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December 11, 2008

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Duke Energy Carolinas, LLC.
William States Lee III Nuclear Station - Docket Nos. 52-018 and 52-019
AP1000 Combined License Application for the William States Lee III Nuclear Station Units 1 and 2
Partial Response to Request for Additional Information
(RAI No. 826)
Ltr # WLG2008.12-06

References: Letter from Brian Hughes (NRC) to Peter Hastings (Duke Energy), *Request For Additional Information Letter No. 012 {sic}[017] Related To SRP Section 2.3.4 {sic}[2.4] for the William States Lee III Units 1 and 2 Combined License Application*, dated September 22, 2008.

Dolan to NRC Document Control Desk, Partial Response to Request For Additional Information, (RAI Nos. 820, 821, 822, 823, 824, and 825), Ltr# WLG2008.10-14, Dated October 27, 2008.

Dolan to NRC Document Control Desk, Partial Response to Request for Additional Information, (RAI No. 818), Ltr# WLG2008.11-10, Dated November 18, 2008.

Dolan to NRC Document Control Desk, Partial Response to Request for Additional Information, (RAI No. 828), Ltr# WLG2008.11-07, Dated November 25, 2008.

Dolan to NRC Document Control Desk, Partial Response to Request for Additional Information, (RAI No. 826), Ltr# WLG2008.11-02, Dated December 4, 2008.

This letter completes the Duke Energy response to the Nuclear Regulatory Commission's requests for additional information (RAIs) included in the referenced letter.

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Responses to the NRC information requests described in the referenced letter are addressed in separate enclosures, which also identify associated changes, when appropriate, that will be made in a future revision of the Final Safety Analysis Report for the Lee Nuclear Station. This letter addresses RAIs 02.04.12-001 through 02.04.12-014, including public versions of RAIs 02.04.12-002 and 02.04.12-007. The non-public responses to RAIs 02.04.12-002 and 02.04.12-007 have been provided in separate correspondence.

The responses to RAIs for FSAR sections 2.4.1 through 2.4.11 and 2.4.13 were provided in the referenced Duke Energy letters.

If you have any questions or need any additional information, please contact Peter S. Hastings, Nuclear Plant Development Licensing Manager, at 980-373-7820.

Bryan J. Dolan
Vice President
Nuclear Plant Development

Enclosures:

1) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-001
2) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-002 (public version)
3) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-003
4) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-004
5) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-005
6) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-006
7) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-007 (public version)
8) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-008
9) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-009
10) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-010
11) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-011
12) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-012
13) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-013
14) Duke Energy Response to Request for Additional Information Letter 017, RAI 02.04.12-014

AFFIDAVIT OF BRYAN J. DOLAN

Bryan J. Dolan, being duly sworn, states that he is Vice President, Nuclear Plant Development, Duke Energy Carolinas, LLC, that he is authorized on the part of said Company to sign and file with the U. S. Nuclear Regulatory Commission this supplement to the combined license application for the William States Lee III Nuclear Station and that all the matter and facts set forth herein are true and correct to the best of his knowledge.

Bryan J. Dolan

Bryan J. Dolan

Subscribed and sworn to me on December 11, 2008

Phoebe P. Elliott

Notary Public

My commission expires: June 26, 2011

SEAL

xc (w/o enclosures):

Luis Reyes, Regional Administrator, Region II
Loren Plisco, Deputy Regional Administrator, Region II
Stephanie Coffin, Branch Chief, DNRL

xc (w/ enclosures):

Brian Hughes, Senior Project Manager, DNRL

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number(s): 02.04.12-001

NRC RAI:

The applicant needs to describe the process followed to determine the conceptual models used to establish subsurface site characteristics related to groundwater to ensure that plausible conceptual models that are adequately conservative have been identified.

Duke Energy Response:

Site specific soil data were collected during the 1970s and in 2006 to aid in characterizing the fill, saprolite, residual soil, and partially weathered rock present at the Lee Nuclear Site. Groundwater wells were also installed to characterize seasonal trends and to aid in the identification of preferential flow pathways in the site vicinity. Literature values were used for those soil characteristics that were not able to be obtained during the site investigation (i.e. bulk density of partially weathered rock).

Conceptual modeling of groundwater flow included the consideration for potential releases from Units 1 and 2 radwaste storage tanks and flow paths to five plausible points of exposure (Attachment 2):

- Pathway 1: Unit #2 to Hold-Up Pond A (1250 ft)
- Pathway 2: Unit #2 to the Broad River (1935 ft)
- Pathway 3: Unit #2 to Make-Up Pond A (1950 ft)
- Pathway 4: Unit #1 to the non-jurisdictional wetland area (1110 ft)
- Pathway 5: Unit #1 to Make-Up Pond B (1630 ft)

Each pathway was evaluated based on hydraulic conductivity (Subsection 2.4.12.2.4.2), effective porosity (Subsection 2.4.12.2.4.1) and hydraulic gradients (derived from Figure 2.4.12-204, Sheet 8). Additional information on the development of these and other soil characteristics (i.e. whether they were calculated or site specific) can be found in FSAR RAIs 2.4.12-005 (this letter) and FSAR RAIs 02.04.13-010, 02.04.13-012, and 02.04.13-005 (submitted under separate cover).

The distances through the various aquifer materials in which groundwater movement occurs were estimated from cross-sections of soil along the pathways. The use of Darcy's equation allows travel times for each alternative flow path to be determined. Although the pathway from Unit #2 to the Broad River has the second longest travel distance, it was deemed to be the most limiting based on its shortest travel time of 2.8 years, mainly due to the hydraulic conductivity of the material in this pathway.

A revision of FSAR Subsections 2.4.12.3.1 and 2.4.12.3.2, to further describe the conceptual model, is provided as Attachment 1. The addition of a new FSAR figure (Figure 2.4.12-208) shows the alternative groundwater pathways and is provided as Attachment 2. Attachments 1 and 2 will be incorporated into a future revision of the Final Safety Analysis Report.

Associated Revisions to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsections 2.4.12.3.1 and 2.4.12.3.2

FSAR Figure 2.4.12-208

Attachments:

1) Revision to FSAR Subsections 2.4.12.3.1, 2.4.12.3.2, and the List of Figures
2) FSAR Figure 2.4.12-208 “Groundwater Pathway Analysis”

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-001

Revision to FSAR Subsections 2.4.12.3.1, 2.4.12.3.2, and the List of Figures

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.3.1, insert a new second paragraph, as follows:

<u>The projected groundwater movement in the vicinity of the Lee Nuclear Station power block was assessed to evaluate contaminant migration for the postulated release scenario (Subsection 2.4.13). For the release scenario, radwaste contaminant sources include the Units 1 and 2 radwaste storage tanks, located 33.5 ft. below plant grade (elevation 556.5 ft. above msl). For the assessment of alternative pathways, five locations were assumed to be plausible points of exposure (i.e., locations at which groundwater would be discharged to the surface to allow human contact or to facilitate transport). The pathways evaluated are:</u>

- <u>Pathway 1: Unit #2 to Hold-Up Pond A</u>
- <u>Pathway 2: Unit #2 to the Broad River</u>
- <u>Pathway 3: Unit #2 to Make-Up Pond A</u>
- <u>Pathway 4: Unit 1 to the non-jurisdictional wetland located northwest of Unit 1</u>
- <u>Pathway 5: Unit #1 to Make-Up Pond B</u>

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.3.2 will be revised as follows:

The rate of flow (i.e., the velocity) of groundwater depends on (1) the permeability and effective porosity of the medium through which it is moving and (2) the hydraulic gradient. Average interstitial groundwater velocity within the water table aquifer was determined using a form of the Darcy equation as follows:

$$V = K(dh/dl)/\ \eta_e$$

Where: V = average groundwater velocity (ft. per year [ft/yr])

K = hydraulic conductivity (cm/s converted to ft/yr)

dh/dl = groundwater gradient (ft/ft)

η_e = effective porosity

~~Following the completion of construction dewatering and the return to static conditions, the potentiometric surface beneath the reactor buildings is expected to rebound to a maximum elevation of approximately 579 ft. above msl, the maximum operational groundwater level. Long-term changes in the local groundwater regime are not anticipated after groundwater elevations return to equilibrium conditions.~~

~~The projected groundwater flow direction is to the north with an average gradient projected to be approximately 0.034 ft/ft along a preferential flow path from the reactor buildings to the Hold-Up~~

~~Pond A (Figures 2.4.12-204, Sheet 8 and Figure 2.4.12-205, Sheet 3). The groundwater flow path represents the shortest travel distance to a potential exposure point, a distance of 1340 ft. An alternative travel path from the reactor buildings to the Broad River through the partially weathered rock was also evaluated. This alternative flow path, though greater in distance at 1935 ft., results in faster travel time to the point of exposure due to a slightly greater groundwater gradient (0.036 ft/ft) and a greater hydraulic conductivity. Groundwater velocities calculated for the soil and saprolite zone, partially weathered rock zone, and fill material of the surficial hydrogeologic unit at the Lee Nuclear Site are listed in Table 2.4.12-204. Velocities ranged from 56 ft. per year (ft/yr) in the saprolite/soil zone to 290 ft/yr in the partially weathered rock. The flow velocity within the fill material was found to be 70 ft/yr. As such, travel times for water to migrate~~
~~from the reactor areas to points of exposure are 6.7 years and greater for the alternative flow path from the reactor building to the Broad River through the bedrock.~~

After construction dewatering and the return to static conditions, the potentiometric surface beneath the reactor buildings is expected to rebound to a maximum elevation of approximately 584 ft. above msl, the maximum anticipated groundwater level during operations. Based on the preceding discussion of hydraulic conductivity (Subsection 2.4.12.2.4.2), effective porosity (Subsection 2.4.12.2.4.1) and hydraulic gradients (derived from Figure 2.4.12-204, Sheet 8), groundwater velocities were determined for multiple flow paths. For example, one projected groundwater flow path (Pathway 1) is to the north from the Unit 2 reactor building to Hold-Up Pond A, with an average projected gradient of approximately 0.040 ft/ft and a distance to a potential exposure point of 1250 ft., which is the shortest of the flow paths evaluated. Another flow path (Pathway 2) from the Unit 2 reactor building to the Broad River, through partially weathered rock, had a faster travel time to the point of exposure because of greater hydraulic conductivity, even though it has a greater distance of 1935 ft. These two pathways are shown in Table 2.4.12-204.

Three additional pathways were evaluated to determine the most conservative travel pathway from potential points of release to exposure points, based on hydrogeologic conditions. The distances through the various aquifer materials in which groundwater movement occurs were estimated from cross-sections, allowing travel times for each alternative flow path to be determined. In summary, the estimated travel times for the alternative groundwater pathways are as follows:

- Pathway 1: Groundwater travels from Unit 2 to Hold-Up Pond A in approximately 7.2 years.
- Pathway 2: From Unit 2 to the Broad River in approximately 2.8 years.
- Pathway 3: From Unit 2 to Make-Up Pond A in approximately 23 years.
- Pathway 4: From Unit 1 to the non-jurisdictional wetland area in approximately 53 years.
- Pathway 5: From Unit 1 to Make-Up Pond B in approximately 9.8 years.

These pathways are represented on Figure 2.4.12-208. The results of the analysis identified the conservative flow path for a postulated release to be from the Unit 2 radwaste storage tank to the Broad River (Pathway 2, Figure 2.4.12-205, Sheet 3).

Soil distribution characteristics for radiological isotopes (i.e., Co-60, Cs-137, Fe-55, I-129, Ni-63, Pu-242, Tc-99, U-235) were determined from soil and water samples collected along the preferred groundwater flow path. This data is presented in Subsection 2.4.13 to assist in the development of calculations for fate and transport analyses in the event of accidental releases of effluents to groundwater.

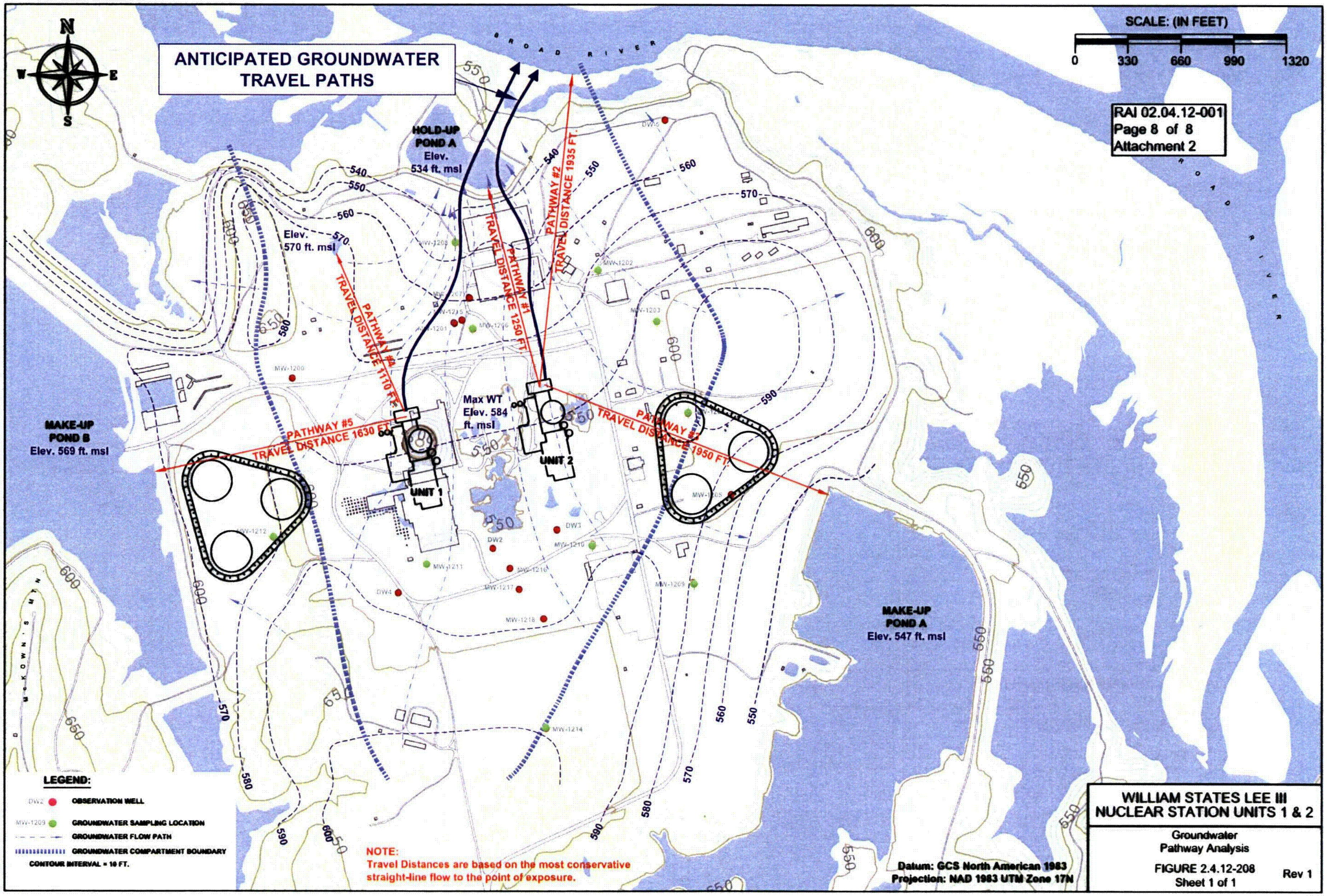
COLA Part 2, FSAR. Chapter 2, List of Figures, insert Figure 2.4.12-208 as a new figure, as follows:

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.04.12-001

FSAR Figure 2.4.12-208

Enclosure No. 1
Duke Letter Dated: December 11, 2008



Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-002

NRC RAI:

In Section 2.4.12.3.3, quantify the distribution of well depths in the region. If there are any wells deeper than 150 ft deep, provide the number and whether any are within a mile of the plant boundary. If the modern trend is for people to abandon wells and convert over to public water from Draytonville (or elsewhere), provide a reference.

