 2.5.1-332) (RAI 02.05.01-26 Figure 1). High-angle fractures are most abundant in the hanging wall of the W8 fault, and fracture density also may increase near minor faults (Reference 2.5.1-332). The bedding-parallel fractures tend to occur at the boundaries of units that have significantly different mechanical properties, such as coarse-grained sandstone in contact with mudstone. Many of these boundary areas have accommodated slip during ancient faulting and tilting episodes (Reference 2.5.1-332).

2.5.1.2.4.1.2 Mesozoic Brittle Structures East of the Jonesboro Fault.

Map-scale brittle faults and linear cataclastic zones that overprint late Paleozoic structures and penetrative fabrics are recognized in the site vicinity (RAI Reference 02.05.01-20 01). Both north-south and east-west trending structures are observed. West/northwest-east/southeast-trending faults east of the Jonesboro fault south of Raleigh (Figure 2.5.1-230) are brittle faults that range up to 13 km (8 mi.) in length and dip moderately (50 to 60 degrees) to the north or south. These faults commonly are characterized by quartz breccia zones and offset discrete shear zones and fabrics associated with the 312 to 282 Ma Nutbush Creek fault zone (Figure 2.5.1-230). The largest structure which is mapped for over 13 km (8 mi.) is named the Swift Creek fault after the drainage that lies subparallel to the fault zone. Displacement on the faults appear to be predominantly dip-slip. The orientations of the different fault sets suggest that WNW-ESE extension and north-south extension were components of post-Alleghanian deformation along the western edge of the eastern Piedmont. (RAI Reference 02.05.01-20 01) This deformation likely was associated with extension and opening of Mesozoic basins. The faults and cataclastic zones are most commonly manifest as ridge-top float of vuggy rich quartz or breccia. Topographic expression is generally subtle to nonexistent; locally the zones are roughly parallel to steep, discontinuous bluffs having up to 25 m (82 ft.) of relief. Similarly, northwest-southeast-trending folds located west of the bend in the Jonesboro fault are either syndepositional fault-bend folds or were formed from differential movement along the Jonesboro fault.

2.5.1.2.4.2 Structures in the vicinity of the Main Dam

Twenty-four minor faults having lengths measured in meters to tens of meters (tens of feet) and displacements measured in centimeters (inches), all judged to be noncapable, were mapped in pre-Triassic crystalline rocks in the foundation of the Main Dam (Reference 2.5.1-202, Reference 2.5.1-331). The Main Dam is located approximately 900 m (3000 ft.) southeast of the Jonesboro fault in an area of Late Proterozoic to Cambrian igneous and metamorphic rocks consisting of granite, hornblende-mica gneiss, layered quartz-feldspar gneiss, and mica schist (Reference 2.5.1-331, Figure 2.5.1-230).

The dominant joint set in the crystalline rocks at the Main Dam strikes approximately north 60 degrees to 70 degrees east and dips 50 to 70 degrees southeast. Another set strikes north 20 degrees to 35 degrees west and dips 70 to 90 degrees southwest. (Reference 2.5.1-331) The foliation in this area generally strikes approximately north 55 degrees east and dips 60 degrees northwest. Joints typically are spaced approximately 1 m

(2 – 3 ft.) apart and strike northeast and northwest (Reference 2.5.1-331). Folding in the site area is most common in gneisses and schists exposed in the foundation of the Main Dam. These rocks appear to have undergone several periods of folding, predominately isoclinal folding (Reference 2.5.1-331). The magnitude of this folding could not be determined because of the limited area of exposure of the crystalline rocks.

Most of the faults have strikes between N30°E and N75°E and dip steeply to the southeast. A few strike northwest and have steep northeast or nearly vertical dips. A majority of the faults exhibit right lateral strike separation, but those showing left lateral separation are also common. (Reference 2.5.3-201) It was documented that the small amount of movement along these faults is typical of deformation features in metamorphic rocks and took place prior to deformation and mineralization, associated with intrusion of granitic plutons throughout the Piedmont, that occurred more than 225 Ma. Because the small amount of movement along these faults took place prior to deformation and mineralization that occurred more than 225 Ma, the faults are not considered to be capable faults. (Reference 2.5.3-201, Reference 2.5.3-203) The NRC concurred that any movement along the faults occurred prior to or during deformation-mineralization processes which terminated more than 225 million years ago, and that the faults are not capable (Reference 2.5.3-203)."

2.5.1.2.4.3 Cretaceous and Cenozoic Structures

Most faults in the site vicinity are pre-Cretaceous, but there are reports of minor localized faults that cut Upper Cretaceous to Miocene [?] and Pliocene [?] sediments at five localities (Features 41, 47, 49, 57 and, 150 Table 2.5.1-201). None of these features could be confirmed by field reconnaissance conducted for this study, likely because they were exposed in road cuts or exposures that no longer exist or have since been obscured by vegetation, or imprecision of the reported location coordinates did not provide sufficient information to locate the specific features. The best documented post-Cretaceous fault, which is reported to displace Pliocene/Pleistocene terrace deposits in a formerly exposed railroad cut near the town of Banks (approximately 23 km [14 mi.] east of the HAR site), is described by Parker (Reference 2.5.1-228 (Feature 150, Table 2.5.1-201).(Figure 2.5.1-230, Reference 2.5.1-228, Reference 2.5.1-256). At this location, which is now totally obscured by vegetation and slopewash, Parker observed a southward-dipping, low-angle thrust fault that exhibited approximately 2.5 m (8 ft.) of dip-slip displacement in pebbly sand terrace deposits of probable Pliocene or Pleistocene age (Reference 2.5.1-228) (Feature 150, Figure 2.5.1-230)

With the exception of the fault identified by Parker (Reference 2.5.3-213), the reported displacements on the other faults identified in the site vicinity is less than 1 m (3 ft.) in deposits of Cretaceous to Tertiary age. None of the Cretaceous or post-Cretaceous faults identified in the site vicinity have been mapped beyond the outcrop scale. Based on the limited extent of these features combined with the apparent absence of geomorphic evidence of Quaternary surface deformation noted during the aerial reconnaissance and from examination of hillshade relief maps derived from the LiDAR data, these faults are not considered to be capable tectonic sources."

References:

Reference RAI 02.05.01-20 01

Heller, M. J., Stoddard, E. F., Grimes, W. S., Blake, D. E., "Brittle Faulting Along the Western Edge of the Eastern Piedmont," Southeastern Geology, v. 38, no. 2, pp. 103-116, 1998.

Reference RAI 02.05.01-20 02

Fleishmann, K. H., M. J., Bartholomew, and J. R. Law, "Triassic-Jurassic Development of the Deep River Basin, NC." Geological Society of America 46th Annual Southeastern Section, Abstracts with Program, p. 16,1997.

Reference RAI 02.05.01-20 03

Bain, G.L and B.W. Harvey, "Field Guide to the Geology of the Durham Triassic Basin," Carolina Geological Society Fortieth Anniversary Meeting, October 7-9, 1977

Attachments/Enclosures:

Attachment 02.05.01-20A: Figure 2.5.1-231 (Revised)

Attachment 02.05.01-20B: RAI 02.05.01-26 Figure 1

Attachment 02.05.01-20C1: RAI 02.05.01-20 Figure 1

Attachment 02.05.01-20C2: RAI 02.05.01-20 Figure 2

Attachment 02.05.01-20C3: RAI 02.05.01-20 Figure 3

Attachment 02.05.01-20C4: RAI 02.05.01-20 Figure 4

Attachment 02.05.01-20C5: RAI 02.05.01-20 Figure 5

Attachment 02.05.01-20C6: RAI 02.05.01-20 Figure 6

Attachment 02.05.01-20C7: RAI 02.05.01-20 Figure 7

Attachment 02.05.01-20C8: RAI 02.05.01-20 Figure 8

Attachment 02.05.01-20D1: RAI 02.05.01-20 Figure 9

Attachment 02.05.01-20D2: RAI 02.05.01-20 Figure 10

Attachment 02.05.01-20E: Figure 2.5.1-236 (Revised)

Attachment 02.05.01-08D: Figure 2.5.1-230 (Revised)

Attachment 02.05.01-20F: Figure 2.5.1-232 (Revised)

Attachment 02.05.01-20G: Figure 2.5.1-241 (Revised)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-21

Text of NRC RAI:

FSAR Section 2.5.1.2.4.1 (p. 2.5-83) discusses the geophysical studies of structural features that were discussed previously in section 2.5.1.2.4. The gravity map being discussed in this section is not illustrated and the discussion in the text cannot be followed without that map. Please provide a figure for this discussion.

PGN RAI ID #: H-0158

PGN Response to NRC RAI:

A map showing the site and local structures overlying the gravity map of Mann and Zablocki (1961) is presented on RAI 02.05.01-21 Figure 1. A more current gravity study in the site vicinity was completed in Bain and Brown (1981) and will be added as RAI 02.05.01-21 Figure 2 in a future revision.

Associated HAR COL Application Revisions:

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

1. Revise last paragraph of FSAR Section 2.5.1.2.4.1.1 from:

   "Gravity profiles of Bain and Brown show variations in the depth to basement rocks and in delineation of subbasins within the Deep River basin (Reference 2.5.1-334). A gravity low near Apex is separated from the northern part of the basin by a northeast-southwest-trending fault zone in the basement that extends from approximately 3 km (1.8 mi.) north of Moncure to the area around Morrisville (Reference 2.5.1-334). This fault, referred to as the Bonsal-Morrisville fault, is also seen in magnetic, resistivity, and geologic mapping studies (Figure 2.5.1-230)."

   To read:

   "Gravity data presented by Bain and Brown show variations in the depth to basement rocks and in delineation of subbasins within the Deep River basin (RAI 02.05.01-21 Figure 2) (Reference 2.5.1-334). A gravity low near Apex is separated from the northern part of the basin by a northeast-southwest-trending fault zone in the basement that extends from approximately 3 km (1.8 mi.) north of Moncure to the area around Morrisville (Reference 2.5.1-334). This fault, referred to as the Bonsal-Morrisville fault, is also seen in magnetic, resistivity, and geologic mapping studies (Figure 2.5.1-230)."

Attachments/Enclosures:

Attachment 02.05.01-21A: RAI 02.05.01-21 Figure 1

Attachment 02.05.01-21B1: Figure 2.5.1-237, Sheet 1 (Revised)

Attachment 02.05.01-21B2: RAI 02.05.01-21 Figure 2

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-22

Text of NRC RAI:

FSAR Section 2.5.1.2.4.1.3 (p. 2.5-87) provides a discussion of the Jonesboro fault based on seismic reflection data. The Figure 2.5.1-241 called out in the text is an interpretive drawing of the seismic reflection line, not the actual seismic data. Please provide 2 additional figures that have the portion of interest in an un-interpreted seismic reflection line and a reflection line with the major points discussed in text drawn in.

PGN RAI ID #: H-0159

PGN Response to NRC RAI:

A scanned version of a hardcopy image of the Texaco seismic line 85SD12 was used to develop the line interpretation shown on Figure 2.5.1-241. Per written authorization from Chevron Corporation that permits use of these data with restrictions, the image of the seismic line should be treated as proprietary data subject to governing regulation § 2.390 'Public inspections, exemptions, requests for withholding' (in particular, § 2.390 (a) (9)). Per § 2.390(b) (1) (ii) it is requested that the Commission waive the affidavit requirements in lieu of the attached letter from Chevron Corporation (see Attachment A in RAI 02.05.02-8).

The requested additional figures showing the un-interpreted seismic data and the seismic line with interpretation are provided as Attachments B and C in RAI 02.05.02-8.

Associated HAR COL Application Revisions:

No COLA revisions have been identified associated with this response.

Attachments/Enclosures:

None

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-23

Text of NRC RAI:

FSAR Section 2.5.3 (p. 2.5-198) discusses seismic reflection studies at the site area scale.

a) The FSAR states that seismic refraction survey lines were shot to find evidence for surface faulting on the Harris fault and figure 2.5.3-201 is referenced. The geophysical lines, as indicated in map explanation, did not cross the interpreted Harris fault trace. Please clarify if there are seismic refraction lines that were not plotted on that map.

b) The FSAR states that: "The results of this study are well documented in a report by Ebasco Services, Inc. (Reference 2.5.3-202)". The pertinent material from that report needs to be included in this document. Please provide a detailed summary of that previous work, evaluated in terms of current scientific knowledge. The previous work needs to be integrated with the current work, under headings of the specific faults or structures being discussed so that all evidence past and present is one paragraph or section.

c) Figure 2.5.1-230 is a site vicinity scale geologic map. It does not show the location of the minor faults exposed in igneous and metamorphic rock at the Main Dam, 5 mi south of SHNPP. Please revise figure.

PGN RAI ID #: H-0160

PGN Response to NRC RAI:

a) The geophysical lines surveyed across the Harris fault are magnetic survey lines, as shown on Figure 2.5.3-201. The reference to seismic refraction survey lines in the FSAR was in error. There are no seismic refraction lines that cross the Harris fault. Text will be revised accordingly in a future revision (see Response to RAI 02.05.01-20 that includes revisions to FSAR Section 2.5.1.2.4).

b) Descriptions of geologic structures in the site area (FSAR Subsection 2.5.3.2.1) is being incorporated into a revised Subsection 2.5.1.2.4 that will be submitted in a future revision (see Response to RAI 02.05.01-20). Groupings and subheadings from FSAR Subsection 2.5.3.2.1 will be incorporated into the revised Section 2.5.1.2.4. The revised Section 2.5.1.2.4 will integrate the results of previous detailed studies (e.g., Ebasco, 1975) with more current work and assessments of activity for specific structures into a single section of the FSAR. Accordingly, changes have been made to FSAR Section 2.5.3 to address organizational issues in this and other RAIs. Revisions to Section 2.5.3 that will be incorporated in a future revision are attached.

c) The location of the Main Dam is shown on revised Figures 2.5.1-230 and 2.5.1-231. The faults at and near the Main Dam were only exposed in trenches and can only be shown at a very detailed scale for each trench location. Several detailed plates showing faulting at the Main Dam are provided by Ebasco (1981) and are shown in RAI 02.05.01-23 Figures 1 through 5. Text will be added to the revised Subsection 2.5.1.2.4 to further describe minor faults exposed at the main dam.

Associated HAR COL Application Revisions:

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

1. The following text will be added to FSAR Section 2.5.1.2.4.1.1:

   "Extensive geologic investigations were performed to assess surface faulting at the HNP site during the construction and licensing of the HNP facilities. The Harris fault, a minor cross-basin fault within the basin, also referred to as the "Site fault" in the HNP FSAR and HNP FSER documents and NUREG-1038, was discovered in the foundation of the Plant Waste Processing Building during excavation (Reference 2.5.3-201, Reference 2.5.3-202). Preconstruction site characterization activities, which included 3700 m (12,125 ft.) of trenching (at depths of 0.6 to 3.6 m [2 to 12 ft.]), numerous geologic borings to depths of 15 to 76 m (50 to 250 ft.), and approximately 1500 linear m (5000 linear ft.) of magnetic survey lines (Figure 2.5.3-201), failed to show evidence of this fault or other surface faulting (Reference 2.5.3-201). The two trenches appear to have intersected each other and the fault at a location along the margin of a gully (Figure 2.5.3-201). At this location the trenches do not appear to have been excavated deep enough to provide sufficient exposure of unweathered bedrock in which the fault would have been more easily identified. After the Harris fault was discovered in the waste building excavation, a comprehensive fault investigation program was completed by Ebasco Services, Inc., to evaluate the location, style of faulting, and age of the most recent movement. The results of this study are well documented in a report by Ebasco Services, Inc. (Reference 2.5.3-202).

2. The following text will be added to FSAR Section 2.5.1.2.4.2:

   "Most of the faults have strikes between N30°E and N75°E and dip steeply to the southeast. A few strike northwest and have steep northeast or nearly vertical dips. A majority of the faults exhibit right lateral strike separation, but those showing left lateral separation are also common. (Reference 2.5.3-201) It was documented that the small amount of movement along these faults is typical of deformation features in metamorphic rocks and took place prior to deformation and mineralization, associated with intrusion of granitic plutons throughout the Piedmont that occurred more than 225 Ma. Because the small amount of movement along these faults took place prior to deformation and mineralization that occurred more than 225 Ma, the faults are not considered to be capable faults. Reference 2.5.3-201, Reference 2.5.3-203) The NRC concurred that any movement along the faults occurred prior to or during deformation-mineralization processes which terminated more than 225 million years ago, and that the faults are not capable (Reference 2.5.3-203)."

Attachments/Enclosures:

Attachment 02.05.01-23A1:	RAI 02.05.01-23 Figure 1
Attachment 02.05.01-23A2:	RAI 02.05.01-23 Figure 2
Attachment 02.05.01-23A3:	RAI 02.05.01-23 Figure 3
Attachment 02.05.01-23A4:	RAI 02.05.01-23 Figure 4
Attachment 02.05.01-23A5:	RAI 02.05.01-23 Figure 5
Attachment 02.05.01-08D:	Figure 2.5.1-230, Sheet 1 (Revised)
Attachment 02.05.01-20A:	Figure 2.5.1-231, Sheet 1 (Revised)
Attachment 02.05.01-23B:	FSAR Section 2.5.3 Draft 11-2-08

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-24

Text of NRC RAI:

FSAR section 2.5.3.2.1.1 (p. 2.5-200) concludes that the Jonesboro fault is not capable mostly based on documents that are old: the Carolina Power and Light Co. 1983 report, Ebasco Services (1975) report, and Prowell, 1983. Then the FSAR states: "More recent studies do not reveal any evidence of faulting in Cretaceous or younger sediments on the Jonesboro fault (Reference 2.5.3-208). Field and aerial reconnaissance reveal little to no geomorphic expression of the Jonesboro fault to suggest reactivation of the fault in the contemporary tectonic environment, and there are no known localities at present where the fault is exposed (Figure 2.5.3-205). Field and aerial reconnaissance investigations conducted for this study confirm the observations and conclusions cited in the HNP FSAR that indicate the Jonesboro fault is not a capable tectonic source."

a) The "more recent studies" cited is unpublished NCGS geologic mapping with a nebulous date of May 25, Sept 8 and Oct 10, 2006. Please provide more details about this mapping so that NRC staff can understand what was actually done. Include figures. Since this mapping is unpublished how is this information an official agency record? Has it been peer reviewed at the NCGS?

b) Who did the field and aerial reconnaissance, HAR or NCGS? What was examined and what criteria were used to determine 'no expression'.

PGN RAI ID #: H-0161

PGN Response to NRC RAI:

a) NCGS mapping dated May 25, Sept 8 and Oct 10, 2006 refers to unpublished NCGS STATEMAP geologic mapping at a 1:24,000 scale for the Cokesbury and New Hill quadrangles and unpublished mapping for the Raleigh 1:100,000 quadrangle. Digital GIS shapefile data and explanations of map units were provided in emails from the NCGS. The mapping for the Raleigh 100k quadrangle is posted on the National Geologic Map Database at this link http://ngmdb.usgs.gov/Prodesc/proddesc_82610.htm. The reference for 2.5.1-275 will be revised to include the Raleigh 100k Quadrangle in Section 2.5.7 (see RAI 02.05.01-13). The final versions of the above maps have not yet been released. A hard-copy version of the current preliminary draft of the Raleigh 100k map dated 10/10/08 is attached.

b) Field and aerial reconnaissance was performed by Geomatrix Consultants and Tyler Clark of the NCGS in June and December 2006. Field reconnaissance involved visiting identified faults within the site vicinity, including faults identified by Prowell (1983) as post-Cretaceous faults, locations along the Jonesboro fault, and geologic mapping of exposures in the site location. Stratigraphy was examined in exposures in the site area. Aerial reconnaissance was done by helicopter flight, and included observation of areas of the ECFS-Central segment, the Jonesboro fault, the Bonsal-Morrisville fault, and other areas of potential interest within the site vicinity. The attached field reconnaissance reports provide detailed descriptions of field investigations, maps, and notes (see Attachment 02.05.01-24B).

The term 'no expression' is used to describe areas along the Jonesboro fault with flat topography, and lack of fault scarps in Cretaceous or younger deposits, and lack of other geomorphic indicators that would be indicative of Quaternary faulting (see Figures 2.5.3-204 and 205).

Associated HAR COL Application Revisions:

No COLA revisions have been identified associated with this response.

Attachments/Enclosures:

Attachment 02.05.01-13A:	Preliminary Bedrock Geologic Map of the Raleigh Quadrangle, North Carolina.
Attachment 02.05.01-24A:	Geomatrix Field Documentation

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-25

Text of NRC RAI:

FSAR section 2.5.3.2.1.2 (p. 2.5-201) is about the Harris fault. The entire section about the Harris fault is based on two references: Reference 2.5.3-202, Reference 2.5.3-201, from 1975 and 1983.

a) Are there more recent studies that have been completed? If there are not, the FSAR should specifically state that the applicant looked and found none more recent or did no further work.

b) Please include one typical trench map from the original investigation of the Harris fault.

c) What marker horizon proved to be the most continuous? Please provide one example of a geophysical /geological log correlation across the fault.

PGN RAI ID #: H-0162

PGN Response to NRC RAI:

a) There have not been more recent studies of the Harris fault conducted since the completion of the HNP FSAR. A sentence will be added to the first paragraph of Subsection 2.5.3.2.1.2 in a future revision to clarify this.

b) A typical trench map and photographs from the original investigation of the Harris fault are included as RAI_02.05.01-25 Figures 1 through 3.

c) The most useful markers for assessing horizontal offset were diabase dikes. Sandstone beds were used to assess vertical offset at and near the site. In one location at the site, a thick lense of medium to coarse-grained, white to gray arkosic sandstone identified in borings was used to estimate vertical offset across the Harris fault (Reference 2.5.3-202). Correlations across the Harris fault based on borehole data are shown in RAI_02.05.01-25 Figure 4.

Associated HAR COL Application Revisions:

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

1. Revise the first paragraph of FSAR Section 2.5.3.2.1.2 from:

   Detailed investigations conducted by Ebasco demonstrated that the Harris fault is a minor tensional normal fault whose last movement was prior to 150 Ma (Reference 2.5.3-202, Reference 2.5.3-201). Observations and conclusions from these studies regarding the location, style of faulting, and timing of deformation that demonstrate that the Harris fault is not a capable tectonic source are summarized in the following paragraphs. A compilation map showing the locations of trenches, boreholes, and geophysical surveys completed as part of both the pre-construction characterization studies and the subsequent more detailed fault investigations are shown on Figure 2.5.3-201.

To read:

"Detailed investigations conducted by Ebasco demonstrated that the Harris fault is a minor tensional normal fault whose last movement was prior to 150 Ma (Reference 2.5.3-202, Reference 2.5.3-201). Observations and conclusions from these studies regarding the location, style of faulting, and timing of deformation that demonstrate that the Harris fault is not a capable tectonic source are summarized in the following paragraphs."

and

"Based on search of current literature and discussions with researchers in the area, no more recent work on the Harris fault has been completed. Given the detailed level of investigation by Ebasco (Reference 2.5.3-202) that demonstrated that the fault is not a capable tectonic source, it was judged that no further work was needed to characterize the Harris fault."

Attachments/Enclosures:

Attachment 02.05.01-25A: RAI 02.05.01-25 Figure 1 (Photograph of Ebasco (1975) Harris Fault Excavation Along East Dike 2)

Attachment 02.05.01-25B: RAI 02.05.01-25 Figure 2 (Photograph of Ebasco (1975) Harris Fault Excavation along Fault at intersection of East Dike 2)

Attachment 02.05.01-25C: RAI 02.05.01-25 Figure 3 (Trench logs from Ebasco (1975) Harris Fault Excavation)

Attachment 02.05.01-25D: RAI 02.05.01-25 Figure 4 (Geologic Sections from Ebasco (1975) Borings)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-26

Text of NRC RAI:

FSAR section 2.5.3.2.1.4 (p. 2.5-203) discusses the work that NCGS did on the Borrow pit faults. There are some confusing statements in this section that need clarification.

a) Why are there 2 names for each fault, in the text and on figure 2.5.3-201?

b) Please explain how the faults are interpreted with respect to field data, how shear sense is determined, and how timing on the fault is determined.

c) If the faults are solely inferred from orientation of bedding planes as stated in the text, then a close-up field map with outcrop locations and associated strike and dip measurements need to be provided.

d) Explain "longitudinal normal faulting".

PGN RAI ID #: H-0163

PGN Response to NRC RAI:

This RAI requests additional clarification and discussion of the faults exposed in the borrow pits to the west and southwest of the HNP site.

a) The text in FSAR section 2.5.3.2.1.4 refers to four faults, the South Borrow Pit fault, fault A, fault B, and fault C. The acronyms for these faults used in both the text and on figures are SBPF, FA, FB, and FC, respectively. The text will be modified in a future revision to clarify the fault terminology. The acronyms are linked to the fault names in the explanations of the figures.

b) Wooten et al. (1996) provides a detailed discussion of the data and observations used to infer the sense of slip and timing of deformational events on faults exposed in the borrow pit area. Revisions to FSAR Section 2.5.1.2.4 that will be made in future revision (see Response to RAI 02.05.01-20) provide additional description of the field evidence used by Wooten et al. (1996) to evaluate the style of faulting and deformational history of the faults exposed in the borrow pit area.

c) RAI 02.05.01-26 Figure 1 has been added to show the relationships of bedding and faults in the borrow pits as outlined by Wooten et al. (2001)

d) The term 'longitudinal basin faulting' is used by Wooten et al. (1996) to refer to normal displacements that occurred during the opening of the basin on faults that parallel the major north to northeast trend of the basin. Predominantly normal movement on faults that are perpendicular to the major basin-bounding faults is referred to as 'transverse basin faulting. The text will be updated to change the term from longitudinal normal faulting to longitudinal basin faulting.

Associated HAR COL Application Revisions:

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

1. Revise paragraphs 1 and 2 of FSAR Section 2.5.3.2.1.4 from:

   "Detailed geologic mapping at scales of 1:12 to 1:3750 that was performed at both the north and south borrow pits to the west and southwest of the HNP site revealed four faults: the SBPF and faults A, B, and C (FA, FB, and FC). The Harris fault was exposed north of the north borrow pit (Figure 2.5.3-201). The borrow pits are partially located within the area of the proposed Wake/Chatham LLRW disposal facility site (Figure 2.5.3-201). (Reference 2.5.3-205) Different structural patterns were seen in the north and south borrow pits. Faulting and fault-related folding in the south borrow pit were inferred from changes in the orientation of bedding (Reference 2.5.3-205) (see Subsection 2.5.1.2.4).

   Faulting exposed in the borrow pits can be divided into two stages: Stage 1 faulting occurred on FA and is interpreted to be associated with longitudinal normal faulting and tilting of beds within the Triassic Deep River basin, antithetic to the Jonesboro fault; Stage 2 faulting represents a later stage of transverse faulting along the SBPF, involving both normal and dextral strike-slip components that produced map-scale folding in the hanging wall of the SBPF. Stage 2 also involved reactivation of FA and formation of east- and north-striking shear mode fractures. Based on exposures in the borrow pits, total displacement cannot be determined on any of the faults. (Reference 2.5.3-205)"

   To read:

   "Detailed geologic mapping at scales of 1:12 to 1:3750 that was performed at both the north and south borrow pits to the west and southwest of the HNP site revealed four faults: the South Borrow Pit fault (SBPF), fault A (FA), fault B (FB), and fault C (FC) (Figure 2.5.3-201). The borrow pits are partially located within the area of the proposed Wake/Chatham LLRW disposal facility site (Figure 2.5.3-201). (Reference 2.5.3-205) Different structural patterns were seen in the north and south borrow pits. Faulting and fault-related folding in the south borrow pit were inferred from changes in the orientation of bedding (Reference 2.5.3-205) (see Subsection 2.5.1.2.4).

   Faulting exposed in the borrow pits can be divided into two stages: Stage 1 faulting occurred on fault A and is interpreted to be associated with longitudinal normal faulting and tilting of beds within the Triassic Deep River basin, antithetic to the Jonesboro fault; Stage 2 faulting represents a later stage of transverse faulting along the SBPF, involving both normal and dextral strike-slip components that produced map-scale folding in the hanging wall of the SBPF. Stage 2 also involved reactivation of FA and formation of east- and north-striking shear mode fractures. Based on exposures in the borrow pits, total displacement cannot be determined on any of the faults. (Reference 2.5.3-205)"

Attachments/Enclosures:

See attached file:

Attachment 02.05.01-20B: RAI 02.05.01-26 Figure 1

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-27

Text of NRC RAI:

FSAR section 2.5.3.2.1.5 (p. 2.5-204) discusses the faults exposed at the LLRW Disposal Site. The text states: "A comparison was made between topographic lows and faulting at the LLRW disposal facility site. Many of the topographic lows appear to be controlled by stratigraphy rather than by structure. Saddles and strike-parallel drainages tend to be underlain by fine-grained units such as mudstones and ridges tend to be associated with sandstone units (Reference 2.5.3-204)." The figure provided for this section, 2.5.3-201, does not illustrate the topographic highs and lows that the text speaks to when examining the faults for evidence of recent movement. Please provide an additional figure that shows how this interpretation is possible or revise figure -210.

PGN RAI ID #: H-0164

PGN Response to NRC RAI:

The observations regarding the correlation between lithology and topography at the LLWR were based on the detailed geologic mapping and trenching investigations conducted by Harding Lawson Associates (1997) (FSAR Reference 2.5.3-204). The relationship between topography and faulting in the LLRW site area is shown in Figure 2.5.3-207, which includes a shaded relief map derived from LIDAR data, with faults, geologic units and bedding attitudes superimposed. The FSAR text will be modified to cite the correct figure, which will involve renumbering of Figures 2.5.3-206 and 2.5.3-207.

Associated HAR COL Application Revisions:

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

1. Revise FSAR Section 2.5.3 List of Figures from:

"2.5.3-201	Locations of Fault Investigation Trenches and Geophysical Studies
2.5.3-202	Lineaments from HNP Fault Investigations
2.5.3-203	Lineaments Based on Interpretation of 2005 LIDAR Data
2.5.3-204	Photograph Showing the Jonesboro Fault in the Vicinity of the Main Dam
2.5.3-205	Photograph Showing the Jonesboro Fault in the Vicinity of Apex
2.5.3-206	Rose Diagrams Showing Orientations of Lineaments
2.5.3-207	Geologic Map of the Site Location (1-km [0.6-mi.] Radius)
2.5.3-208	Photograph of Siltstone and Sandstone Exposed North of HAR 3
2.5.3-209	Photograph of E-W Trending Fracture Exposed North of HAR 3"

To read:

"2.5.3-201	Locations of Fault Investigation Trenches and Geophysical Studies
2.5.3-202	Lineaments from HNP Fault Investigations
2.5.3-203	Lineaments Based on Interpretation of 2005 LIDAR Data
2.5.3-204	Photograph Showing the Jonesboro Fault in the Vicinity of the Main Dam
2.5.3-205	Photograph Showing the Jonesboro Fault in the Vicinity of Apex
2.5.3-206	Geologic Map of the Site Location (1-km [0.6-mi.] Radius)
2.5.3-207	Rose Diagrams Showing Orientations of Lineaments
2.5.3-208	Photograph of Siltstone and Sandstone Exposed North of HAR 3
2.5.3-209	Photograph of E-W Trending Fracture Exposed North of HAR 3"

2. Revise paragraph 3 of FSAR Section 2.5.3.2.1.5 from:

   "A comparison was made between topographic lows and faulting at the LLRW disposal facility site. Many of the topographic lows appear to be controlled by stratigraphy rather than by structure. Saddles and strike-parallel drainages tend to be underlain by fine-grained units such as mudstones and ridges tend to be associated with sandstone units (Reference 2.5.3-204). On a more localized scale, isolated zones of deep weathering and minor topographic lows tend to correlate with small faults or zones of increased fracturing. Where linear drainages were associated with faults, the drainages were located slightly south of the actual fault in the hanging wall block, probably due to the presence of more fractured and deformed rock compared to the relatively undeformed rock on the footwall block. (Reference 2.5.3-204) Hydrologic tests also showed that groundwater was localized within the fractured sediments adjacent to the faults, similar in some cases to the localization of groundwater along the dikes (Reference 2.5.3-204)."

   To Section 2.5.1.2.4.1.1 to read:

   "A comparison was made between topographic lows and faulting at the LLRW disposal facility site. Many of the topographic lows appear to be controlled by stratigraphy rather than by structure. Saddles and strike-parallel drainages tend to be underlain by fine-grained units such as mudstones and ridges tend to be associated with sandstone units (Reference 2.5.3-204). On a more localized scale, isolated zones of deep weathering and minor topographic lows tend to correlate with small faults or zones of increased fracturing. Where linear drainages were associated with faults, the drainages were located slightly south of the actual fault in the hanging wall block, probably due to the presence of more fractured and deformed rock compared to the relatively undeformed rock on the footwall block (Figure 2.5.3-206) (Reference 2.5.3-204) Hydrologic tests also showed that groundwater was localized within the fractured sediments adjacent to the faults, similar in some cases to the localization of groundwater along the dikes (Reference 2.5.3-204)."

3. Revise paragraph 2 of FSAR Section 2.5.3.2.2 from:

   "Several trends of lineaments are apparent in the LIDAR data (Figure 2.5.3-203 and Figure 2.5.3-206). The main trends are between N30W to N30E and east to west to N60E or N60W (Figure 2.5.3-206). Many of these, which are defined by small drainages, appear to reflect the dominant joint and fracture sets that are recognized in the region. As reported in the HNP FSAR (Reference 2.5.3-201), three joint sets are present in the Triassic sedimentary rocks: the two dominant sets are approximately vertical, one striking N40 to 50E and the other N20 to 30W; a third set strikes north to northwest and dips 55° to 70° southwest. Bedding in the Triassic in the site area primarily is between north to south to N35E, and it appears that many of the small drainages are parallel to bedding and probably formed by differential weathering of the more easily eroded beds. The dikes generally are aligned subparallel to the N20° to 30W trend, but shorter east-to-west-trending dikes have been mapped in the New Hill 7.5-minute quadrangle (Figure 2.5.1-231). (Reference 2.5.3-208) East-to-west-oriented lineaments also are apparent in the LIDAR data. Lineament analysis by Bain and Brown (Reference 2.5.3-214) from SLAR data could not identify east-to-west lineaments because of the flight direction. Bain and Brown (Figure 2.5.3-206) also identified more distinct preferred directions of lineaments compared to the LIDAR analysis in this study (Reference 2.5.3-214). This may be due in part to cultural features identified in the SLAR imagery."

   To FSAR Section 2.5.3.2.1 to read:

   "Several trends of lineaments are apparent in the LIDAR data (Figure 2.5.3-203 and Figure 2.5.3-207). The main trends are between N30W to N30E and east to west to N60E or N60W (Figure 2.5.3-207). Many of these, which are defined by small drainages, appear to reflect the dominant joint and fracture sets that are recognized in the region. As reported in the HNP FSAR (Reference 2.5.3-201), three joint sets are present in the Triassic sedimentary rocks: the two dominant sets are approximately vertical, one striking N40 to 50E and the other N20 to 30W; a third set strikes north to northwest and dips 55° to 70° southwest. Bedding in the Triassic in the site area primarily is between north to south to N35E, and it appears that many of the small drainages are parallel to bedding and probably formed by differential weathering of the more easily eroded beds. The dikes generally are aligned subparallel to the N20° to 30W trend, but shorter east-to-west-trending dikes have been mapped in the New Hill 7.5-minute quadrangle (Figure 2.5.1-231). (Reference 2.5.3-208) East-to-west-oriented lineaments also are apparent in the LIDAR data. Lineament analysis by Bain and Brown (Reference 2.5.3-214) from SLAR data could not identify east-to-west lineaments because of the flight direction. Bain and Brown (Figure 2.5.3-207) also identified more distinct preferred directions of lineaments compared to the LIDAR analysis in this study (Reference 2.5.3-214). This may be due in part to cultural features identified in the SLAR imagery."

4. Revise paragraph 4 of FSAR Section 2.5.3.2.2 from:

   "One of the longer of these east-west-trending lineaments extends across the northernmost part of the HAR site, approximately 150 m (500 ft.) north of the HAR 3 site (Figure 2.5.3-207). The lineament, which trends east to southeast, is identified primarily by a series of aligned drainages. The HNP, HAR 2, and HAR 3 sites appear to lie between the Harris fault and the lineament that aligns along the drainage currently occupied by the fire pond. This additional lineament, which is referred to as the fire pond lineament (FPL), is approximately 150 m (500 ft.) north of the proposed safety-related structures for HAR 3.

Exposures of interbedded siltstones and sandstones of Lithofacies I Unit Trcs/si2 (Figure 2.5.3-208) in the outflow channel for the fire pond north of HAR 3 display four prominent fracture sets: N5E, N30° to 50W, N35E, and N85W. The N85W-trending fracture is open and parallels the trend of the FPL (Figure 2.5.3-209). Bedding is oriented approximately N15E, and dips approximately 17 to 30 degrees northeast at this location. The FPL obliquely crosses Highway 1 just to the west of the highway and Tom Jack Creek intersection (at the Chatham County/Wake County border). The lineament also intersects Old Highway 1 approximately 2.9 km (1.8 mi.) southwest of Bonsal. To the east, the lineament crosses the access road (SR 1134) into the HNP site and a spur off of SR 1134 that projects toward the northeastern part of the HNP site boundary. The lineament appears to be coincident with the northern end of an approximately 5-km (3-mi.) wide zone of hanging wall deformation associated with the Jonesboro fault and defined by small normal faults identified in Texaco (Reference 2.5.3-216) seismic line 85SD12 (Figure 2.5.1-241). HAR 2 and HAR 3 lie within this zone of minor hanging wall deformation, which includes the Harris fault (Figure 2.5.1-241). There do not appear to be any mappable lineaments that would intersect either the HAR 2 or HAR 3 sites (Figure 2.5.3-207)."