Duke Energy Response:

The Draytonville Water Works was contacted to gather supplemental data on the trend to abandon wells and convert to public water supplies in the area of Lee Nuclear Site. Summit Engineering Group, Inc., a consulting engineering firm providing civil engineering services for Draytonville Water Works and the Gaffney Board of Public Works, provided the data shown in Attachment 2. These data were used to establish a general trend involving local conversion from water wells to public water supplies. Review of public records did not identify a trend related to for the abandonment (plugging) of water wells in the area, and generally, based on field observations, residents that had converted to public water supplies did not routinely plug and abandon their existing water wells.

Regarding well depths, only three of the 50 wells identified in the Cherokee Nuclear Station ER[1] were reported to be completed to depths of 150 feet or greater. Those wells are identified on the attached figure (Attachment 3). A review of data[2] provided by the South Carolina Department of Health and Environmental Control identified 22 wells completed since 1985 to depths greater than 150 feet within a 1-mile radius of the Lee Nuclear Site property boundary (Attachment 3).

FSAR Subsection 2.4.12.3.3 is revised by this RAI response to augment the discussion on wells in the region. The identified changes will be incorporated in a future revision of the Final Safety Analysis Report.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.4.12.3.3

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1 Duke Power Company, Cherokee Nuclear Station – Environmental Report, Sections 2.2, 2.4 and 2.5, revised 1975.

2 SCDHEC, "LASTREP2 - Private Well Report for Cherokee County for dates 01/01/1985 to 06/22/2006" (text file), revised 2006 (ER Reference 2.3-15).

Attachments:

1) Revision to FSAR Subsection 2.4.12.3.3
2) Public Water Supply Lines near Lee Nuclear Station
3) Water Wells Completed to Depths ≥ 150 ft. within One Mile of Lee Nuclear Site Boundary

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-002

Revision to FSAR Subsection 2.4.12.3.3

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.3.3, will be revised by inserting the following paragraph at the end of the subsection:

The Cherokee Nuclear Station Construction Permit ER identified 50 domestic water wells and provided construction details for these wells, including well diameter, well depth, and depth to water (see Table 2.4.1-212 and Figure 2.4.1-212). Only three of these 50 wells have total depths of 150 ft. or greater. Since 1985, 22 wells have been installed within a 1-mi. radius of the Lee Nuclear Site property boundary and to a depth greater than 150 ft. (Reference 261). However, according to information provided by the Draytonville Water District, public water supply lines were installed in the late 1990s and continue to be added in the area surrounding the Lee Nuclear Site. As of 2007, since public water supply lines were installed in the area, approximately 55 percent of residents within a 2-mi. radius of the reactor buildings have converted from self-supplied groundwater systems to public water supplies. Furthermore, with the addition of water-supply lines planned for completion in 2009, the public water is expected to be available to approximately 83 percent of those residents within the 2-mi. radius of the plant. The projected use of self-supplied groundwater systems is expected to continue to decline as public water supply lines are built into rural areas and residents increase their dependence on the public water supply.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.04.12-002

Public Water Supply Lines
Near Lee Nuclear Station

Public Water Supply Users (~1999)
Within 2 Miles of Lee Nuclear Station

Street/Road	Total Potential Customers	Potential Customers		
		Served	Not served	Not Available
Bear Creek & Rains	13	-	-	13
Martin Ridge & Lanier	9	-	-	9
Ninety-Nine Island	37	-	-	37
McGill	2	-	-	2
Backwater Drive	3	-	-	3
Chester	10	-	-	10
Parris & Gorski	10	-	-	10
Hambright	7	-	-	7
York County	5	-	-	5
Ninety-Nine Ferry	3	-	-	3
River Valley	5	-	-	5
Hess	1	-	-	1
Davis Estates	4	-	-	4
McKowns Mtn	92	-	-	92
Judson	8	-	-	8
Sardis	27	-	-	27
Jefferson	0	-	-	-
Mullinax	3	-	-	3
Peterson	0	-	-	-
Hunter & Buck Ridge	5	-	-	5
Rolling Mill	8	-	-	8
Marvin	6	-	-	6
	258	**0**	**0**	**258**

~1999 Status of Water Users		
Residents served by public water supply in 1999	0%	=0/258
Residents with available water supply from public water supply in 1999	0%	=(0+0)/258

Data provided (Aug-Oct 2008) by Vernon Atkinson, P.E.
Summit Engineering Group, Inc.

Public Water Supply Users (~2004)
Within 2 Miles of Lee Nuclear Station

Street/Road	Total Potential Customers	Potential Customers		
		Served	Not served	Not Available
Bear Creek & Rains	13	-	-	13
Martin Ridge & Lanier	9	-	-	9
Ninety-Nine Island	37	-	-	37
McGill	2	-	-	2
Backwater Drive	3	-	-	3
Chester	10	-	-	10
Parris & Gorski	10	-	-	10
Hambright	7	-	-	7
York County	5	-	-	5
Ninety-Nine Ferry	3	1	2	-
River Valley	5	-	5	-
Hess	1	1	-	-
Davis Estates	4	-	-	4
McKowns Mtn	92	65	27	-
Judson	8	7	1	-
Sardis	27	18	9	-
Jefferson	0	-	-	-
Mullinax	3	-	3	-
Peterson	0	-	-	-
Hunter & Buck Ridge	5	-	-	5
Rolling Mill	8	6	1	1
Marvin	6	-	-	6
	258	**98**	**48**	**112**

~2004 Status of Water Users		
Residents served by public water supply in 2004	38%	=98/258
Residents with available water supply from public water supply in 2004	57%	=(98+48)/258

Data provided (Aug-Oct 2008) by Vernon Atkinson, P.E.
Summit Engineering Group, Inc.