To read:

"One of the longer of these east-west-trending lineaments extends across the northernmost part of the HAR site, approximately 150 m (500 ft.) north of the HAR 3 site (Figure 2.5.3-206). The lineament, which trends east to southeast, is identified primarily by a series of aligned drainages. The HNP, HAR 2, and HAR 3 sites appear to lie between the Harris fault and the lineament that aligns along the drainage currently occupied by the fire pond. This additional lineament, which is referred to as the fire pond lineament (FPL), is approximately 150 m (500 ft.) north of the proposed safety-related structures for HAR 3. Exposures of interbedded siltstones and sandstones of Lithofacies I Unit Trcs/si2 (Figure 2.5.3-208) in the outflow channel for the fire pond north of HAR 3 display four prominent fracture sets: N5E, N30° to 50W, N35E, and N85W. The N85W-trending fracture is open and parallels the trend of the FPL (Figure 2.5.3-209). Bedding is oriented approximately N15E, and dips approximately 17 to 30 degrees northeast at this location. The FPL obliquely crosses Highway 1 just to the west of the highway and Tom Jack Creek intersection (at the Chatham County/Wake County border). The lineament also intersects Old Highway 1 approximately 2.9 km (1.8 mi.) southwest of Bonsal. To the east, the lineament crosses the access road (SR 1134) into the HNP site and a spur off of SR 1134 that projects toward the northeastern part of the HNP site boundary. The lineament appears to be coincident with the northern end of an approximately 5-km (3-mi.) wide zone of hanging wall deformation associated with the Jonesboro fault and defined by small normal faults identified in Texaco (Reference 2.5.3-216) seismic line 85SD12 (Figure 2.5.1-241). HAR 2 and HAR 3 lie within this zone of minor hanging wall deformation, which includes the Harris fault (Figure 2.5.1-241). There do not appear to be any mappable lineaments that would intersect either the HAR 2 or HAR 3 sites (Figure 2.5.3-206)."

Attachments/Enclosures:

Attachment 02.05.01-27A: Figure 2.5.3-206 (Revised)

Attachment 02.05.01-27B: Figure 2.5.3-207 (Revised)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-28

Text of NRC RAI:

FSAR section 2.5.3.2.1.6 (p. 2.5-204) discusses several un-named faults in the site area (5 miles).

a) Please provide a map at the proper scale to demonstrate the items discussed in text.

b) Provide a table of all these un-named faults that provides character of fault, data available for interpretation; best estimate of timing on movement.

c) The applicant has not consistently provided a concluding statement for all the foregoing fault discussions about the age of last movement or the likelihood of the fault being active. Please provide that information.

PGN RAI ID #: H-0165

PGN Response to NRC RAI:

a) Unnamed faults discussed in section 2.5.3.2.1.6 are shown on Figure 2.5.1-230 (geologic map of the site vicinity) and Figure 2.5.1-231 (geologic map of the site area). Reference to these figures will be added to the text in a future revision. Names of faults and folds based on the Raleigh 100k Quadrangle acquired on 10/10/08 will be added to these Figures.

b) There is not enough data to justify addition of a table for these four unnamed faults in the site area. Additional information regarding these faults was provided in an electronic communication from Tyler Clark on 10/08/08 (RAI 02.05.01-28 Attachment C). FSAR section 2.5.3.2.1.6 will be revised in a future revision based on this additional information. Additional information regarding the northeast-trending (approximately 630 m [2067 ft.] long) fault that was identified approximately 2 km (1.2mi.) northwest of the HAR site during the widening of US 1 in May 1997 in Triassic sediments (Figure 2.5.1-231, Reference 2.5.3-208) is as follows:

   - The exposure was in a storm water drain excavation that is now under the highway. The excavation contained a fault zone consisting of at least four curvi-planar fault surfaces in a zone of disrupted lithology. The fault surfaces were extremely slickensided.
   - There were four main fault surfaces measured, all striking NE-SW, dipping moderately-high to the NW: 1) 041 60 NW; 2) 057 74 NW; 3) 042 54 NW; 4) 062 54 NW. Due to the heavily slickensided surfaces, it was difficult to determine a sense of slip, but in almost all cases, it is assumed to be normal movement.
   - One antithetic fault was observed in the footwall and was truncated against fault plane 1, but also cut across fault plane 2. The antithetic fault plane (5) was oriented 052 20 SE. Similar antithetic faults were observed on normal faults at the LLRW site to the south.

- Typical Triassic lithologies were observed on both sides of the fault zone. The hanging wall consisted of two units: 1) a reddish-brown, fine-grained, muscovite sandstone with occasional green mottling, and 2) a whitish-pink, moderately-sorted, coarse-grained lithic arkose-sandstone. The footwall consisted of olive-green to grey, very fine-grained, laminated sandstone. The fault zone could not be traced beyond the extent of the excavation. However, based on similar observations at the LLRW site to the south, NCGS staff felt the fault zone could be significant, and speculated that it could be a northward extension of the W8 fault.

c) Most age estimates of faults discussed in this subsection are based on very little data. The faults occur within Triassic sediments and are inferred to be structurally associated with the Jonesboro fault and other rift faults based on interpretation of seismic and geophysical data as discussed in FSAR Section 2.5.1.2.4 (See Response to RAI 02.05.01-20) and illustrated on RAI 02.05.02-08 Figure 2 (See Attachment B in RAI 02.05.02-08) . Based on structural association with the Jonesboro fault and related rift structures that have been demonstrated to have had no movement in the past 150 Ma (FSAR Section 2.5.3.2.1.1), these faults are judged not to be capable tectonic sources.

Associated HAR COL Application Revisions:

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

1. Revise paragraph 1 from FSAR Section 2.5.3.2.1.6 from:

   "Several other faults have been mapped within the site area. The most prominent is the Bonsal-Morrisville fault, which is located approximately 7.4 km (4.6 mi.) northwest of the site. The Bonsal-Morrisville fault is approximately 26 km (16 mi.) long, trends ~N37E, and has 600 to 1800 m (2000 to 6000 ft.) of vertical down-on-the-northwest displacement (Figure 2.5.1-241, Reference 2.5.3-214). The Bonsal-Morrisville fault is associated with the Jonesboro fault and has not been observed to offset deposits younger than Triassic; therefore, it is not capable. A smaller, approximately N70E trending fault that crosses the Jonesboro is shown on the 1985 geologic map, but has not been recognized in more recent, more detailed unpublished mapping by the NCGS (Reference 2.5.3-208). Similarly, a north-to-northwest-trending fault that was mapped within approximately 185 m (600 ft.) northeast of the HAR 3 site (Reference 2.5.3-207) has been removed on more recent unpublished maps by the NCGS. Geophysical data and field reconnaissance show no indication of a fault in this location, but rather identify the presence of a diabase dike. Another small (approximately 460 m [1500 ft.] long), high-angle normal fault has been mapped approximately 7.2 km (4.5 mi.) northeast of the site (Reference 2.5.3-208). The fault displays drag in Triassic sediments and is associated with a zone of syndepositional, fault-bend folding in the hanging wall of the Jonesboro fault (Figure 2.5.1-231). Additionally, one other unnamed northeast-trending (approximately 630 m [2067 ft.] long) fault was identified approximately 2 km (1.2 mi.) northwest of the HAR site during excavation work along Highway 1 in Triassic sediments (Figure 2.5.1-231, Reference 2.5.3-208).

   To FSAR Section 2.5.1.2.4.1.1 subsection on "Other Small Intrabasinal Faults in the Site Area" to read:

   "Several other faults and folds have been mapped within the site area (Figures 2.5.1-230 and 2.5.1-231)). The most prominent is the Bonsal-Morrisville fault, which is discussed above. A smaller, approximately N70E trending fault that crosses the Bonsal-Morrisville fault was shown on the 1985 geologic map and is retained on more recent, more detailed unpublished mapping by the NCGS (Reference 2.5.3-208). Although more recent studies could not identify the fault in the field it was retained in more recent mapping because high-angle bedding measurements, "different"-looking strata than the rest of the basin (possibly Lithofacies Association I), and abundant fractures were seen in the area of the mapped fault. Additionally, seismic reflection studies by Bain and Harvey (1977) indicated anomalous seismic reflectors in that area.

A north-to-northwest-trending fault that was shown on the 1985 geologic map of North Carolina within approximately 185 m (600 ft.) northeast of the HAR 3 site (Reference 2.5.3-207) has been removed on more recent unpublished maps by the NCGS. Geophysical data and field reconnaissance show no indication of a fault in this location, but rather identify the presence of a diabase dike.

Two short faults were recognized during excavation along Highway 1. The easternmost of these two faults, which lies approximately 7.2 km (4.5 mi.) northeast of the HAR site (Figure 2.5.1-231) is an approximately 460 m [1500 ft.] long, high-angle normal fault (Reference 2.5.3-208). The fault displays drag in Triassic sediments and is located at the northwest end of the Holly Springs anticline, part of a zone of syndepositional, fault-bend folding in the hanging wall of the Jonesboro fault (Figure 2.5.1-231). The westernmost of these two faults is a northeast-trending (approximately 630 m [2067 ft.] long) fault that lies approximately 2 km (1.2 mi.) northwest of the HAR site (Figure 2.5.1-231) and was identified during the widening of US 1 in May 1997 (Figure 2.5.1-231, Reference 2.5.3-208). The exposure was in a storm water drain excavation that is now under the highway. The excavation showed a fault zone of disrupted Triassic sediments in which at least four slickensided fault surfaces all striking northeast-southwest, dipping moderately-steeply to the northwest were mapped. The fault zone could not be traced beyond the extent of the excavation. However, based on similar observations at the LLRW site to the south, NCGS staff felt the fault zone could be significant, and speculated that it could be a northward extension of the W8 fault. (Tyler Clark, pers. comm., 10/8/08)"

No evidence of post-Triassic movement on any of these structures is reported in the literature or has been documented by recent mapping by the NCGS. The faults are interpreted to have formed in the same tectonic stress field as the other better studied Mesozoic rift faults in the site area (e.g., the Jonesboro fault, the Harris fault, and the faults in the LLRW and borrow pit study areas). Based on the absence of evidence for post-Triassic deformation and the structural association with noncapable faults, these faults are judged not to be capable tectonic fault sources.

Attachments/Enclosures:

Attachment 02.05.01-08D: Figure 2.5.1-230, Sheet 1 of 2 (Revised)

Attachment 02.05.01-20A: Figure 2.5.1-231, Sheets 1 of 3 (Revised)

Attachment 02.05.01-28A: Email from Tyler Clark

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-29

Text of NRC RAI:

FSAR section 2.5.3.2.2 (p. 2.5-206) discusses the lineament analysis and identifies the possible extension of several close-by faults to HAR as well as the description of a new structural element that may carry some significance to the site.

a) The FSAR states that: "The possible eastward extension of the Harris fault, as well as the SBPF and W82 faults, characterized in the LLRW disposal facility site to the west all appear to coincide with a set of generally east-to-west trending lineaments having regional extent (Figure 2.5.3-203)." If the LiDAR lineaments extend the traces of the nearby LLRW and Harris faults, please explains what additional investigation has the applicant completed to determine the veracity of this conclusion?

b) The FSAR states that bedding in the Fire Pond Lineament area strikes N15E with dips of 17 to 30° to the NE. Do you mean with dips to the NW or SE. Dips to the NE are not possible.

c) In the Results of Lineament analysis, the FSAR states that many new lineaments were interpreted with the new, higher-resolution LiDAR data. One lineament, oriented N85W, warranted field checking and this is now identified as the Fire Pond lineament (FPL). The FSAR provides a map with the hillshade base layer with the interpreted FPL (FSAR Figure 2.5.3-206) and a photo of a rock fracture or joint, the outcrop expression of that lineament. The fracture is described as 'open'. The FSAR indicates that this lineament lies just north of 3 and is sub-parallel to the Harris fault. This lineament is extended to the east, to the Jonesboro fault and tied it in with the northern end of an approximately 5-km (3-mi.) wide zone of hanging wall deformation associated with the Jonesboro fault and defined by small normal faults identified in Texaco (Reference 2.5.3-216) seismic line 85SD12 (Figure 2.5.1-241).

- Please provide further explanation along with illustration how the FPL can be extended east in the LIDAR data to the Jonesboro fault.
- What is the implication for the FPL with connecting it with deformation associated with the Jonesboro fault.
- Reference a map to show where the Texaco 85Sd12 seismic reflection line is located. Provide a full reference for this seismic reflection data. Provide an un-interpreted seismic reflection line figure.
- Do the FPL and the Harris fault merge?
- Can the FPL be interpreted as a fault?

d) Examination of Figure 5.2.1-230 suggests that the projection of both structural features (FPL and Harris extended fault) may intersect a group of folds (NW axial plane strike). Are the antithetic hanging wall faults of the Jonesboro fault and these folds the same feature?

e) The applicant correlated/projected the hanging wall deformation of the Jonesboro fault back to the HAR site and located HAR 2 and 3 in this zone between the Harris fault and the FPL. Is there direct evidence to do make this interpretation or is it speculation?

f) There seems to be no seismic data (reflection or refraction) lines that actually cross the Harris fault normal to strike nor including the FPL. Please identify any seismic refraction or reflection lines completed normal to the Harris fault and the FPL If there are none how do you determine if the hanging deformation associated with the Jonesboro fault and implied for Harris fault and the FPL is present or not?

g) The applicant has not provided a concluding statement about the significance of these features (Harris fault, FPL and Jonesboro fault) and the correlation with the regional features. Further explanation is needed to explain the analysis and pull it together in one place in the FSAR. Appropriate scale maps and cross sections must be included that contain all the features discussed in the analysis.

PGN RAI ID #: H-0166

PGN Response to NRC RAI:

a) LIDAR lineaments that are coincident with SBPF and W82 and a lineament that appears to be aligned along the eastern projection of the Harris fault suggest that the faults may extend beyond their mapped lengths (Figure 2.5.3-206). No additional investigations were conducted to determine if the Harris fault continues to the east of the site because 1) it has already been characterized in great detail at the site and 2) these investigations showed that the Harris fault is not a capable tectonic source. The SBPF and W82 faults also are not judged to be capable tectonic sources. None of these faults intersect the HAR 2 or HAR 3 sites; therefore, no additional characterization of these faults is needed to address ground motion or surface fault hazards.

b) "Dips to the NE" will be corrected to "dips to the SE". Revised text below also includes figure number changes based on RAI 02.05.01-27.

c) (1) As shown on FSAR Figure 2.5.3-203, the east-west-trending lineament directly north of HAR 3 (referred to as the Fire Pond lineament [FPL]) is not continuously mapped east to the Jonesboro fault.

(2) On the Texaco seismic line (RAI 02.05.02-08 Figure 2; see Attachment C in RAI 02.05.02-08) there is a wide zone of antithetic faults that are interpreted to be secondary deformation in the hanging wall on the Jonesboro fault.

(3) The location of the seismic reflection line is shown on the revised Figure 2.5.3-203 (Attachment 02.05.01-29A). The full reference for the seismic reflection line is "Texaco, Inc., "Seismic Reflection Profiles Line 85SD12 (Migration and Final Stack)," Display Scale 1 inch = 2000 ft., Project Number FED001, 1988." An uninterpreted version of the seismic line is provided in RAI 02.05.02-08 Figure 1 (See Attachment B in RAI 02.05.02-08).

(4) East–west trending lineaments (1a and 1b, FSAR Figure 2.5.3-203) are generally coincident with this zone of subsurface deformation. Lineament 1a lies along an eastward projection of the Harris fault; this suggests that the Harris fault may be related to the zone of secondary faulting imaged in the seismic profile between stations 2920 and 2970. The fault imaged at 2920, which may project to the surface in the vicinity of lineament 1b, appears to merge at depth with south-dipping faults within the broad zone of secondary faulting.

(5) If a similar zone of secondary faulting is present at the site, the FPL may be a fault-related lineament. There are no discrete geomorphic features along the FPL that would be indicative of Quaternary fault deformation. The FPL may be due to differential erosion of a zone of weakness associated with fracturing or faulting. Based on the evidence for timing of

most recent deformation on the Harris fault as pre-150 Ma, the apparent structural association of the zone of secondary faulting with the Jonesboro fault, which does not displace Cretaceous sediments, and the lack of geomorphic expression of Quaternary faulting, the FPL is judged not to be a capable tectonic feature.

d) Lineaments along the eastward projected trends of the Harris fault and the FPL, are traced eastward towards the sharp bend in the Jonesboro fault (Figure 2.5.3-203) that marks the boundary between the Durham segment to the north and the Holly Springs segment to the south. A series of northwest-tending folds also are present near the segment boundary. These folds are either syndepositional fault-bend folds or were formed from differential movement along the Jonesboro fault (personal communication Tyler Clark, 2006). Wooten et al. (2001) speculates that the east-west trending faults, such as the Harris and W82 faults originated as strike-slip faults accommodating displacement at the southern end of the Durham segment. There is no subsurface information to evaluate structural relationships between possible east-west-trending faults and the northwest-trending folds. The structures may be related in that they both are accommodation structures at the sharp bend in the main basin bounding fault that formed in response to different amounts and directions of movement on the two segments of the fault.

e) The inference that the HAR 2 and HAR 3 sites are located within a zone of secondary faults comparable to the faults imaged in Texaco seismic line 85SD12 is speculative. There is no direct link between the Harris fault, the FPL and the faults imaged on the Texaco seismic line. However, as outlined in item (c) above, a possible link between the Harris fault and the zone of faulting imaged in the Texaco seismic line cannot be precluded.

f) There are no seismic data (reflection or refraction) lines that cross the Harris fault or the FPL normal to strike. The identification of faults related to hanging wall deformation on the Jonesboro fault, between the Harris fault and the FPL that could intersect the safety-related structures at the HAR 2 and HAR 3 sites will be addressed through detailed mapping of the excavation walls and additional excavations in the surrounding areas as needed to demonstrate the absence of faulting that could pose a hazard to HAR 2 and HAR 3.

g) Revised text in a future revision will provide additional supporting figures and text to support the conclusions regarding the structural relationships among various faults and folds identified in the site area. Specific observations regarding the Harris fault (see Response to RAI 02.05.01-18 and RAI 02.05.01-25), the FPL (see Response to RAI 02.05.01-30 and RAI 02.05.01-31), and the Jonesboro fault (item a) and Response to RAI 02.05.01-8, RAI 02.05.01-18, RAI 02.05.01-20, RAI 02.05.01-22, and RAI 02.05.01-24) have been incorporated into revised FSAR Section 2.5.1.2.4 and Section 2.5.3.

Associated HAR COL Application Revisions:

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

1. Revise 4th paragraph of FSAR Section 2.5.3.2.2 from:

   "One of the longer of these east-west-trending lineaments extends across the northernmost part of the HAR site, approximately 150 m (500 ft.) north of the HAR 3 site (Figure 2.5.3-206). The lineament, which trends east to southeast, is identified primarily by a series of aligned drainages. The HNP, HAR 2, and HAR 3 sites appear to lie between the Harris fault and the lineament that aligns along the drainage currently occupied by the fire pond. This additional lineament, which is referred to as the fire pond lineament (FPL), is approximately 150 m (500 ft.) north of the proposed safety-related structures for HAR 3.

Exposures of interbedded siltstones and sandstones of Lithofacies I Unit Trcs/si2 (Figure 2.5.3-208) in the outflow channel for the fire pond north of HAR 3 display four prominent fracture sets: N5E, N30° to 50W, N35E, and N85W. The N85W-trending fracture is open and parallels the trend of the FPL (Figure 2.5.3-209). Bedding is oriented approximately N15E, and dips approximately 17 to 30 degrees northeast at this location. The FPL obliquely crosses Highway 1 just to the west of the highway and Tom Jack Creek intersection (at the Chatham County/Wake County border). The lineament also intersects Old Highway 1 approximately 2.9 km (1.8 mi.) southwest of Bonsal. To the east, the lineament crosses the access road (SR 1134) into the HNP site and a spur off of SR 1134 that projects toward the northeastern part of the HNP site boundary. The lineament appears to be coincident with the northern end of an approximately 5-km (3-mi.) wide zone of hanging wall deformation associated with the Jonesboro fault and defined by small normal faults identified in Texaco (Reference 2.5.3-216) seismic line 85SD12 (Figure 2.5.1-241). HAR 2 and HAR 3 lie within this zone of minor hanging wall deformation, which includes the Harris fault (Figure 2.5.1-241). There do not appear to be any mappable lineaments that would intersect either the HAR 2 or HAR 3 sites (Figure 2.5.3-206)."

To read:

"One of the longer of these east-west-trending lineaments extends across the northernmost part of the HAR site location, approximately 150 m (500 ft.) north of the HAR 3 site (Figure 2.5.3-206). The lineament, which trends east to southeast, is identified primarily by a series of aligned drainages, including the drainage currently impounded to form the fire pond. The HNP, HAR 2, and HAR 3 sites appear to lie between the Harris fault and this lineament, which is referred to as the fire pond lineament (FPL).
The origin of the FPL is unknown. There are no surface exposures of bedrock where the lineament crosses Old Highway 1 approximately 2.9 km (1.8 mi.) southwest of Bonsal (point FPL-1), Highway 1 (point FPL-2), along the railroad and stream cuts northwest of HAR 3 (FPL-3), or along the projected trend of the lineament where it crosses a spur off SR 1134 (FPL-4), and in the stream approximately 100 m (300 ft.) west of the main access road into the HNP site (SR 1134) (FPL-5) (Figure 2.5.3-206).

The closest exposure of bedrock to the FPL is located along the outflow channel to the fire pond northeast of the HAR 3 site. Exposures of interbedded siltstones and sandstones of Lithofacies I Unit Trcs/si2 (Figure 2.5.3-208) in the outflow channel for the fire pond north of HAR 3 display four prominent fracture sets: N5E, N30° to 50W, N35E, and N85W. The N85W-trending fracture is open and parallels the trend of the FPL (Figure 2.5.3-209). Bedding is oriented approximately N15E, and dips approximately 17 to 30 degrees southeast at this location. No evidence of faulting or disruption of the soils formed in these deposits was observed.

East-west trending lineaments along the projected trends of the FPL and the Harris faults intersect the Texaco seismic line 85SD12 (Figure 2.5.1-203). These lineaments appear to be associated with an approximately 5-km (3-mi) wide zone of secondary faults in the hanging wall of the Jonesboro fault (Figure 2.5.1-241). Based on the possible alignments of the FPL and Harris faults with the lineaments associated with the faults identified in the Texaco seismic line, it is reasonable to assume that the HNP, HAR 2, and HAR 3 sites lie within a similar zone of secondary, small normal faults in the hanging wall of the Jonesboro fault. It is noted, however, that the FPL lineament cannot be directly linked to the east-west trending lineament that crosses the seismic line.

The FPL may be related to a secondary fault of similar age to the Harris fault based on similarities in orientation and geomorphic expression. If the FPL is coincident with a fault, it is likely that the lineament represents differential erosion of more highly fractured or deformed rock. No scarps were observed across the projected trends of the FPL during field reconnaissance conducted for this study. There is no evidence to indicate that the FPL is the surface expression of a capable tectonic source."

Attachments/Enclosures:

Attachment 02.05.01-29A: Figure 2.5.3-203 (Revised)

Attachment 02.05.01-27A: Figure 2.5.3-206 (Revised)

Attachment 02.05.01-20G: Figure 2.5.1-241 (Revised)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-30

Text of NRC RAI:

FSAR Section 2.5.3.4 (p. 208) discusses ages of most recent deformations in the study area.

a) Please provide a concluding statement about the FPL with respect to age of formation and significance.

b) Please provide a concluding statement about the FPL's relationship to regional structures.

PGN RAI ID #: H-0167

PGN Response to NRC RAI:

a) Based on the projection of the FPL onto the Texaco Seismic Line 85SD12, it is possible that the FPL is the surface expression of a fault similar to the Harris fault in the hanging wall of the Jonesboro fault. No age data is available for the feature. Based on structural relationships interpreted from the Texaco Seismic Line 85SD12, the FPL likely formed at approximately the same time as the Jonesboro and Harris faults, likely greater than 135 Ma.

b) A discussion of the FPL's relationship to regional structures will be added to Section 2.5.3.2.1 in a future revision. East-west trending lineaments along the projected trends of the FPL and the Harris faults intersect the Texaco seismic line 85SD12 (Figure 2.5.3-203). These lineaments appear to be associated with an approximately 5-km (3-mi) wide zone of secondary faults in the hanging wall of the Jonesboro fault (Figure 2.5.1-241). It is noted, however, that the FPL lineament cannot be directly linked to the east-west trending lineament that crosses the seismic line.

Associated HAR COL Application Revisions:

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

1. Revise FSAR Section 2.5.3.4 from:

   "Detailed studies to determine the age of mapped faults in the study area were performed as part of the HNP fault investigations (Reference 2.5.3-202, Reference 2.5.3-201). The age of last movement on the Jonesboro fault is bracketed between the intrusion of Late Triassic – Jurassic dikes and the deposition of the overlying unfaulted Cretaceous marine sediments, between 180 and 135 Ma (Reference 2.5.3-202).

   Diabase dikes, secondary minerals in fault gouge adjacent to the dikes, and soils were used to constrain the age of the last movement on the Harris fault. Detailed studies to determine the age of most recent deformation on the Harris fault are described in Subsection 2.5.3.2.1.2. Movement along the Harris fault occurred after deposition and lithification of several thousand feet of Triassic basin sediments and ended shortly after intrusion of the latest of the Jurassic dikes (Reference 2.5.3-201). Field observations of undisturbed soil, saprolite, and in one place, a post-Triassic sedimentary deposit overlying the fault, indicated that the most recent movement was probably greater than one million years ago (Reference 2.5.3-201). Secondary zeolite minerals that formed in the fault zone along the Harris fault during thermal conditions that were last present in the region over 150 Ma are undeformed, indicating that the most recent movement predated this time (Reference 2.5.3-201). According to NUREG-1038, the NRC staff concurred that all the faults in the HNP site and Main Dam areas predate the mineralization that formed after regional deformation — at least 2.5 Ma, and likely more than 136 to 190 Ma.

No detailed geochronologic data exist for the borrow pit faults (SBPF, FA, FB, FC), fault W8, or fault W82; however, geologic relations suggest these faults were last active in the Triassic period (see Subsection 2.5.3.1.4 and Subsection 2.5.3.1.5 for a more detailed discussion)."

To read:

"Detailed studies to determine the age of mapped faults in the study area were performed as part of the HNP fault investigations (Reference 2.5.3-202, Reference 2.5.3-201). The age of last movement on the Jonesboro fault is bracketed between the intrusion of Late Triassic – Jurassic dikes and the deposition of the overlying unfaulted Cretaceous marine sediments, between 180 and 135 Ma (Reference 2.5.3-202).

Diabase dikes, secondary minerals in fault gouge adjacent to the dikes, and soils were used to constrain the age of the last movement on the Harris fault. Detailed studies to determine the age of most recent deformation on the Harris fault are described in Subsection 2.5.3.2.1.2. Movement along the Harris fault occurred after deposition and lithification of several thousand feet of Triassic basin sediments and ended shortly after intrusion of the latest of the Jurassic dikes (Reference 2.5.3-201). Field observations of undisturbed soil, saprolite, and in one place, a post-Triassic sedimentary deposit overlying the fault, indicated that the most recent movement was probably greater than one million years ago (Reference 2.5.3-201). Secondary zeolite minerals that formed in the fault zone along the Harris fault during thermal conditions that were last present in the region over 150 Ma are undeformed, indicating that the most recent movement predated this time (Reference 2.5.3-201). According to NUREG-1038, the NRC staff concurred that all the faults in the HNP site and Main Dam areas predate the mineralization that formed after regional deformation — at least 2.5 Ma, and likely more than 136 to 190 Ma.

Based on the location and orientation of the FPL and its projection onto the Texaco Seismic Line 85SD12, it is possible that the FPL is the surface expression of a fault similar to the Harris fault in the hanging wall of, and antithetic to the Jonesboro fault. No age data is available for the feature. Based on structural relationships interpreted from the Texaco Seismic Line 85SD12, the FPL likely formed at approximately the same time as the Jonesboro and Harris faults, likely greater than 135 Ma.

No detailed geochronologic data exist for the borrow pit faults (SBPF, FA, FB, FC), fault W8, or fault W82; however, geologic relations suggest these faults were last active in the Triassic period (see Subsection 2.5.3.1.4 and Subsection 2.5.3.1.5 for a more detailed discussion).

2. The following paragraphs have been added to FSAR Section 2.5.3.2.2:

   "East-west trending lineaments along the projected trends of the FPL and the Harris faults intersect the Texaco seismic line 85SD12 (Figure 2.5.3-203). These lineaments appear to be associated with an approximately 5-km (3-mi) wide zone of secondary faults in the hanging wall of the Jonesboro fault (Figure 2.5.1-241). Based on the possible alignments of the FPL and Harris faults with the lineaments associated with the faults identified in the Texaco seismic line, it is reasonable to assume that the HNP, HAR 2, and HAR 3 sites lie within a similar zone of secondary, small normal faults in the hanging wall of the Jonesboro fault. It is noted, however, that the FPL lineament cannot be directly linked to the east-west trending lineament that crosses the seismic line.

   The FPL may be related to a secondary fault of similar age to the Harris fault based on similarities in orientation and geomorphic expression. If the FPL is coincident with a fault, it is likely that the lineament represents differential erosion of more highly fractured or deformed rock. No scarps were observed across the projected trends of the FPL during field reconnaissance conducted for this study. There is no evidence to indicate that the FPL is the surface expression of a capable tectonic source."

Attachments/Enclosures:

Attachment 02.05.01-29A: Figure 2.5.3-203 (Revised)

Attachment 02.05.01-20G: Figure 2.5.1-241 (Revised)

NRC Letter No.: HAR-RAI-LTR-030

NRC Letter Date: October 14, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.01-31

Text of NRC RAI:

FSAR 2.5.3.6 (p. 209) provides a concluding discussion about all the possible capable tectonic sources. The last 2 bulleted items have not been fully developed in the previous sections and so these concluding statement need more justification.

a) The FSAR has not illustrated how the identified FPL must be interpreted as non-tectonic. What bedrock unit is less resistant and where is that unit mapped with respect to the FPL. What pre-exisitng structure is the FSAR referring to?

b) The FSAR states that folds and faults associated with the Harris fault and expressed as lineaments are not capable tectonic sources. Each fault or lineament that the FSAR has associated with the Harris fault must have its own unique assessment that it is not capable whether by direct or indirect evaluation.

The FPL has not been completely evaluated with respect to the possibility that the feature may be a fault associated not only with the Harris fault but also with the Jonesboro fault.

c) The FSAR states "Excavation exposures for HAR safety-related facilities will be mapped in detail and the surface rupture and ground motion generating potential of any deformation features identified will be assessed." Are there plans to excavate a trench across the FPL?

PGN RAI ID #: H-0168

PGN Response to NRC RAI:

a) Many of the lineaments identified in the site area may be explained as features that are the result of differential erosion of less resistant lithologic units (e.g., siltstone interbeds adjacent to more resistant gravel or sandstone units) or possibly more fractured or faulted bedrock. In the latter case, the lineament may reflect fault line erosion but is not indicative of geologically recent surface deformation. Pre-existing structure as used in the FSAR statement referred to secondary or intrabasinal faults of Mesozoic age that have not been active since the Mesozoic.

b) The statement that faults or folds that may be expressed as lineaments in the site area likely formed during the same time period as the Harris fault is based on detailed studies of faults exposed at the LLRW site and the Borrow Pits to the west of the HAR site (Wooten et al., 1996 [Reference 2.5.3-205]; Wooten et al., 2001[Reference 2.5.3-206]; Harding Lawson Associates, 1997 [Reference 2.5.1-332]) that support interpretations of structural relationships between movement on the varying segments of the Jonesboro fault and sense of slip on secondary intrabasinal faults (such as the Harris and SBPF faults). A detailed discussion of each of the faults in the site area will be provided in Subsection 2.5.3.2.1 in a future revision. Based on previous studies of faults and folds in the site area, mapped features (faults and folds), including the Harris fault, that are located in the Durham basin in the site area are interpreted to have formed in response to Mesozoic extension and rift-related processes. Interpretation of the Texaco seismic line 85SD12 (RAI 02.05.02-08

Figure 2) suggests that there are distributed secondary faults in the hanging wall of the Jonesboro fault that are related to later stage deformation within the rift. Previous studies have shown that the Jonesboro and Harris faults were most recently active prior to 135 to 150 million years ago. There is no reported evidence of Quaternary deformation associated with any of the mapped structures within the Deep River basin in the site area. It is reasonable to assume that the small intrabasinal faults that appear to be structurally related to the Jonesboro and Harris faults likely have a similar history of movement. This combined with the absence of geomorphic expression, such as fault scarps or offset geomorphic features associated with these faults is the basis for concluding that they are not capable tectonic sources. A concluding statement for each structure or group of related structures will be added to the discussion of the individual faults in a future revision.

c) Based on geologic reconnaissance there is no geomorphic expression of recent faulting along the FPL. There is no direct evidence to indicate that the lineament is the surface expression of a discrete fault zone. In addition to the detailed logging of the excavations of the HAR 2 and HAR 3 sites, some additional trenches or excavations in the area between the HAR 2 and HAR 3 sites may be completed and logged in detail to ensure that there are no capable tectonic sources that could pose a surface fault rupture hazard to HAR 2 and HAR 3. The FPL is not judged to be a capable tectonic source, and therefore there are currently no plans to excavate a trench across the FPL.

Associated HAR COL Application Revisions:

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

1. Revise FSAR Section 2.5.3.6 from:

   "A "capable tectonic source," as defined by Regulatory Guide 1.208, is described by at least one of the following characteristics:

   - Presence of surface or near-surface deformation of landforms or geologic deposits of a recurring nature within the last approximately 500,000 years, or at least once in the last approximately 50,000 years.
   - A reasonable association with one or more large earthquakes or sustained earthquake activity that usually is accompanied by significant surface deformation.
   - Structural association with a capable tectonic source having characteristics of section (1) above, such that movement on one could be reasonably expected to be accompanied by movement on the other.

   None of the mapped bedrock faults within a 40-km (25-mi.) radius or lineaments within an 8-km (5-mi.) radius of the HAR site is assessed to be a capable tectonic source. This conclusion is based on the following lines of evidence as discussed in the previous subsections:

   - The Jonesboro fault is overlain by undeformed Cretaceous sediments (Reference 2.5.3-202).
   - Detailed investigations to evaluate the Harris fault, including trenching, drilling, and mapping, have provided detailed geochronologic data that demonstrate faulting is likely older than 150 Ma.
   - No evidence of Quaternary deformation is reported in the literature or was observed during field and aerial reconnaissance conducted for this study.

- There are no associated historical earthquakes or alignments of seismicity to suggest the presence of a capable tectonic source in the site area.
- The identified lineaments can be explained by nontectonic mechanisms, such as differential erosion along less resistant bedrock units or along pre-existing ancient bedrock structures.
- Based on structural association with the Harris fault, it is expected that faults or folds that may be expressed as lineaments in the rift basin sediments in the site area likely formed during the same period of deformation and, therefore, are not capable tectonic sources. Excavation exposures for HAR safety-related facilities will be mapped in detail and the surface rupture and ground motion generating potential of any deformation features identified will be assessed."

To read:

"A "capable tectonic source," as defined by Regulatory Guide 1.208, is described by at least one of the following characteristics:

- Presence of surface or near-surface deformation of landforms or geologic deposits of a recurring nature within the last approximately 500,000 years, or at least once in the last approximately 50,000 years.
- A reasonable association with one or more large earthquakes or sustained earthquake activity that usually is accompanied by significant surface deformation.
- Structural association with a capable tectonic source having characteristics of section (1) above, such that movement on one could be reasonably expected to be accompanied by movement on the other.

None of the mapped bedrock faults within a 40-km (25-mi.) radius possible fault-related lineaments (e.g., the FPL) within an 8-km (5-mi.) radius of the HAR site is assessed to be a capable tectonic source. This conclusion is based on the following lines of evidence as discussed in the previous subsections:

- The Jonesboro fault is overlain by undeformed Cretaceous sediments (Reference 2.5.3-202).
- Detailed investigations to evaluate the Harris fault, including trenching, drilling, and mapping, have provided detailed geochronologic data that demonstrate faulting is likely older than 150 Ma.
- Structural analysis of the development of faults and fractures exposed at the borrow pit and LLRW areas suggest that these structures pre-date or formed during the same stress regime as the Harris fault.
- Evidence observed in trenches that shows that the faults identified at the LLRW disposal facility site, approximately 1.5 mi. west of the HAR site, predate significant weathering and soil formation or exhibit no evidence of recent faulting (Reference 2.5.3-206).
- No evidence of Quaternary deformation is reported in the literature or was observed during field and aerial reconnaissance conducted for this study.
- There are no associated historical earthquakes or alignments of seismicity to suggest the presence of a capable tectonic source in the site area.

- East-west trending lineaments such as the FPL and the lineament along the eastward projection of the Harris fault if related to faults can be explained as due to differential erosion of fractured rock associated with secondary faults in the hanging wall of the Jonesboro fault.
- Based on structural association with the Harris fault, it is expected that faults or folds that may be expressed as lineaments in the rift basin sediments in the site area likely formed during the same period of deformation and, therefore, are not capable tectonic sources. Excavation exposures for HAR safety-related facilities will be mapped in detail and the surface rupture and ground motion generating potential of any deformation features identified will be assessed."

Attachments/Enclosures:

None.