Existing (2007) Public Water Supply Users
Within 2 Miles of Lee Nuclear Station

Street/Road	Total Potential Customers	Potential Customers			
		Served	Not served	Not Available	
Bear Creek & Rains	13	-	-	13	
Martin Ridge & Lanier	9	-	-	9	
Ninety-Nine Island	37	21	16	-	
McGill	2	2	-	-	
Backwater Drive	3	3	-	-	
Chester	10	-	8	2	
Parris & Gorski	10	-	-	10	Water lines to be placed in service in 2009
Hambright	7	-	-	7	
York County	5	-	-	5	
Ninety-Nine Ferry	3	3	-	-	
River Valley	5	5	-	-	
Hess	1	1	-	-	
Davis Estates	4	-	-	4	
McKowns Mtn	92	72	20	-	
Judson	8	7	1	-	
Sardis	27	20	7	-	
Jefferson	0	-	-	-	
Mullinax	3	3	-	-	
Peterson	0	-	-	-	
Hunter & Buck Ridge	5	-	-	5	
Rolling Mill	8	6	1	1	
Marvin	6	-	-	6	
	258	**143**	**53**	**62**	

2007 municipal water users

Residents served by public water supply in 2007	55%	=143/258
Residents with available water supply from public water supply in 2007	76%	=(143+53)/258

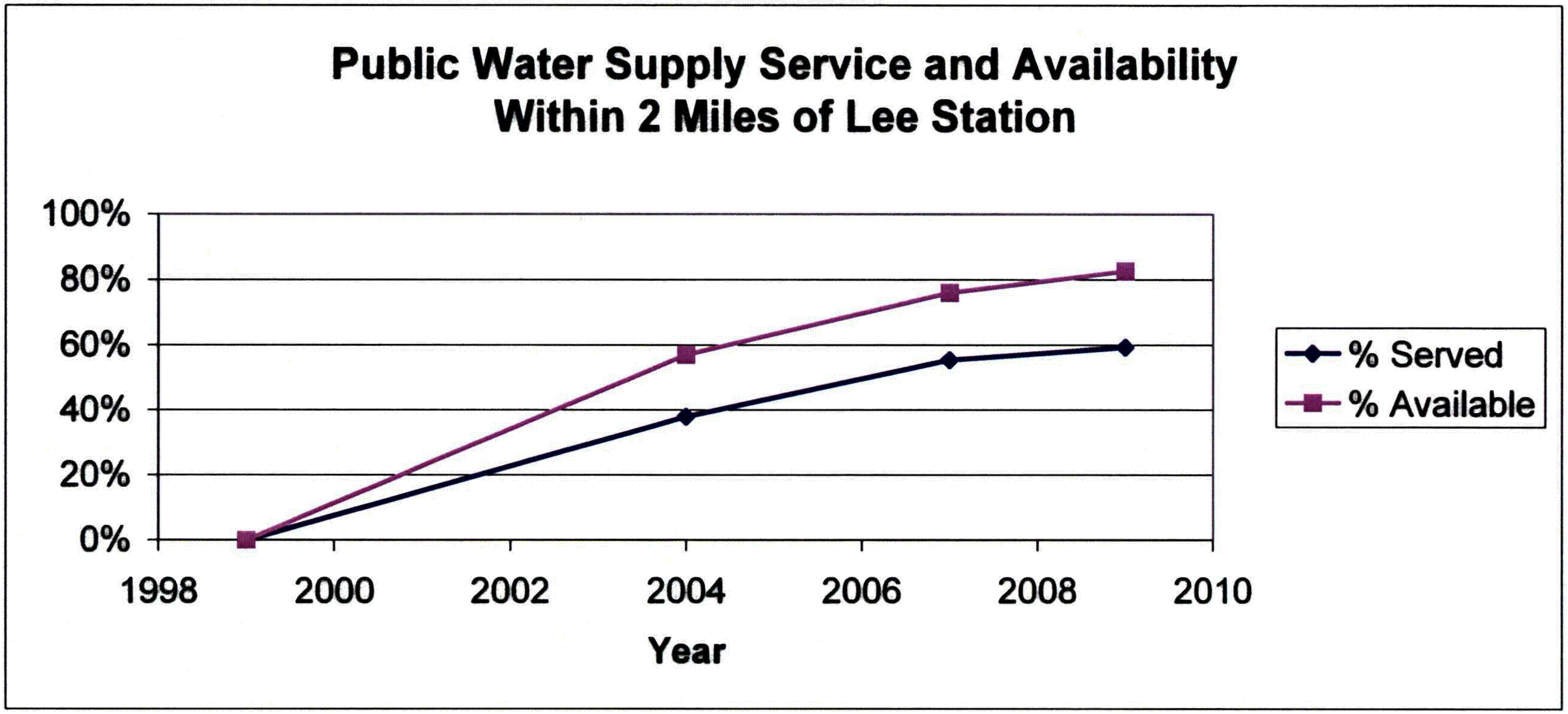
Data provided (Aug-Oct 2008) by Vernon Atkinson, P.E.
Summit Engineering Group, Inc.

**2009 Projection of Public Water Supply Users
Within 2 Miles of Lee Nuclear Station**

Street/Road	Total Potential Customers	Potential Customers			
		Served	Not served	Not Available	
Bear Creek & Rains	13	-	-	13	
Martin Ridge & Lanier	9	-	-	9	
Ninety-Nine Island	37	21	16	-	
McGill	2	2	-	-	
Backwater Drive	3	3	-	-	
Chester	10	-	8	2	Assumes about 60% of potential customers come on-line
Parris & Gorski	10	6	4	-	
Hambright	7	4	3	-	
York County	5	-	-	5	
Ninety-Nine Ferry	3	3	-	-	
River Valley	5	5	-	-	
Hess	1	1	-	-	
Davis Estates	4	-	-	4	
McKowns Mtn	92	72	20	-	
Judson	8	7	1	-	
Sardis	27	20	7	-	
Jefferson	-	-	-	-	
Mullinax	3	3	-	-	
Peterson	-	-	-	-	
Hunter & Buck Ridge	5	-	-	5	
Rolling Mill	8	6	1	1	
Marvin	6	-	-	6	
	258	**153**	**60**	**45**	

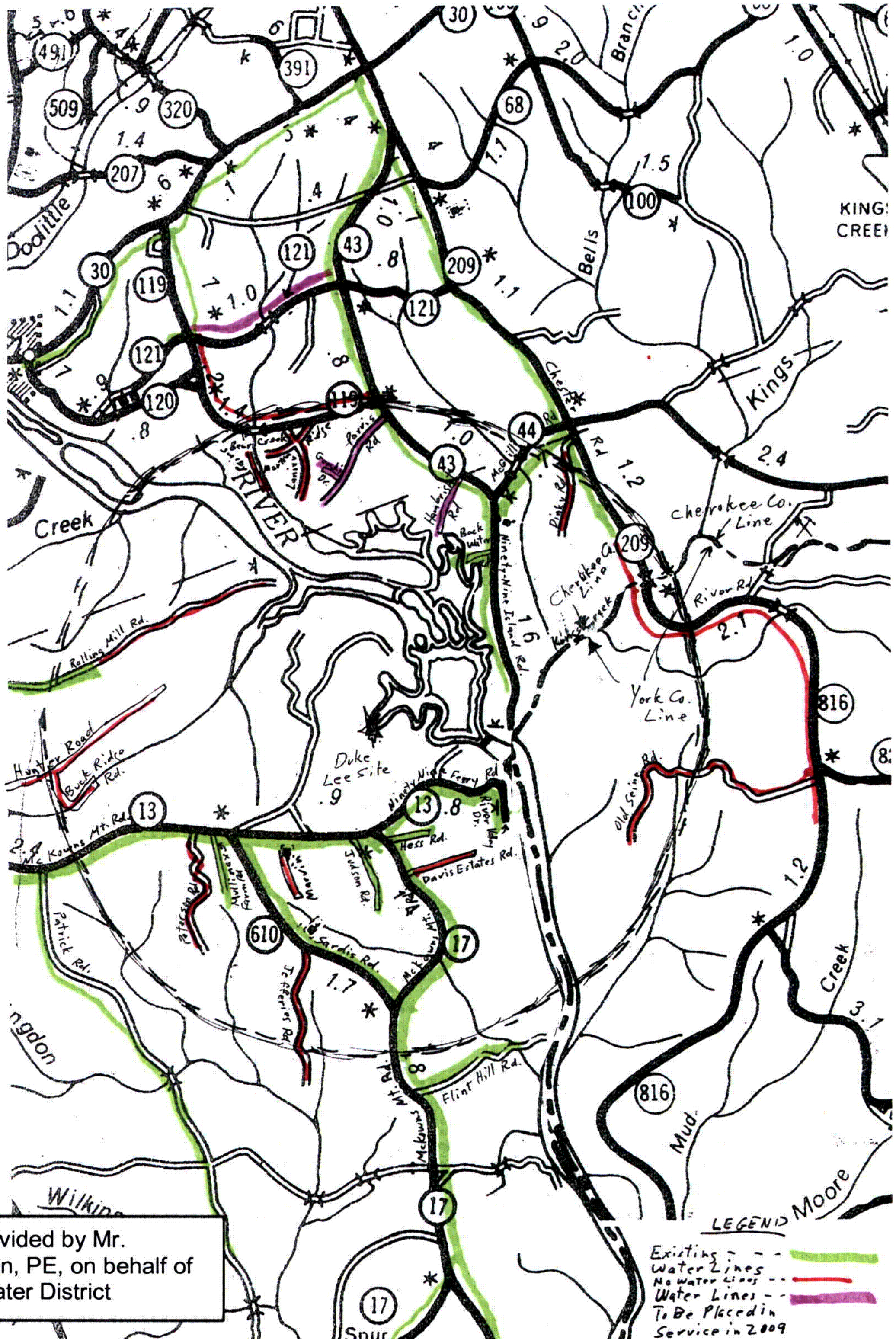
	Including 2009 Projected users (above)	
2009 projection of residents served by public water supply	59%	=153/258
2009 projection of residents with available water from public water supply	83%	=(153+60)/258

**Data provided (Aug-Oct 2008) by Vernon Atkinson, P.E.
Summit Engineering Group, Inc.**



Water Availability implies that the Draytonville Water Works and the Gaffney Board of Public Works water lines were in-place and available to be tapped by residents.

Residents Served implies households were purchasing water from public supplies.



Information provided by Mr. Vernon Atkinson, PE, on behalf of Draytonville Water District

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.04.12-002

Water Wells Completed to Depths $\geq$ 150 ft.
Within One Mile of Lee Nuclear Site Boundary

Withheld From Public Disclosure Under 10 CFR 2.390(a)(6) and 2.390(a)(9)

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-003

NRC RAI:

One of the goals of the one-year monitoring period portrayed by Figure 2.4.12-203 is to demonstrate how groundwater height and flow direction responds to precipitation spatially and temporally. Provide monthly precipitation amounts with the figure (i.e., for April 2006 through April 2007). Explain how the precipitation received during this period related to normal monthly amounts. In addition, characterize the precipitation conditions for the 7 months (i.e., Oct 2005 to April 2006) previous to the monitoring period to provide context to the start of the observation period.

Duke Energy Response:

The Lee Nuclear Site meteorological data (average monthly precipitation amounts) were available for the months of December 2005 through November 2006. These site-specific data were compared with National Oceanic and Atmospheric Administration (NOAA) data (Attachment 4) collected at the Greenville-Spartanburg (GSP) Airport (approximately 45 miles west of the Lee Nuclear Site) for the period October 2005 through April 2007. The correlation between precipitation data obtained from GSP and the Lee Nuclear Site was good, as shown on the attached figure (Attachment 2).

Additionally, using the GSP precipitation data from 1950 to 2008, average monthly values were calculated (Attachment 2, Page 1) to determine "normal" monthly precipitation to evaluate whether the observed average monthly precipitation at the Lee Nuclear Site was relatively wet or dry during the investigation; "normal" in the remainder of this response refers to those average monthly values. The graph presented on Attachment 2, Page 2, shows the monthly precipitation data observed at the Lee Nuclear Site and GSP. It also shows the "normal" average monthly data described above. From October 2005 to January 2006, above normal precipitation occurred at the Lee Nuclear Site. From January 2006 to around October 2006, Lee Nuclear Site conditions were typically drier than normal. November 2006 was wetter than normal. From December 2006 through April 2007, the Lee Nuclear Site had around normal to below normal precipitation amounts.

A comparison was made between the observed monthly precipitation for the period April 2006 through April 2007 at the Lee Nuclear Site and GSP versus the groundwater levels observed in monitoring wells. The comparison is presented on the attached figure (Attachment 3). Along with other factors, precipitation and evapotranspiration play the major role in determining the groundwater behavior. The annual distribution of the precipitation is fairly even throughout the year as shown in Attachment 2 and 3. Although precipitation is relatively evenly distributed throughout the year, the water table fluctuates noticeably, rising during the winter to an annual high in April- May and declining through summer and fall, reaching their lowest levels in

October – November (Attachment 3). These water level fluctuations are consistent with water levels observed in the Piedmont province, with declining water levels due to evapotranspiration through late spring and summer and rising water levels during cooler periods with less evaporation and plant use in late fall and winter.

FSAR Subsections 2.4.1.2.4, 2.4.12.1.1, and 2.4.16 are revised by this RAI response to discuss the impact of precipitation on groundwater. The identified changes will be incorporated in a future revision of the Final Safety Analysis Report.

Associated Revisions to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsections 2.4.1.2.4, 2.4.12.1.1, and 2.4.16

Attachments:

1) Revision to Subsections 2.4.1.2.4, 2.4.12.1.1, and 2.4.16
2) Historical Precipitation Data from the National Oceanic and Atmospheric Administration (NOAA) and the Lee Nuclear Site
3) Lee Nuclear Site Precipitation and Water Table Graphs
4) Monthly Precipitation Data for the Greenville-Spartanburg Area (1893 – Present)

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-003

Revision to FSAR Subsections 2.4.1.2.4, 2.4.12.1.1, and 2.4.16

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.1.2.4, third paragraph, will be revised as follows:

Based on runoff coefficients ranging from 0.55 to 0.71 within the Broad River watershed (Reference 11), an estimated ~~The surface materials in many locations are relatively impermeable, such that only 10 – 15 in. of the average 47 in. annual precipitation~~29 to 45 percent of annual precipitation ~~percolate to~~ infiltrates toward the water table. Groundwater is contained in the pores that occur in the weathered material (residual soil, saprolite) above the relatively unweathered rock and within the fractures in the igneous and metamorphic rock. The depth to the water table depends on climate, topography, rock type, and rock weathering. The water table varies from ground surface elevation in valleys to more than 100 ft. below the surface on sharply rising hills. Although the precipitation in the Piedmont is relatively evenly distributed throughout the year, the water table fluctuates noticeably. ~~The groundwater level normally~~ typically ~~declines~~ declining during the late spring~~,~~ and summer~~, and early fall months as a result of evaporation and transpiration by plants~~ due to evapotranspiration~~. Groundwater also declines in the fall after rainfall has been low during the preceding summer. The groundwater level~~ and riseings in the late fall and winter when the evaporation potential is reduced (Reference 295).

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.1.1, sixth paragraph, will be revised as follows:

The water table varies from ground surface elevation in valleys to more than 100 ~~feet (~~ft.~~)~~ below the surface on sharply rising hills. The groundwater levels in the Piedmont ~~normally~~ typically decline during the late spring~~,~~ and summer~~, and early fall months~~ due to ~~as a result of~~ evapotranspiration ~~and transpiration by plants, and in the fall when rainfall is low. The groundwater level~~ and rises in late fall and winter when the evaporation potential is reduced (Reference ~~220~~ 295).