List of Files included on Attached CD:

Attachment 02.05.01-01A.pdf
Attachment 02.05.01-01B.pdf
Attachment 02.05.01-02A.pdf
Attachment 02.05.01-02B.pdf
Attachment 02.05.01-02C.pdf
Attachment 02.05.01-03A.pdf
Attachment 02.05.01-03B.pdf
Attachment 02.05.01-03C.pdf
Attachment 02.05.01-03D.pdf
Attachment 02.05.01-03E.pdf
Attachment 02.05.01-03F.pdf
Attachment 02.05.01-05A.pdf
Attachment 02.05.01-05B.pdf
Attachment 02.05.01-05C.pdf
Attachment 02.05.01-08A.pdf
Attachment 02.05.01-08B.pdf
Attachment 02.05.01-08C.pdf
Attachment 02.05.01-08D.pdf
Attachment 02.05.01-13A.pdf
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Attachment 02.05.01-20B.pdf
Attachment 02.05.01-20C1.pdf
Attachment 02.05.01-20C2.pdf
Attachment 02.05.01-20C3.pdf
Attachment 02.05.01-20C4.pdf
Attachment 02.05.01-20C5.pdf
Attachment 02.05.01-20C6.pdf
Attachment 02.05.01-20C7.pdf
Attachment 02.05.01-20C8.pdf
Attachment 02.05.01-20D1.pdf
Attachment 02.05.01-20D2.pdf
Attachment 02.05.01-20E.pdf
Attachment 02.05.01-20F.pdf
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Attachment 02.05.01-23B.pdf
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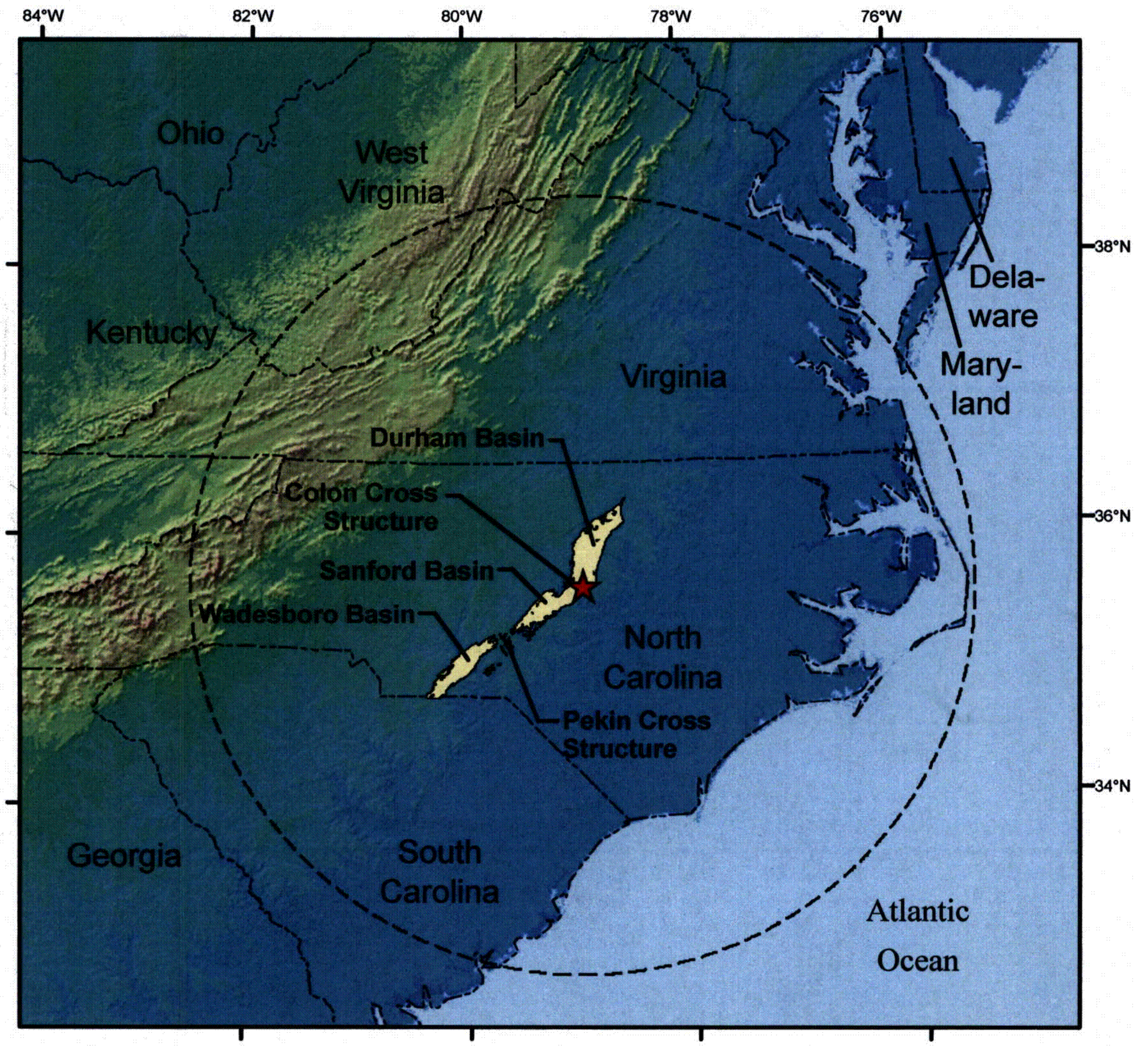
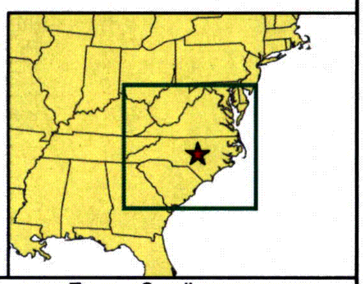
Attachment 02.05.01-25A.pdf
Attachment 02.05.01-25B.pdf
Attachment 02.05.01-25C.pdf
Attachment 02.05.01-25D.pdf
Attachment 02.05.01-27A.pdf
Attachment 02.05.01-27B.pdf
Attachment 02.05.01-28A.pdf
Attachment 02.05.01-29A.pdf

Pre-Flight Report for Files Included on Attached CD

This document serves as a pre-flight report for the attachments to responses specific to NRC RAI LTR-030, in support of the Harris COLA. The following files (mostly individual figure files) do not pass pre-flight, but text is word searchable and clarity/legibility is of high quality. Most of the files that do not pass pre-flight, due to being < 300 ppi, are GIS figures converted from native file types to Adobe PDF, but comply with the NRC electronic submittal checklist.

No.	File Name	Preflight Status	Reason
HAR NRC LTR-030 – FSAR 2.5.1			
1	Attachment 02.05.01-03E.pdf	Error/Failed	< 300 ppi
2	Attachment 02.05.01-08A.pdf	Error/Failed	< 300 ppi
3	Attachment 02.05.01-13A.pdf	Error/Failed	< 300 ppi
4	Attachment 02.05.01-20E.pdf	Error/Failed	< 300 ppi
5	Attachment 02.05.01-20G.pdf	Error/Failed	< 300 ppi
6	Attachment 02.05.01-24A.pdf	Error/Failed	< 300 ppi, embedded fonts (due to handwritten notes, signatures – unable to run OCR).





Source: CP&L (1983)

LEGEND

- HAR Site
- 320-km (200-mi.) Radius from Site
- State Boundary
- Deep River Basin (Clark et al., 2001)

Base Map: ESRI (2004)

N W E S

0 50 100 Miles

0 100 200 Kilometers

Progress Energy Carolinas

Shearon Harris Nuclear Power Plant Units 2 and 3 Part 2, Final Safety Analysis Report

New Hill, North Carolina

Location of the Deep River Basin

FIGURE 2.5.1-202 (Revised)

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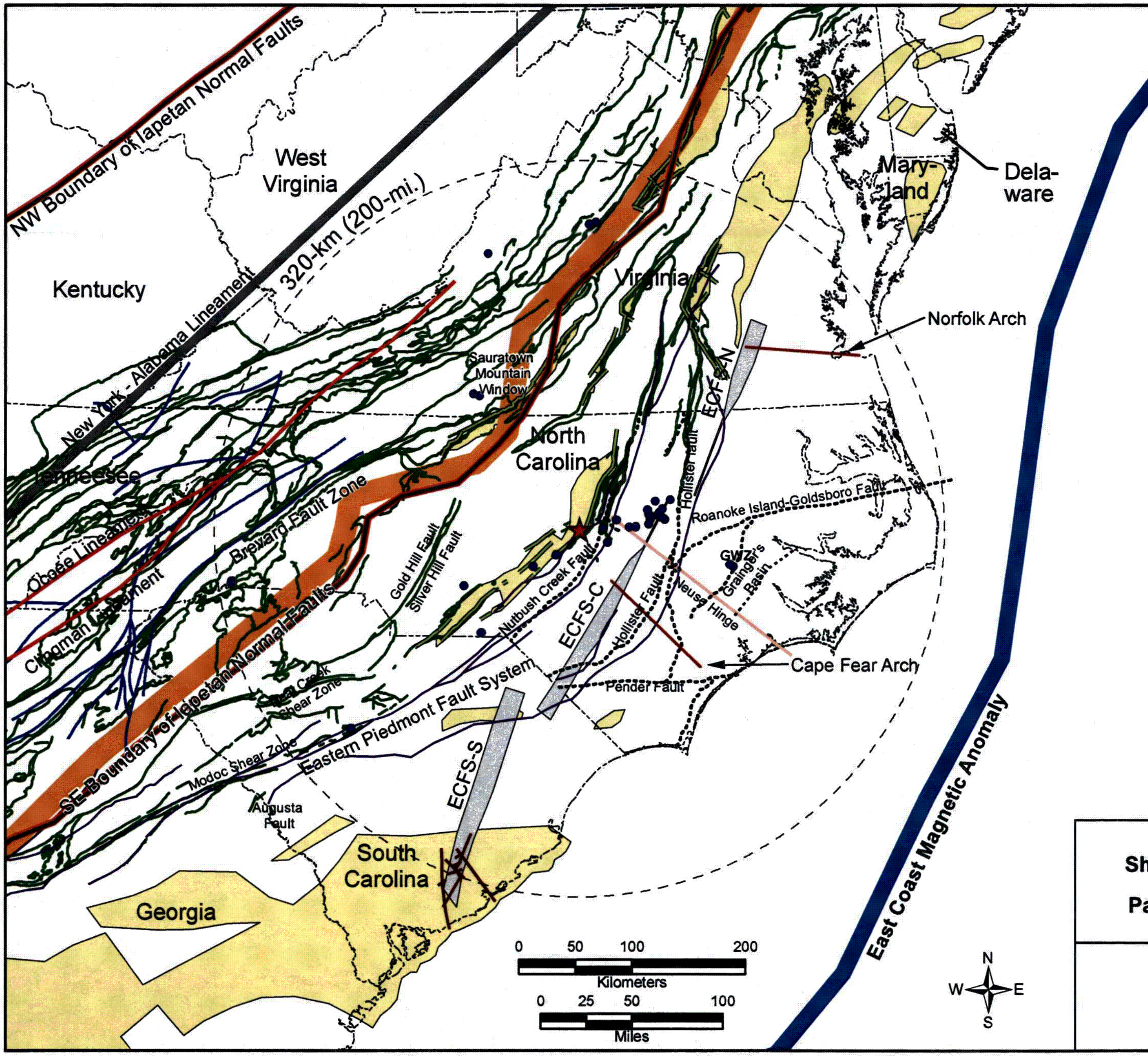


Progress Energy Carolinas

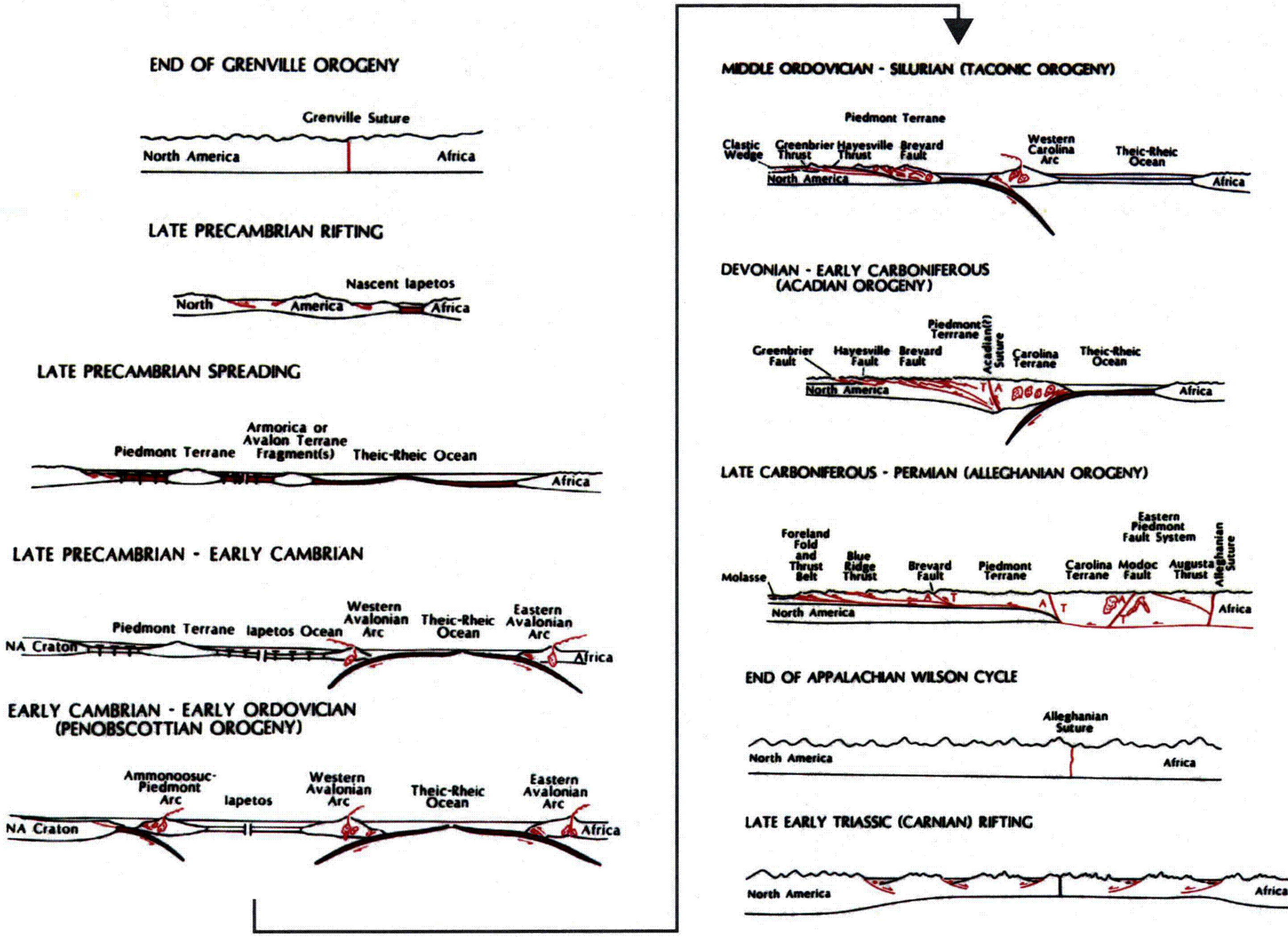
Shearon Harris Nuclear Power Plant
Units 2 and 3
Part 2, Final Safety Analysis Report

New Hill, North Carolina

Principal Tectonic Features in the Study Region

FIGURE 2.5.1-213 (Revised)

File path: S:\11100\11151.002\Figures\2.5.1_figures_fig_2.5.1-213.mxd; Date: [12/10/2008]; User: [sbozkurt]



Source: Hatcher (1989b)

Progress Energy Carolinas

Shearon Harris Nuclear Power Plant
Units 2 and 3
Part 2, Final Safety Analysis Report

New Hill, North Carolina

Central and Southern Appalachian
Tectonic Evolution

RAI 02.05.01-02 FIGURE 1

File Path: S:\11100\11151.002\Figures\RAI_RAI 02.05.01-02 Figure 1.ai; Date: [12/10/2008]; User: [sbozkurt]

Period	Ma.	Orogeny	Plate Tectonic Process
Jurassic	144		Symmetrical Rifting and Opening of Atlantic
Triassic	208		
Permian	245 286	ALLEGHANIAN	Subduction Collision with Africa
Carb. — Pa	320		
Carb. — Miss	360	ACADIAN	Subduction Terrane Accretion
Devonian	408		
Silurian	438	TACONIC	A-Subduction Obduction Arc Collision/ Accretion
Ordovician	505	////////////////// PENOBSCOT	
Cambrian	570		Trailing Margin Development
Late Proterozoic	1000	AVALONIAN	Subduction Volcanic Arc Generation
Middle Proterozoic		GRENVILLE	Rifting and Opening of Iapetus

Source: Hatcher (1989)

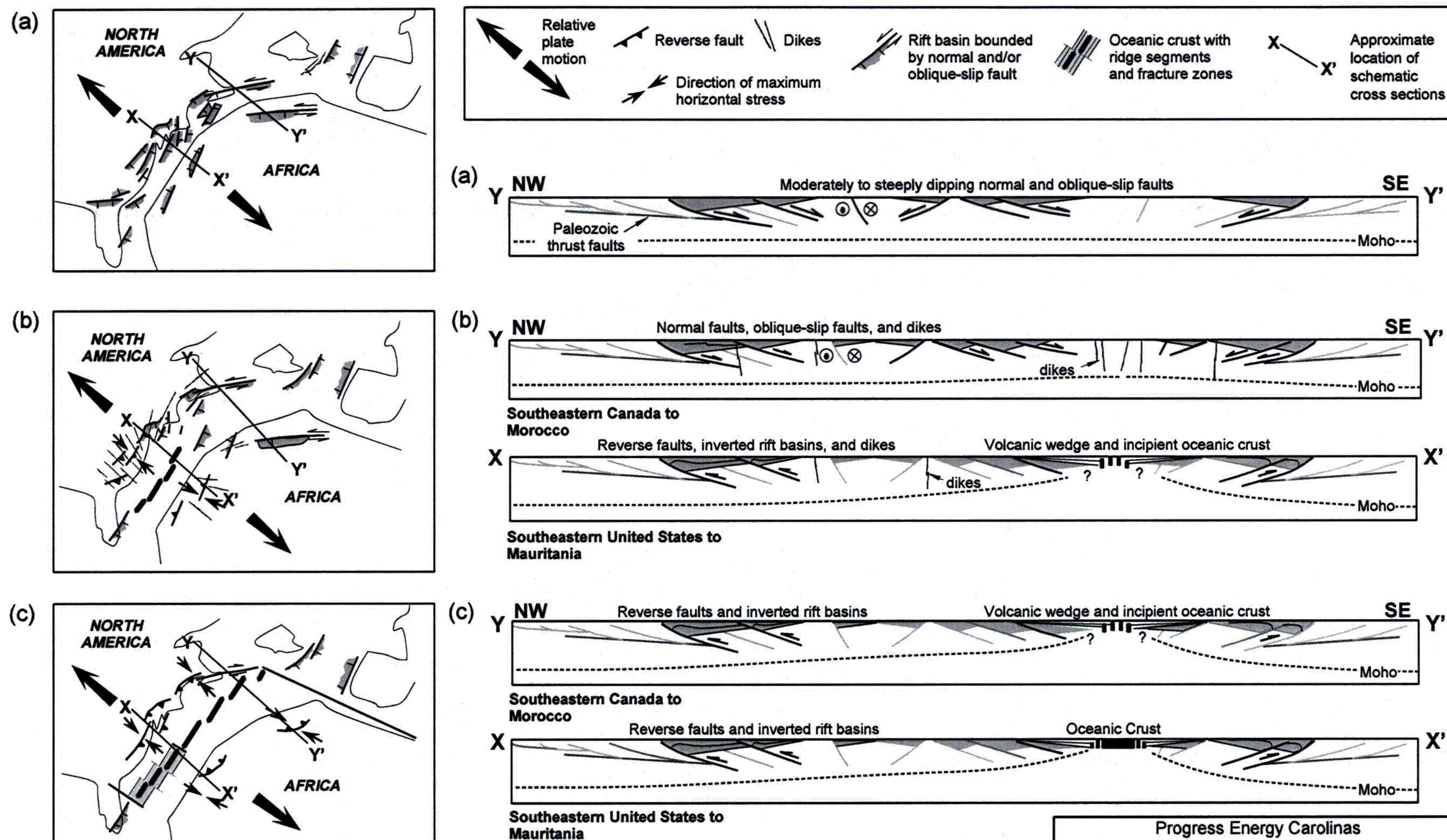
Progress Energy Carolinas

Shearon Harris Nuclear Power Plant
Units 2 and 3
Part 2, Final Safety Analysis Report

New Hill, North Carolina

Central and Southern Appalachian Tectonic Events

RAI 02.05.01-02 FIGURE 2



Notes: (a) Middle to Late Triassic: northeast-striking basins developed, subsiding and filling with sediments. (b) Late Triassic to Early Jurassic, shortly before to after eastern North America (ENA) magmatic activity: in the southeastern United States, rifting ceased, and northeast-striking reverse faults and associated folds developed; ENA magmatic activity led to the emplacement of northwest-striking dikes. (c) Early Jurassic (after ENA magmatic activity) to Early Cretaceous: full-fledged drifting began between the southeastern United States and western Africa.

Source: Modified from Withjack et al. (1998)

Progress Energy Carolinas

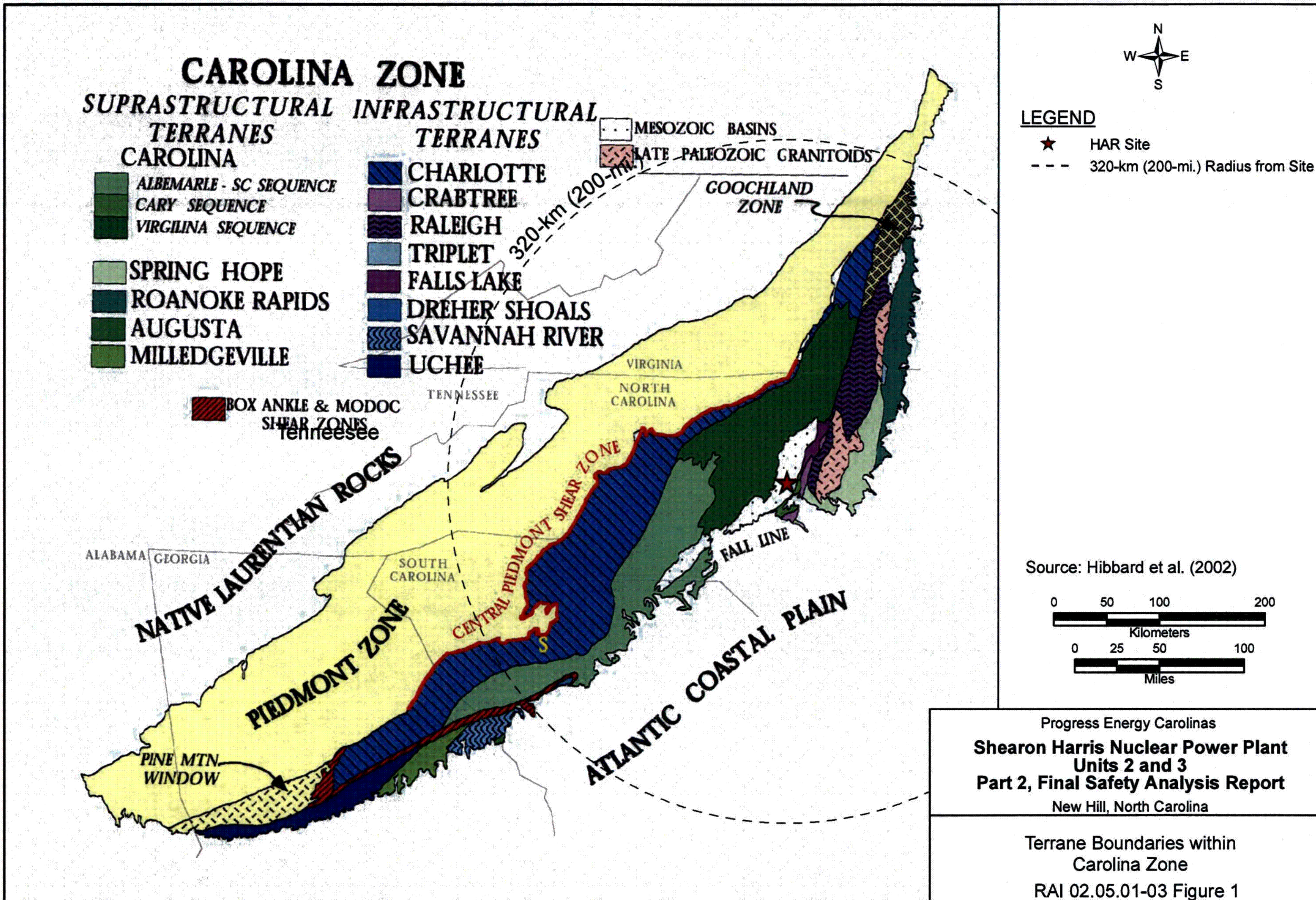
Shearon Harris Nuclear Power Plant Units 2 and 3 Part 2, Final Safety Analysis Report

New Hill, North Carolina

Sketches Showing Evolution of Central Eastern North America during the Mesozoic

FIGURE 2.5.1-206 (Revised)

File Path: S:\11100\11151.002\Figures\2.5.1_figures_fig_2.5.1-206.ai Date: [12/10/2008]; User: [sbozkurt]



Progress Energy Carolinas

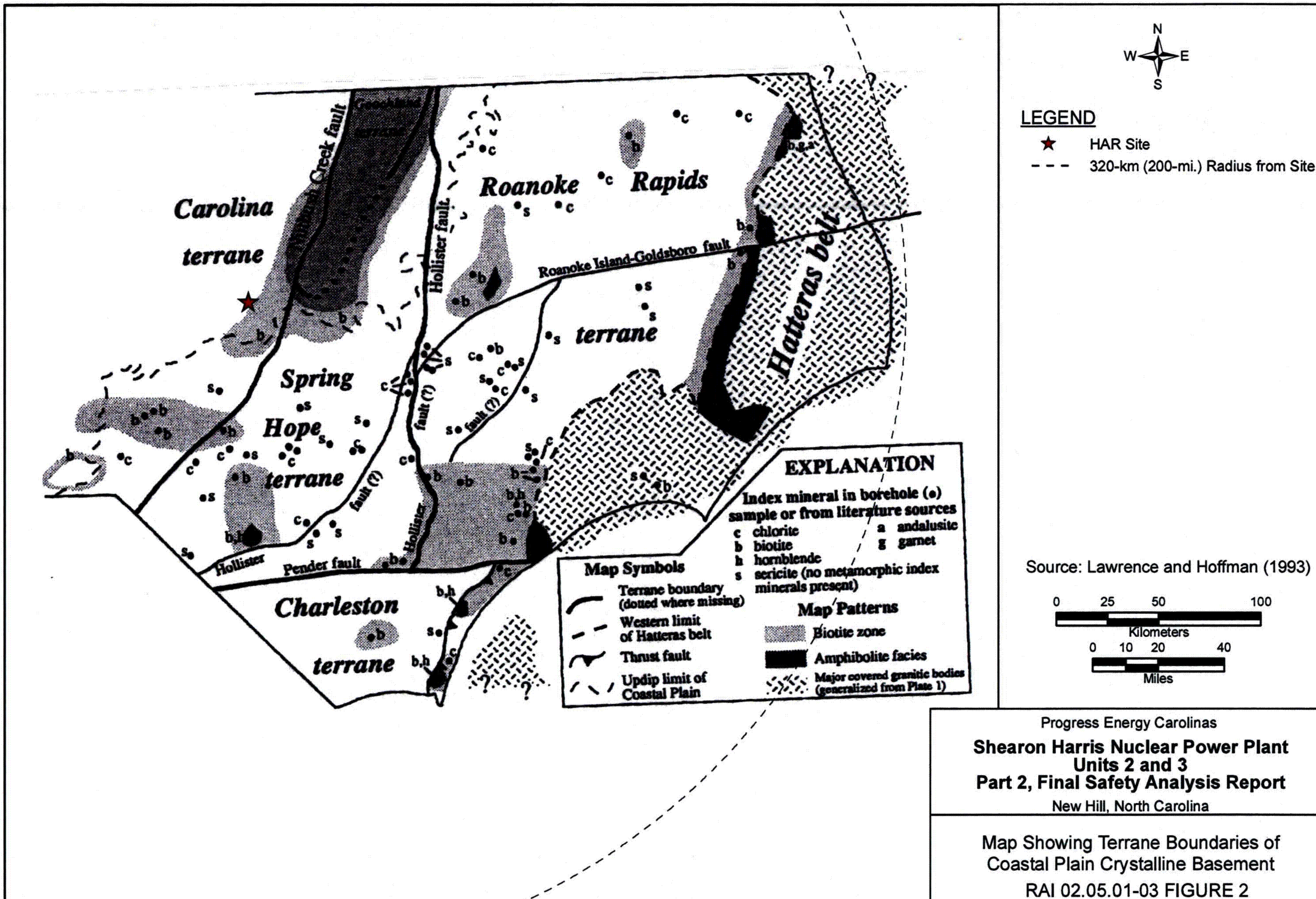
Shearon Harris Nuclear Power Plant Units 2 and 3 Part 2, Final Safety Analysis Report

New Hill, North Carolina

Terrane Boundaries within Carolina Zone

RAI 02.05.01-03 Figure 1

File path: S:\11100\11151.002\Figures\RAI\RAI 02.05.01-03 Figure 1.mxd; Date: [12/03/2008]; User: [sbozkurt]



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Map Showing Terrane Boundaries of Coastal Plain Crystalline Basement

RAI 02.05.01-03 FIGURE 2

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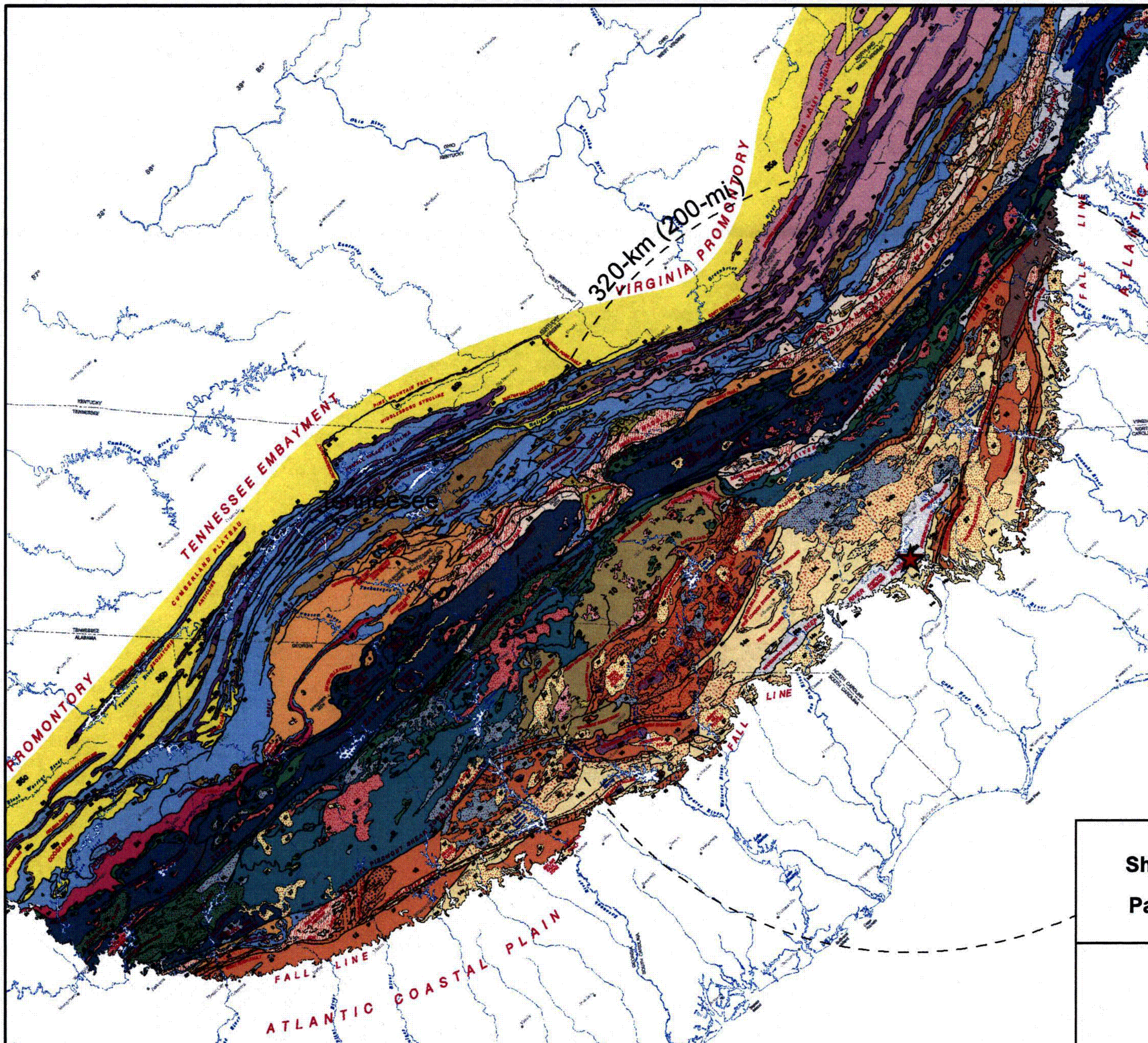

LEGEND

★ HAR Site

- - - 320-km (200-mi.) Radius from Site

Source: Hibbard et al. (2006)

0 50 100 200 Kilometers

0 25 50 100 Miles

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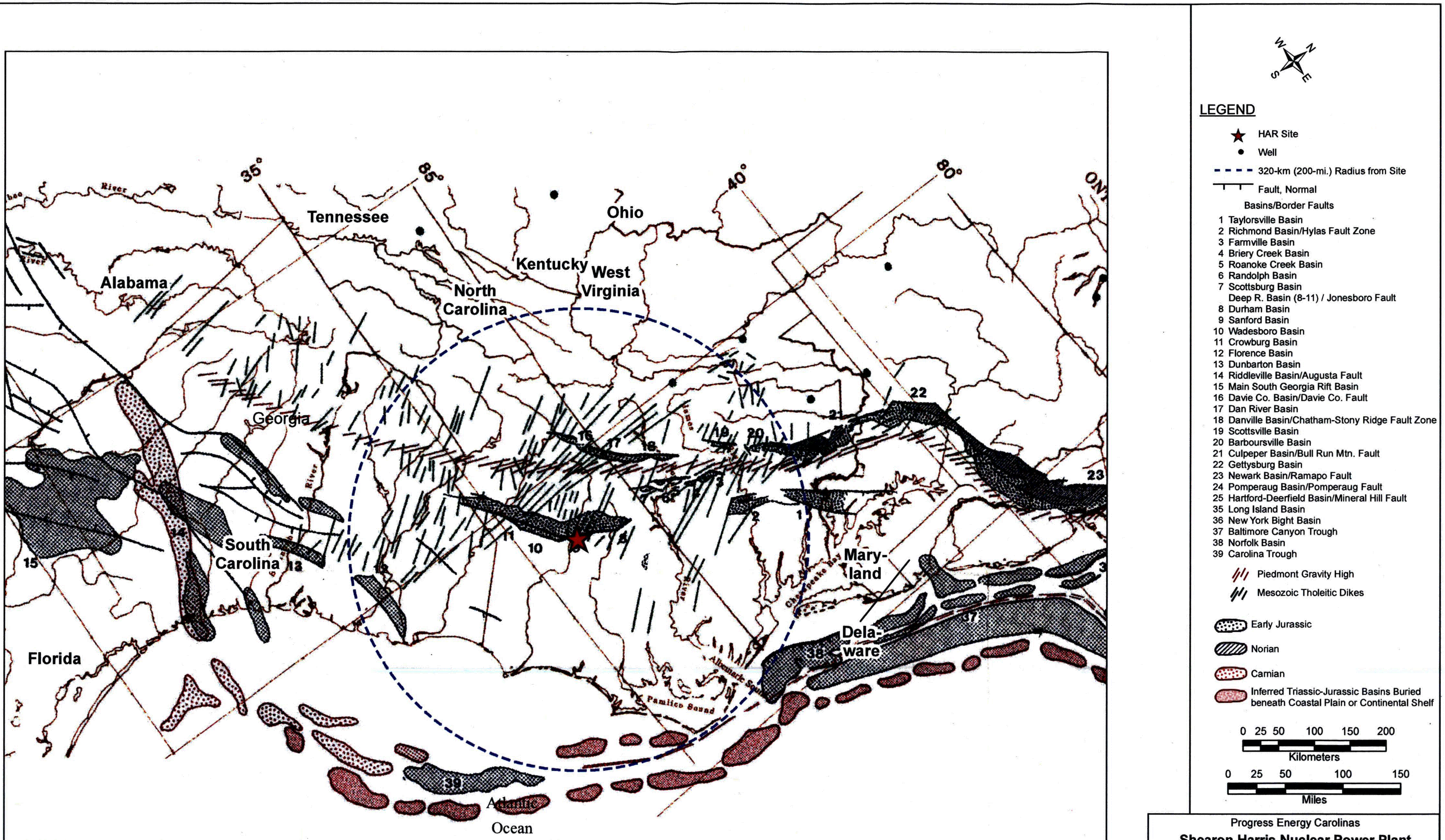
Terrane Boundaries within Carolina Zone

RAI 02.05.01-03 FIGURE 3



Source: Manspeizer et al. (1991)

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Onshore and Offshore Late Triassic to Early Jurassic Basins in the Eastern United States

FIGURE 2.5.1-210 (Revised)