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.16, References, will be revised as follows:

295. LeGrand, Harry E. Sr., *A Master Conceptual Model for Hydrogeological Site Characterization in the Piedmont and Mountain Region of North Carolina*, North Carolina Department of Environment and Natural Resources, Division of Water Quality, Groundwater Section, 2004.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.04.12-003

Historical Precipitation Data from the National Oceanic and Atmospheric Administration (NOAA) and the Lee Nuclear Site

MONTHLY PRECIPITATION
GREENVILLE-SPARTANBURG AREA (1950 - 2008)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	3.09	1.49	3.89	1.02	4.44	3.11	9.02	1.74	3.67	4.47	0.70	4.50	41.14
1951	1.59	2.32	5.25	3.70	0.52	4.61	4.86	7.02	8.85	1.10	2.23	7.71	49.76
1952	3.68	4.71	11.99	3.13	1.90	2.18	3.60	7.27	1.28	1.34	1.35	4.66	47.09
1953	5.16	7.29	4.47	3.09	2.57	1.78	4.27	5.66	6.94	0.49	1.10	6.74	49.56
1954	7.35	2.14	7.08	1.19	2.90	2.02	2.89	1.49	0.52	0.77	3.08	3.62	35.05
1955	2.74	4.01	3.15	6.03	4.46	3.27	7.00	1.01	2.42	3.72	2.73	1.05	41.59
1956	1.58	9.74	4.84	6.57	3.88	2.44	8.14	1.94	8.14	1.97	2.62	2.72	54.58
1957	5.15	4.20	3.62	4.82	2.66	3.61	0.58	3.94	7.09	2.65	7.59	3.56	49.47
1958	4.54	3.66	5.37	8.50	2.60	1.77	6.60	2.72	1.37	1.52	1.60	3.54	43.79
1959	2.74	3.08	5.53	5.88	5.63	1.41	7.04	3.55	8.20	7.32	1.64	3.28	55.30
1960	5.60	5.65	5.65	1.91	2.16	4.38	4.33	5.48	4.76	4.74	0.54	3.26	48.46
1961	2.39	8.34	4.54	4.84	2.60	4.24	5.03	8.46	1.49	0.90	2.94	10.10	55.87
1962	4.65	4.71	8.92	5.37	1.48	7.03	3.57	3.88	2.28	3.24	4.47	3.38	52.98
1963	3.93	3.25	9.66	5.95	3.06	4.73	2.46	1.16	4.68	0.24	4.19	3.78	47.09
1964	5.44	4.67	7.11	11.30	1.59	8.07	7.44	6.64	0.93	10.24	3.36	3.62	70.41
1965	2.39	5.22	7.60	4.93	1.09	8.62	3.13	3.57	2.32	3.60	2.82	0.37	45.66
1966	4.64	6.78	3.26	2.53	3.06	3.84	2.98	5.01	7.98	3.78	1.93	3.15	48.94
1967	3.97	3.32	1.98	2.36	4.97	4.87	3.86	7.51	2.05	2.35	3.50	7.40	48.14
1968	4.12	1.00	3.68	2.40	3.93	5.71	6.92	1.31	3.04	2.82	5.07	3.18	43.18
1969	3.94	5.24	4.56	7.18	1.93	9.59	3.17	6.53	3.68	2.38	2.24	4.60	55.04
1970	1.74	3.74	3.45	2.94	3.13	3.60	2.31	3.59	1.34	7.02	1.77	2.88	37.51
1971	3.33	7.43	5.52	3.09	5.72	2.19	5.64	2.44	3.28	9.51	4.22	3.79	56.16
1972	6.14	3.04	4.59	2.28	8.89	8.16	4.18	3.21	2.20	3.44	5.31	6.68	58.12
1973	4.33	4.88	8.73	4.04	5.59	3.87	3.70	2.03	7.56	0.98	1.34	7.55	54.60
1974	4.24	4.90	3.26	4.06	5.45	3.78	3.23	4.03	3.76	0.24	4.81	2.50	44.26
1975	5.42	5.78	8.64	1.14	7.81	5.39	4.79	3.21	11.65	7.45	3.98	3.07	68.33
1976	4.49	2.15	7.30	0.69	8.10	2.81	5.75	2.09	8.28	8.49	2.75	6.21	59.11
1977	3.53	2.00	8.47	3.23	2.71	2.88	0.80	4.99	9.44	6.39	4.43	3.55	52.42
1978	6.93	0.53	6.09	2.97	4.84	3.51	6.77	2.98	0.27	0.81	1.93	3.39	41.02
1979	7.19	6.11	4.19	10.15	5.69	3.74	8.66	4.34	7.50	3.33	3.91	1.25	66.06
1980	4.28	1.19	11.37	3.47	5.92	6.72	1.05	3.33	5.82	2.83	4.11	0.64	50.73
1981	0.29	3.86	3.22	0.88	4.15	1.29	5.30	1.17	2.08	4.40	1.66	7.19	35.49
1982	6.27	5.21	2.77	4.57	6.18	3.32	12.52	1.66	1.44	3.07	4.17	5.02	56.20
1983	2.70	5.26	6.26	4.66	5.80	4.67	1.13	3.27	3.59	3.05	5.29	8.45	54.13
1984	3.04	7.04	5.67	4.76	8.30	3.07	13.57	4.00	1.34	2.28	2.60	2.22	57.89
1985	4.94	4.29	1.13	1.31	2.42	2.85	6.96	5.93	1.62	4.55	7.52	1.44	44.96
1986	1.10	1.46	2.64	1.10	6.34	0.93	1.63	5.93	2.56	6.11	5.37	4.17	39.34
1987	4.65	7.33	5.01	2.30	1.31	6.68	3.58	2.79	3.33	0.37	2.81	4.62	44.78
1988	3.91	1.79	3.67	3.41	1.96	3.25	2.18	3.93	4.57	3.38	4.26	1.90	38.21
1989	1.51	4.93	4.48	3.15	3.64	6.00	5.11	4.71	5.42	3.10	3.74	4.76	50.55
1990	4.37	5.97	6.67	2.22	2.70	0.90	3.61	6.21	2.12	9.45	1.93	3.26	49.41
1991	4.72	2.24	5.82	5.65	6.37	1.72	5.74	9.02	1.44	0.24	1.39	2.90	47.25
1992	2.50	6.12	5.45	4.81	5.03	4.97	2.66	5.54	4.30	6.27	7.85	5.08	60.58
1993	7.19	3.56	10.27	2.91	3.08	0.17	0.75	0.87	1.71	2.07	3.73	2.94	39.25
1994	4.24	3.47	4.46	2.61	1.44	10.12	6.56	5.76	2.06	4.28	2.43	3.96	51.39
1995	6.42	5.08	2.30	1.58	4.53	4.84	2.69	17.37	2.13	5.96	5.13	2.05	60.08
1996	5.54	3.75	7.64	3.09	5.00	4.03	4.43	6.27	4.62	0.82	4.34	4.17	53.70
1997	4.82	6.07	2.67	4.11	3.37	6.02	6.02	0.92	3.26	4.85	3.70	4.25	50.06
1998	6.76	6.94	4.31	9.15	1.77	3.80	3.27	2.27	4.31	2.77	2.39	4.24	51.98
1999	3.84	2.84	2.33	3.95	1.37	4.67	1.95	0.79	3.04	5.86	2.67	2.62	35.93
2000	3.72	1.87	4.35	4.70	2.19	1.31	5.23	1.42	4.24	0.00	4.06	1.95	35.04
2001	3.01	2.31	6.69	1.10	2.14	3.77	6.01	1.01	6.74	3.39	1.98	2.23	40.38
2002	4.86	1.39	5.11	0.74	3.84	0.52	4.41	4.23	7.20	4.66	4.42	6.47	47.85
2003	1.91	4.02	6.71	7.13	7.64	6.24	8.03	11.34	1.72	2.07	3.64	2.66	63.11
2004	1.36	4.52	1.26	1.84	3.33	5.32	4.74	3.19	11.12	0.89	3.65	6.48	47.70
2005	1.47	3.16	5.79	3.41	3.92	9.99	8.85	3.66	0.16	4.12	3.79	4.82	53.14
2006	3.81	1.19	1.34	3.60	1.22	5.18	2.52	6.48	3.96	4.58	3.58	4.34	41.80
2007	4.67	2.42	3.70	1.82	1.56	3.21	2.99	1.78	1.31	1.58	0.89	5.15	31.08
2008	2.28	3.83	4.34	4.11	1.88								
Avg Since 1950	4.00	4.14	5.25	3.82	3.79	4.19	4.76	4.20	4.04	3.52	3.33	4.05	49.18