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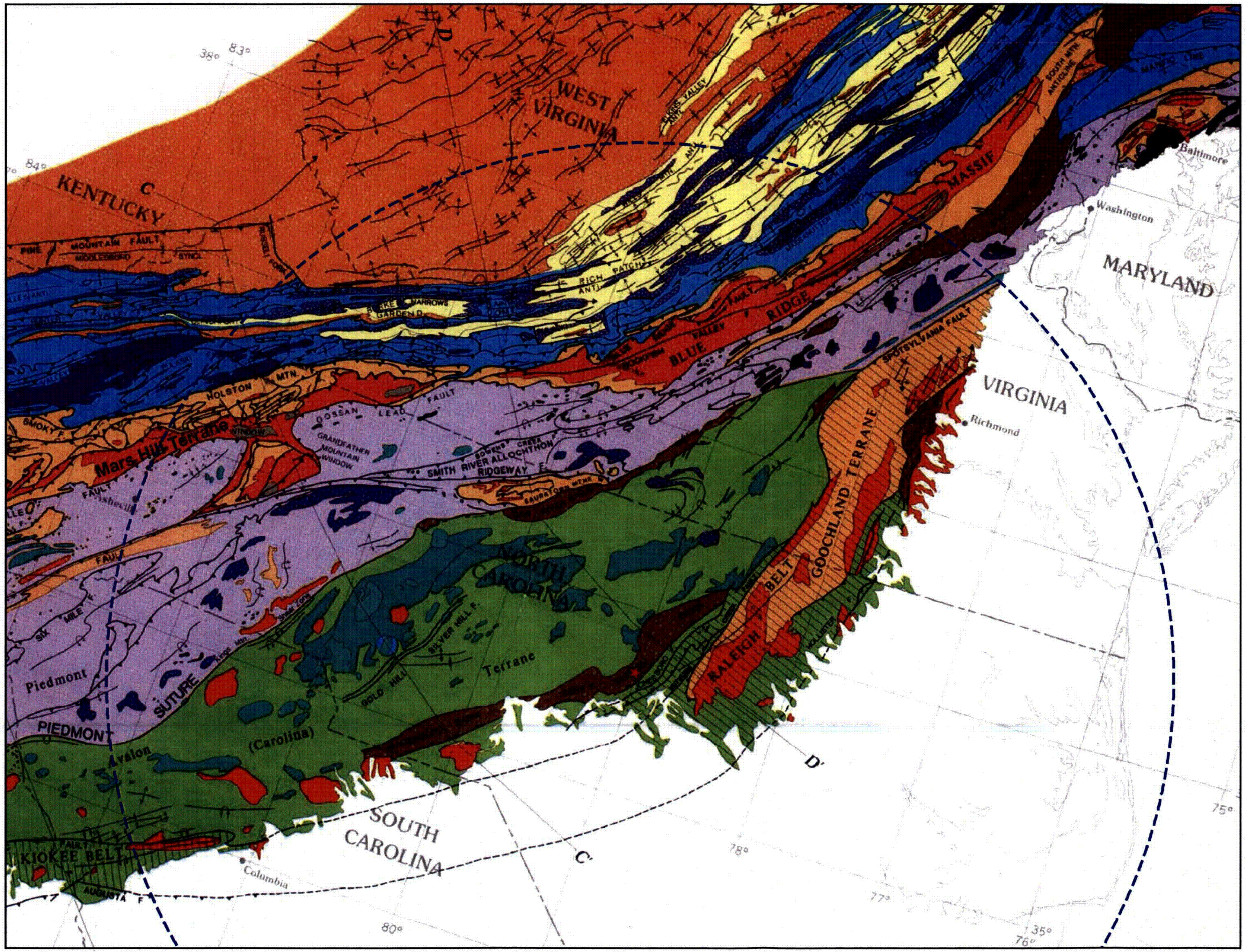
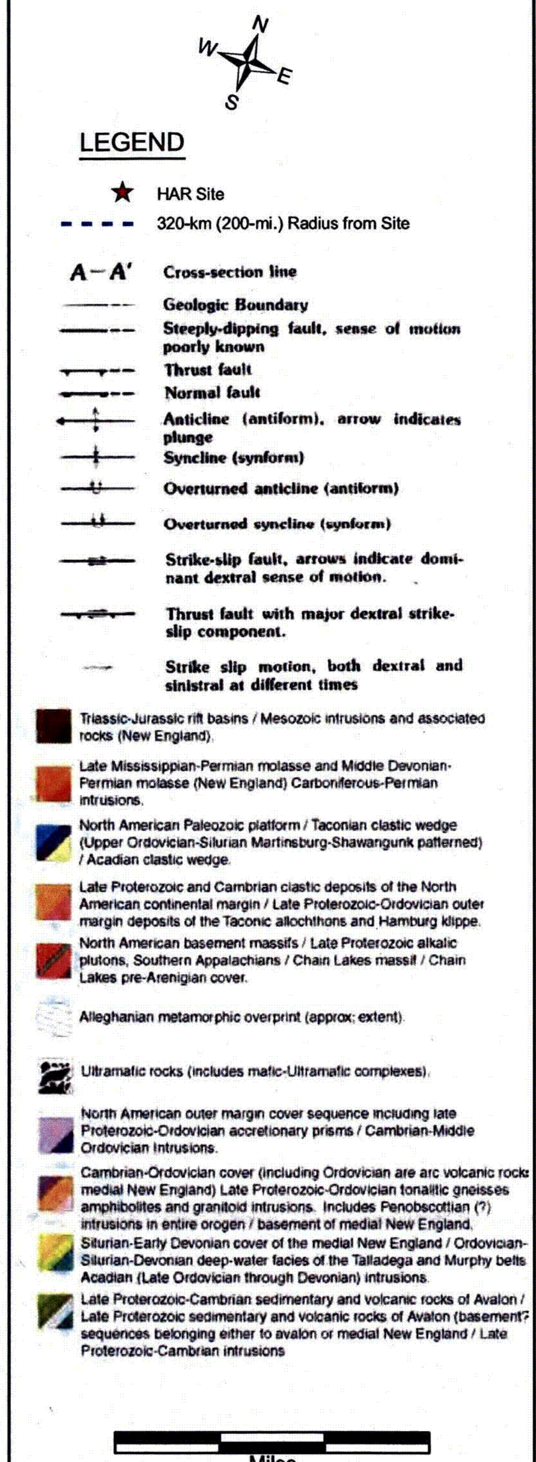


Source: Hatcher et al. (1989)



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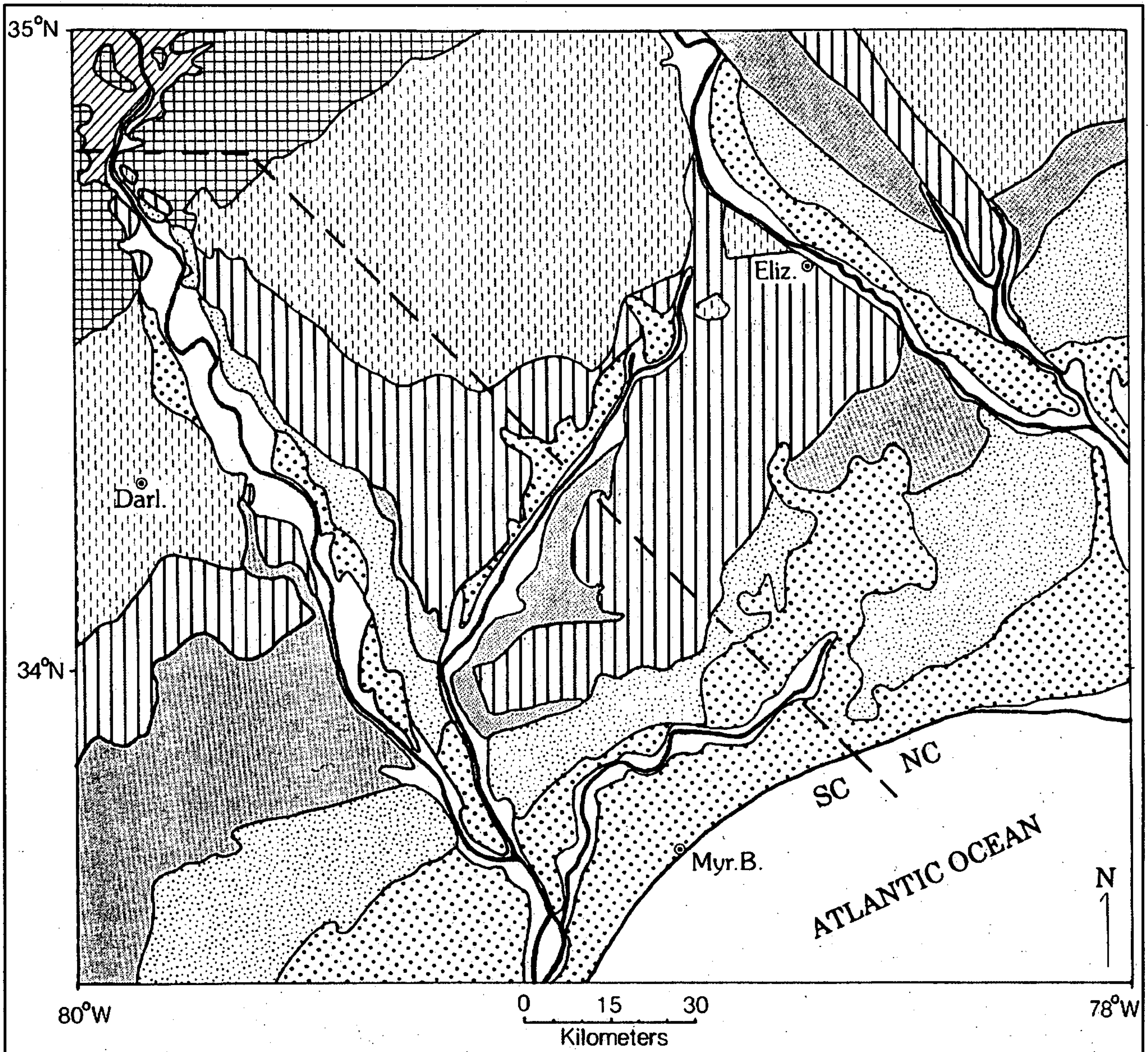
Tectonic Map of the Central Appalachians Showing Locations of Regional Cross Sections C-C' and D-D'
FIGURE 2.5.1-211 (Revised)



EXPLANATION

Wando Formation + Holocene sediment	Bear Bluff Formation
Socastee Formation	Duplin Formation
Penholoway Formation	Inner Coastal Plain, undifferentiated
Waccamaw Formation	Piedmont, undifferentiated

Source: Soller and Mills (1991)

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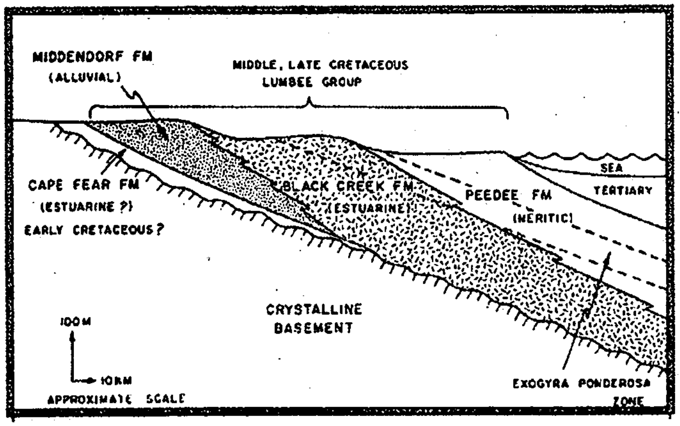
Simplified Geologic Map of the Emerged Coastal Plain in Southeastern North Carolina and Northeastern South Carolina

RAI 2.5.1-3 FIGURE 4

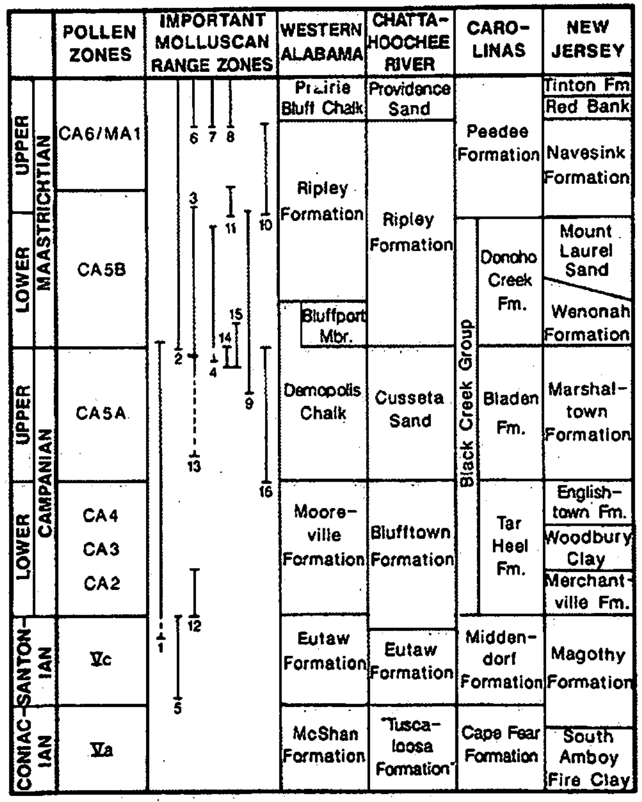
File path: S:\11100\11151.002\Figures\RAI\RAI 02.05.01-03 Figure 4.mxd; Date: [11/18/2008]; User: [sbozkurt]

a)



Diagrammatic cross-section showing general stratigraphic relationship among Cretaceous formations of the Cape Fear Arch

b)



Correlation of the Carolina Upper Cretaceous formations

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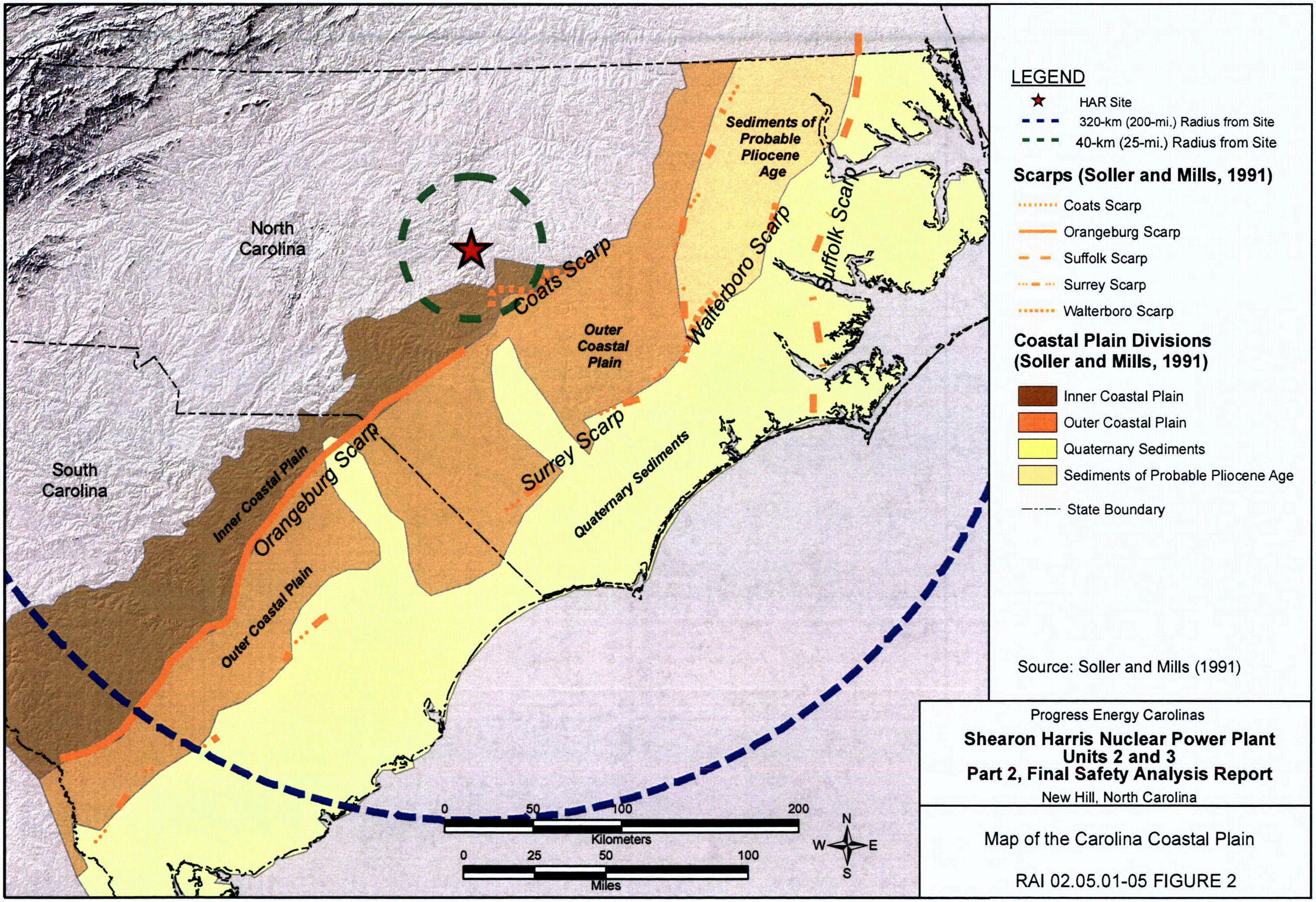
Cretaceous Stratigraphy of the Carolina Coastal Plain

RAI 02.05.01-5 FIGURE1

Source: Farrell et al. (2001)

File Path: S:\11100\11151.002\Figures\RAI_RAI 02.05.01-5 Figure 1.ai



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Map of the Carolina Coastal Plain

RAI 02.05.01-05 FIGURE 2

File path: S:\11100\11151.002\Figures\RAI\RAI 02.05.01-05 Figure 2.mxd

Age		South and central South Carolina[1]	Central South Carolina[2]	Northeastern South Carolina[3]	Northeastern South Carolina and southeastern North Carolina[4]	Central and northeastern North Carolina[5]	Northeastern North Carolina and southern Virginia[6]
Pleistocene	late	Q2	Q2		Wando	Core Creek	Lynnhaven Member of Tabb Formation
Pleistocene	middle	Q3	Q3	Canepatch and Socastee	Socastee	Flanner Beach	Shirley Formation and Sedgefield Member of Tabb Formation
Pleistocene	middle	Q4	Q4			no data	
Pleistocene	early	Q5	Q5	Waccamaw	Penholoway	no data	? Chuckatuck ?
Pleistocene	early	Q6	Q6	Waccamaw	Waccamaw	no data	?
Tertiary: Pliocene	late	sediment beneath Okefenokee terrace		Marietta and Bear Bluff	Bear Bluff	Chowan River	Charles City, Windsor, Moorings, Bacons Castle (Pliocene?)
Tertiary: Pliocene	early	sediment beneath Coharie and Sunderland terraces			Duplin	Macks	?
Tertiary: Miocene							
Tertiary: Oligocene							
Tertiary: Eocene		Barnwell Group					
Tertiary: Paleocene		Black Mingo, Huber					
Upper Cretaceous		Middendorf ?			Tar Heel; Middendorf; Cape Fear		

Source: Soller and Mills (1991)

[1]Pleistocene units from Colquhoun (1986). Pliocene units from Colquhoun (1974). Older units from Smith (1979b, 1980), Smith and White (1979), Kite (1982b), Mittwede (1982), Nystrom and Willoughby (1982b), and Nystrom, Willoughby, and Kite (1986).

[2]From McCartan and others (1984).

[3]From DuBar and others (1974b).

[4]From Owens (1989).

[5]From Mixon and Pilkey (1985), Blackwelder (1981b), and Daniels and others (1966).

[6]From Johnson and Peebles (1986) and Cleaves and others (1987).