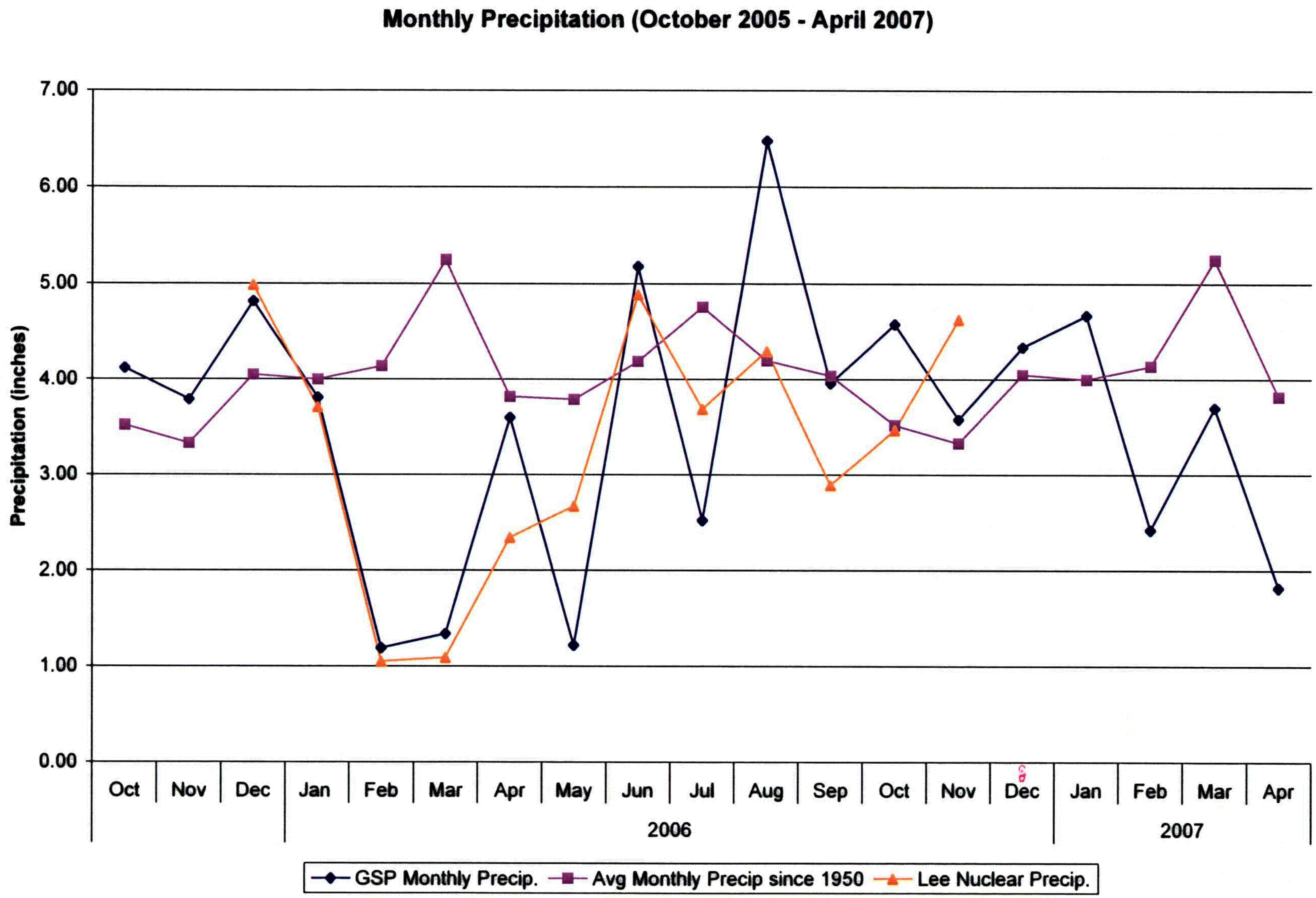
All precipitation values in Inches

From: NOAA Website, MONTHLY PRECIPITATION GREENVILLE-SPARTANBURG AREA
http://www.erh.noaa.gov/gsp/climate/gsppcp.htm Last Accessed 8/15/2008

Monthly Precipitation
Greenville-Spartanburg Area

From: NOAA Website, www.erh.noaa.gov/gsp/climate/gsppcp.htm
Last Accessed 8/15/2008

		Monthly Precipitation (in.) from Greenville-Spartanburg Area (GSP)	Average Monthly Precipitation (in.) Based on GSP data collected since 1950 (see page 1)	Lee Nuclear Precipitation (in.)
2005	Jan	1.47		
	Feb	3.16	4.14	
	Mar	5.79	5.25	
	Apr	3.41	3.82	
	May	3.92	3.79	
	Jun	9.99	4.19	
	Jul	8.85	4.76	
	Aug	3.66	4.20	
	Sep	0.16	4.04	
	Oct	4.12	3.52	
	Nov	3.79	3.33	
	Dec	4.82	4.05	4.99
2006	Jan	3.81	4.00	3.71
	Feb	1.19	4.14	1.05
	Mar	1.34	5.25	1.09
	Apr	3.60	3.82	2.34
	May	1.22	3.79	2.67
	Jun	5.18	4.19	4.89
	Jul	2.52	4.76	3.69
	Aug	6.48	4.20	4.30
	Sep	3.96	4.04	2.89
	Oct	4.58	3.52	3.47
	Nov	3.58	3.33	4.63
	Dec	4.34	4.05	
2007	Jan	4.67	4.00	
	Feb	2.42	4.14	
	Mar	3.70	5.25	
	Apr	1.82	3.82	
	May	1.56	3.79	
	Jun	3.21	4.19	
	Jul	2.99	4.76	
	Aug	1.78	4.20	
	Sep	1.31	4.04	
	Oct	1.58	3.52	
	Nov	0.89	3.33	
	Dec	5.15	4.05	
2008	Jan	2.28	4.00	
	Feb	3.83	4.14	
	Mar	4.34	5.25	
	Apr	4.11	3.82	
	May	1.88	3.79	
	Average	**3.53**	**4.09**	**3.31**