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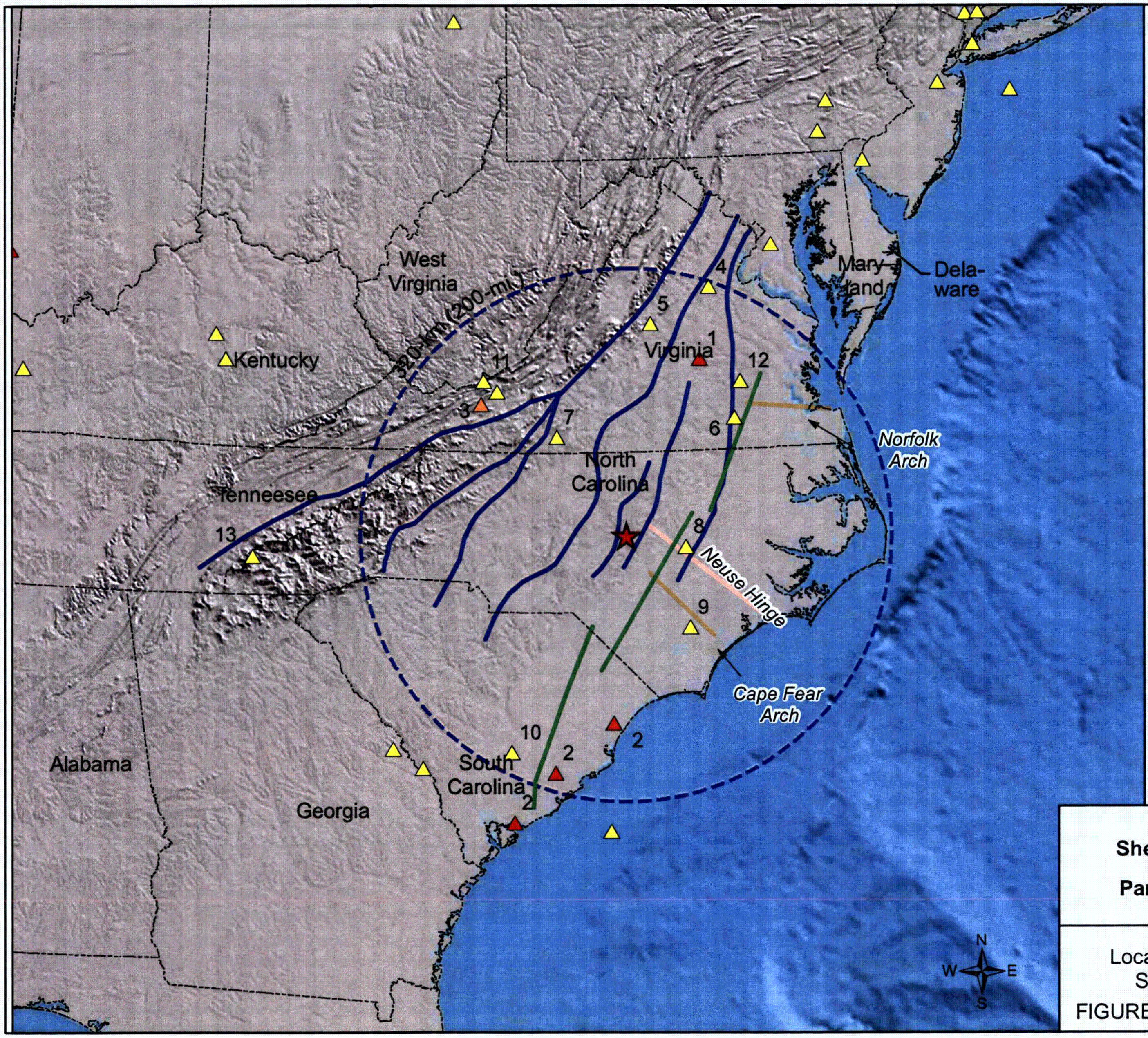
Stratigraphy of the Carolina Coastal Plain

RAI 02.05.01-5 Figure 3

File Path: S:\11100\11151.002\Figures\RAI_RAI 02.05.01-5 Figure 3.ai



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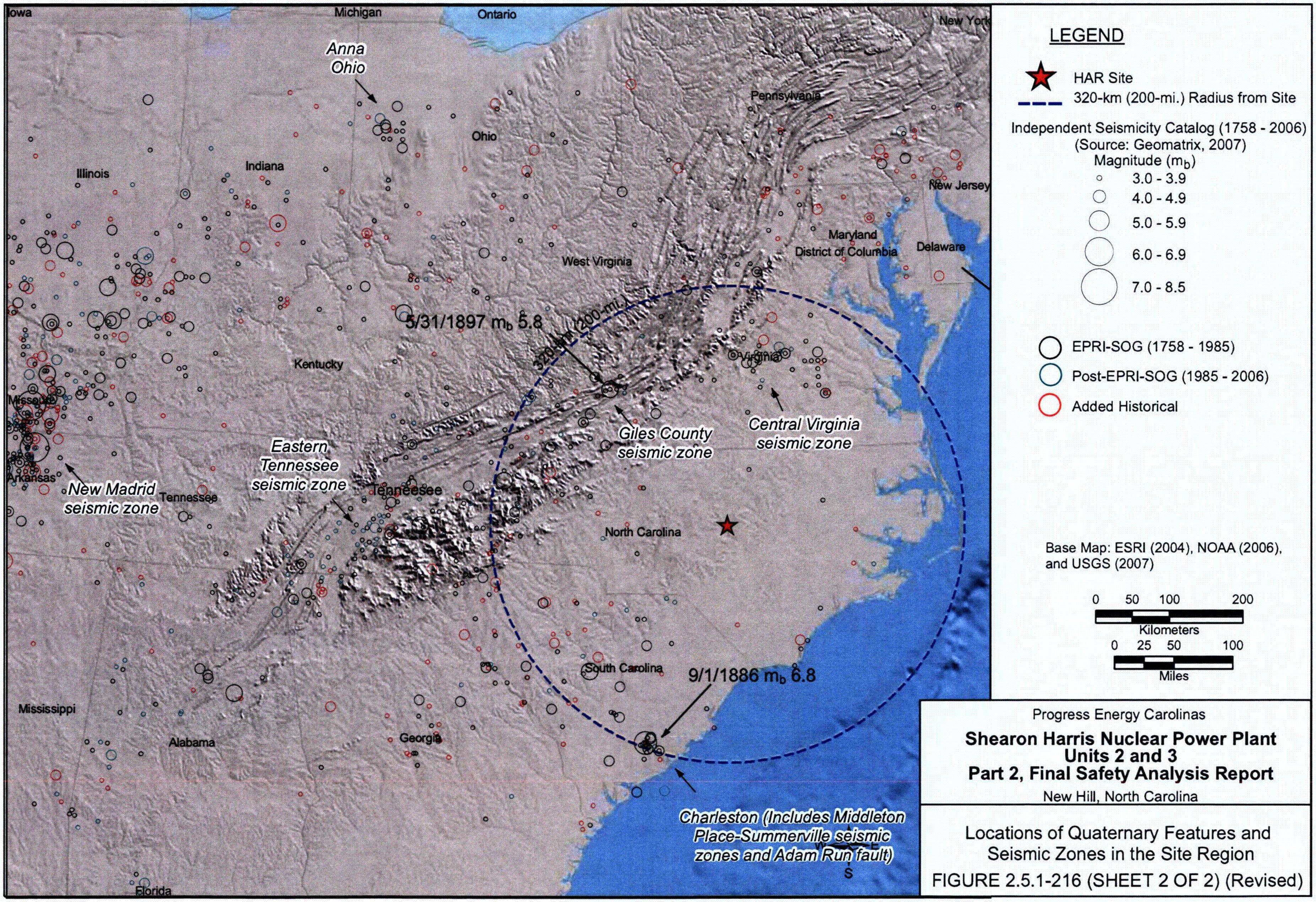
New Hill, North Carolina

Locations of Quaternary Features and Seismic Zones in the Site Region

FIGURE 2.5.1-216 (SHEET 1 OF 2) (Revised)

File path: S:\11100\11151.002\Figures\2.5.1_figures_fig_2.5.1-216_Sheet_1.mxd; Date: [12/10/2008]; User: [sbozkurt]



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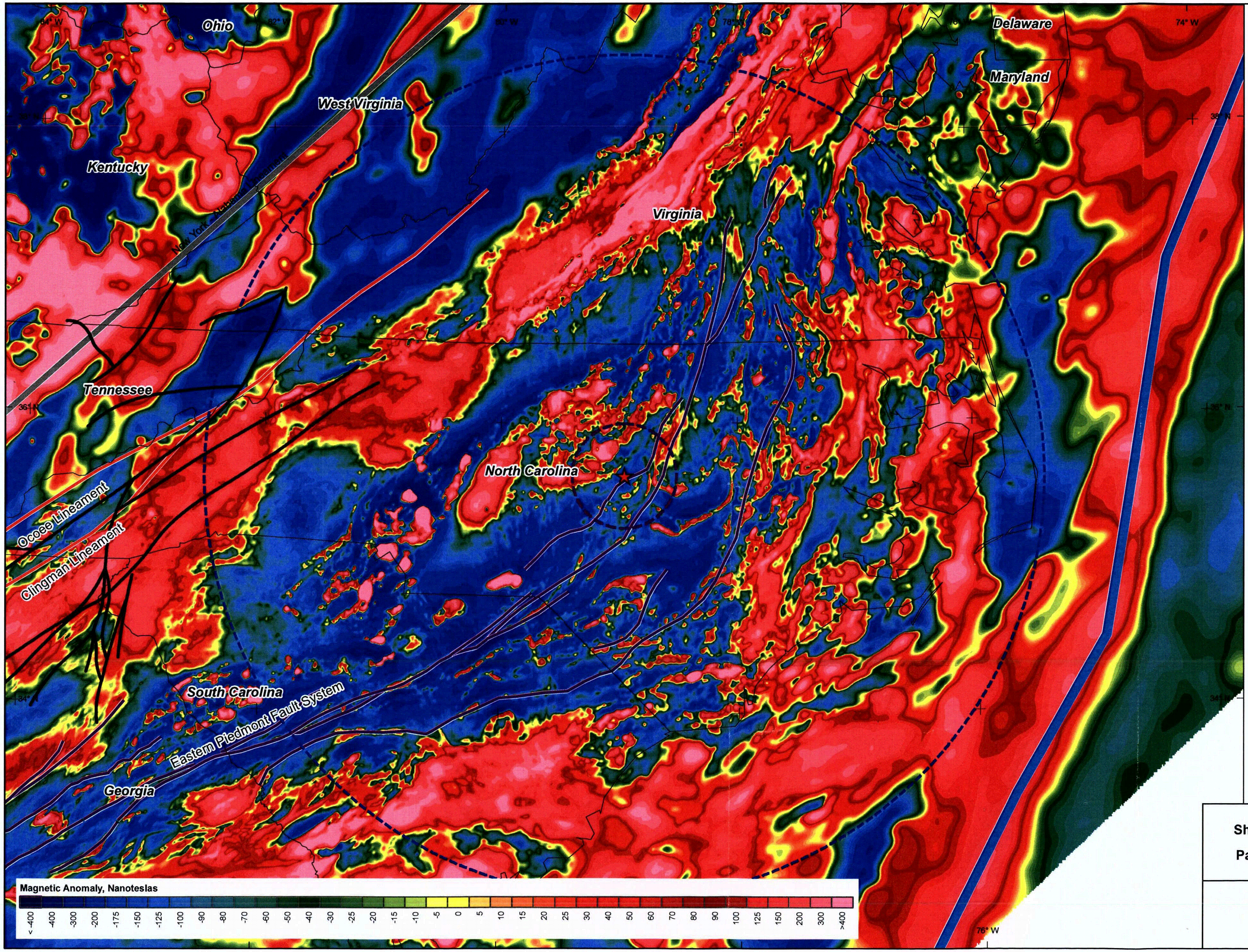
Locations of Quaternary Features and Seismic Zones in the Site Region

FIGURE 2.5.1-216 (SHEET 2 OF 2) (Revised)

File path: S:\11100\11151.002\Figures\2.5.1_figures_fig_2.5.1-216_Sheet_2.mxd; Date: [12/10/2008]; User: [sbozkurt]



N
W E
S

LEGEND

★ HAR Site

40-km (25-mi.) Radius from HAR Site

320-km (200-mi.) Radius from HAR Site

Eastern Piedmont Fault System (Hatcher et al., 1977)

Clingman and Ocoee Lineaments (Johnston et al., 1985)

Basement Faults (Hatcher and Lemiszki, 1998)

New York-Alabama Lineament (King, 1998)

East Coast Magnetic Anomaly (Nelson et al., 1985)

Base Map: Magnetic Anomaly (NAMAG, 2002) and SRTM30 (2005)

0 15 30 60 90
Kilometers
0 15 30 60
Miles

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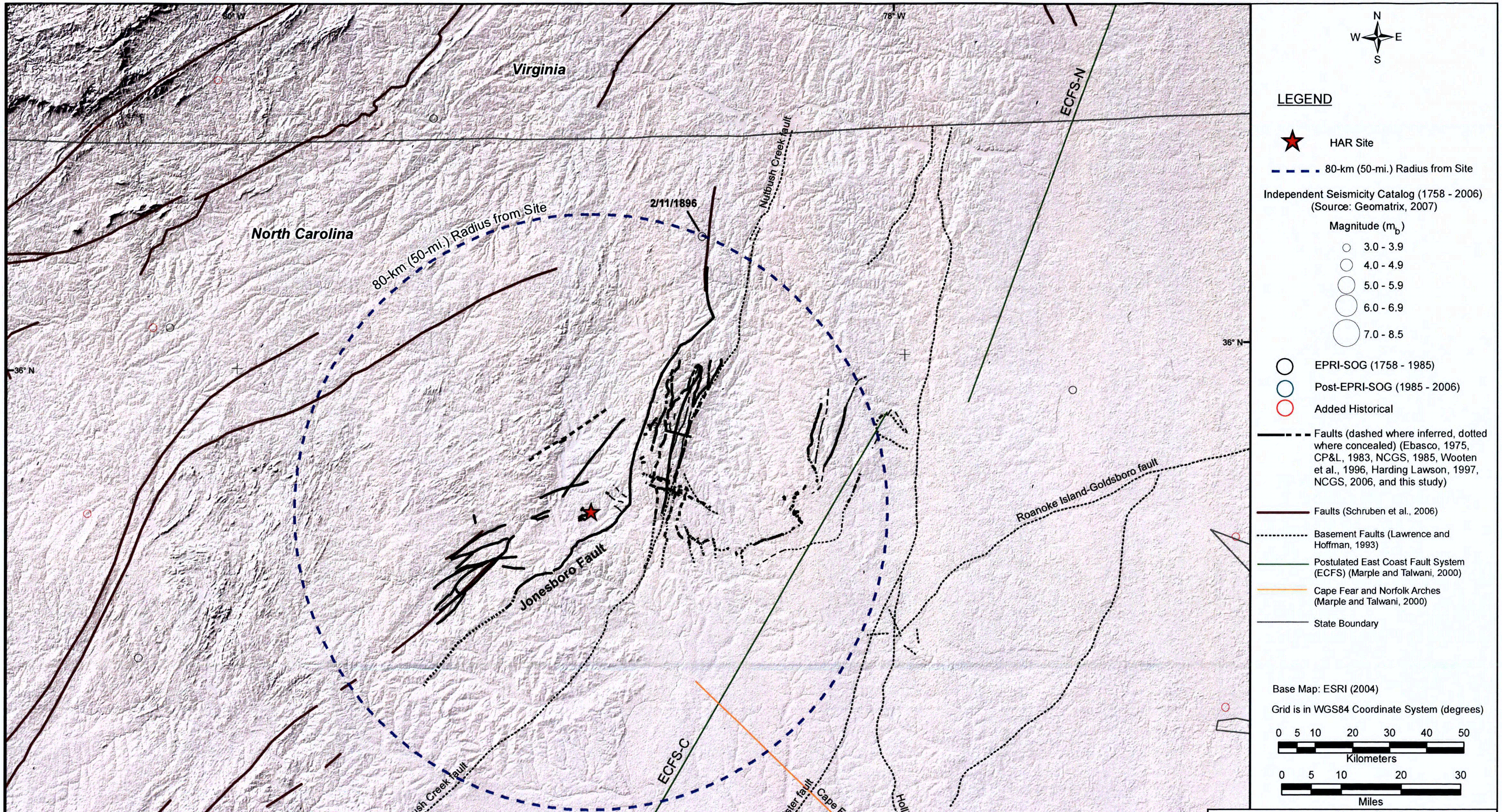
Regional Magnetic Anomaly Map
(320-km [200-mi.] Radius)

FIGURE 2.5.1-229 (Revised)

File path: S:\11100\11151.002\Figures\2.5.1_figures_fig_2.5.1-229.mxd; Date: [12/10/2008]; User: [sbozkurt]



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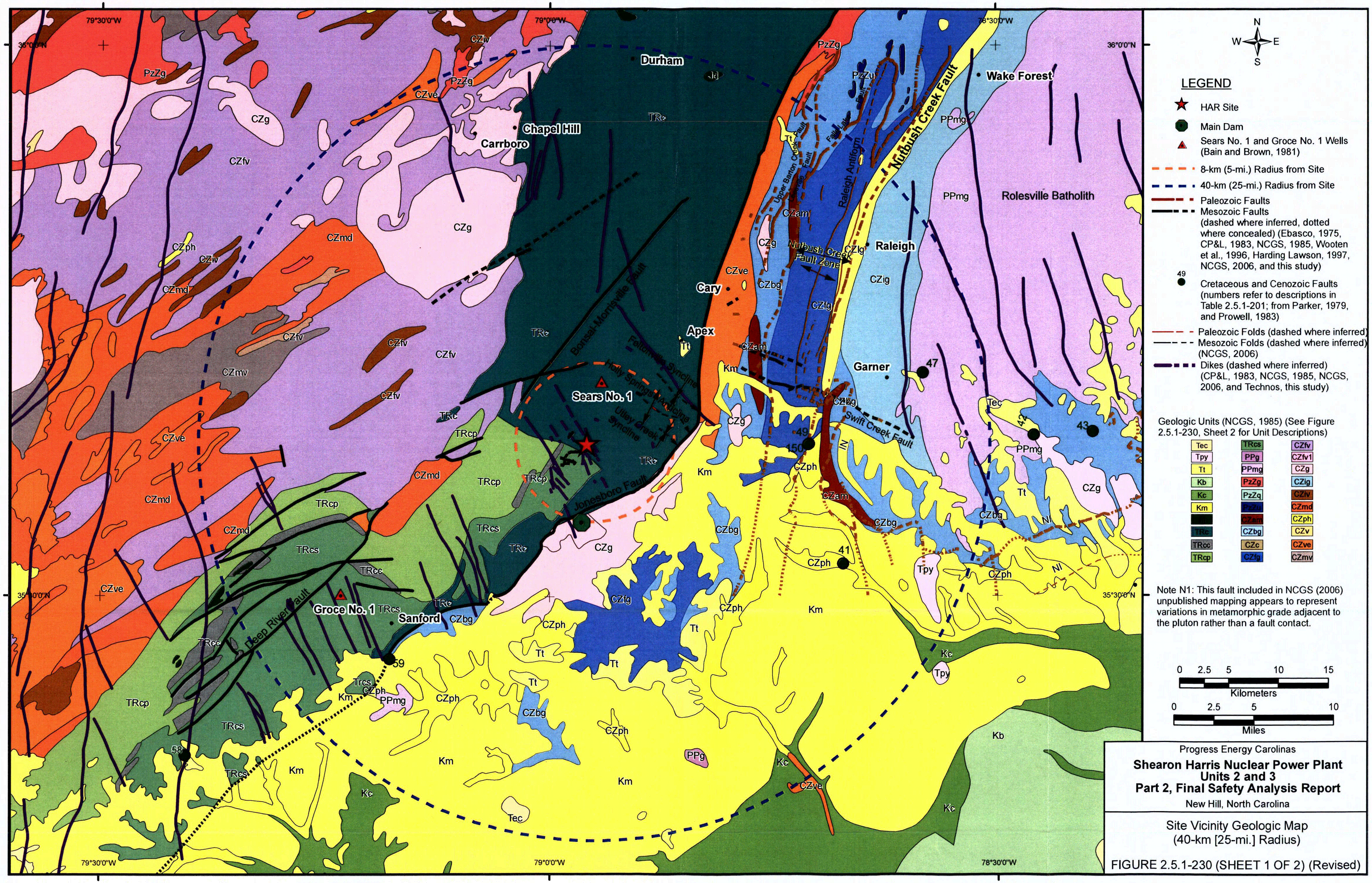
Seismicity and Structures within 80 km (50 mi.) of the HAR Site

RAI 02.05.01-08 Figure 1

File path: S:\11100\11151.002\Figures\RAI\RAI 02.05.01-08 Figure 1.mxd; Date: [11/18/2008]; User: [sbozkurt]



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Site Vicinity Geologic Map (40-km [25-mi.] Radius)

FIGURE 2.5.1-230 (SHEET 1 OF 2) (Revised)

File path: S:\11100\11151.002\Figures\2.5.1_figures_fig_2.5.1-230a.mxd; Date: [12/10/2008]; User: [sbozkurt]