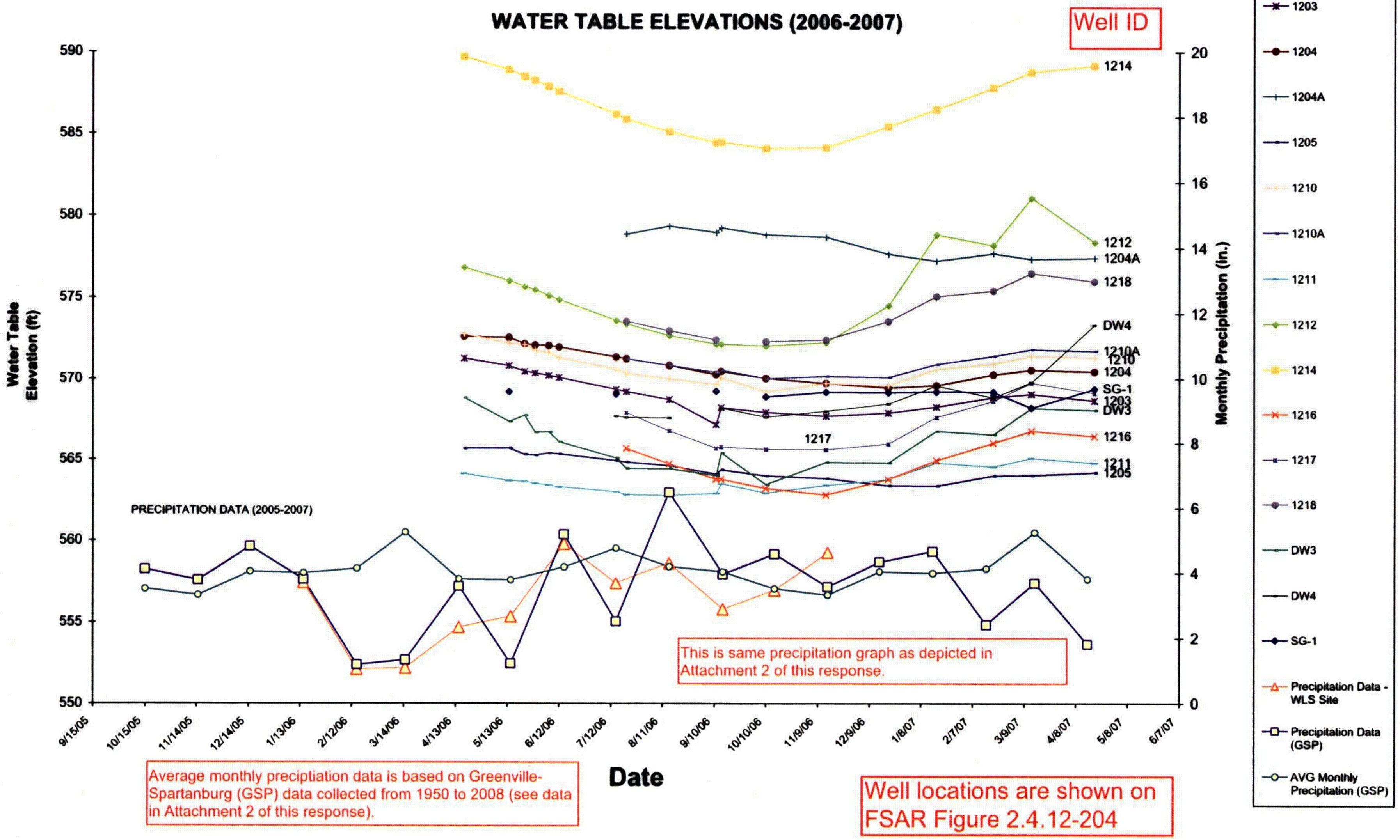

Monthly Precipitation (October 2005 - April 2007)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Precipitation (inches)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
2006
2007
GSP Monthly Precip.
Avg Monthly Precip since 1950
Lee Nuclear Precip.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.04.12-003

Lee Nuclear Site Precipitation and Water Table Graphs

Enclosure No. 3
Duke Letter dated: December 11, 2008



Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 4 to RAI 02.04.12-003

Monthly Precipitation Data for the Greenville-Spartanburg Area (1893 – Present)

MONTHLY PRECIPITATION GREENVILLE SPARTANBURG AREA (1893 - August 2008)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1893			2.01	1.21	3.87	6.66	4.88	5.69	4.49	5.43	2.89	1.99	39.12
1894													
1895		0.00	5.85	5.89									11.74
1896		4.68	1.87	1.37	5.07	4.56	11.07	2.27	3.49	2.73	9.48	2.16	48.75
1897	3.45	7.05	7.79	4.65	2.88	3.63	5.75	3.45	2.42	3.94	4.54	2.39	51.94
1898	3.54	0.80	3.42	4.51	1.50	2.18	11.20	10.10	6.31	5.18	3.35	3.29	55.38
1899	5.78	7.43	7.51	4.63	0.80	2.31	1.64	2.82	2.30	2.03	1.57	3.84	42.66
1900	2.88	9.13	7.58	7.92	1.90	9.75	2.23	1.39	3.51	2.86	4.41	3.68	57.24
1901	4.55	3.38	8.68	7.13	7.48	7.99	4.51	16.76	7.35	0.82	0.68	9.52	78.85
1902	3.02	9.35	4.52	1.94	1.47	5.34	3.41	4.49	4.42	3.39	2.39	5.78	49.52
1903	4.94	11.59	7.31	4.47	1.13	9.06	4.04	4.05	2.16	1.39	1.95	2.30	54.39
1904	2.25	3.98	3.99	2.29	1.93	3.41	2.15	11.09	2.45	0.00	3.70	5.40	42.64
1905	4.09	3.73	2.05	2.38	6.51	1.95	8.88	7.98	1.97	3.32	1.44	8.85	53.15
1906	10.63	0.96	7.48	1.35	2.94	4.28	10.00	4.23	10.35	3.43	1.30	4.66	61.61
1907	0.38	2.23	2.14	3.38	4.32	6.90	2.27	5.05	5.31	1.27	6.25	6.82	46.32
1908	4.73	6.65	4.25	3.89	1.45	4.56	9.25	19.52	3.82	6.14	3.09	5.18	72.53
1909	3.07	4.90	5.64	1.43	8.91	10.31	7.86	5.49	4.95	2.29	1.30	4.60	60.75
1910	3.10	4.34	2.20	1.56	12.81	6.69	3.73	3.76	3.79	2.95	0.30	3.62	48.85
1911	3.29	3.08	3.62	5.07	0.48	2.90	6.56	5.71	2.74	5.71	4.41	7.34	50.91
1912	3.91	6.39	10.29	8.17	7.14	6.58	4.89	2.65	4.30	3.03	3.62	3.16	64.13
1913	5.68	4.98	7.47	2.67	2.74	4.63	6.60	2.56	4.45	3.65	2.58	4.64	52.65
1914	1.79	4.11	2.41	5.08	1.36	0.86	3.64	5.55	2.40	4.63	3.95	9.45	45.23
1915	6.29	5.56	2.93	0.57	6.33	3.99	3.06	8.33	1.74	5.82	2.92	6.52	54.06
1916	3.10	5.96	1.29	2.41	4.59	3.75	12.16	1.25	2.63	1.58	2.01	3.23	43.96
1917	4.48	6.34	10.79	3.98	3.35	3.22	8.19	5.95	7.83	2.35	0.59	1.00	58.07
1918	7.42	2.99	2.56	4.84	5.61	5.96	2.14	3.07	4.38	11.41	3.18	7.37	60.93
1919	6.53	6.48	3.58	1.89	6.61	3.99	4.84	4.34	0.07	5.50	3.09	6.70	53.62
1920	5.83	3.42	8.26	7.18	1.62	6.11	7.90	5.96	2.65	0.53	4.52	5.39	59.37
1921	5.10	8.87	2.42	2.85	5.61	1.75	3.15	3.77	6.49	2.56	3.38	2.80	48.75
1922	5.32	7.21	5.95	4.97	6.28	6.59	5.21	0.95	0.72	4.77	0.48	6.80	55.25
1923	2.68	4.62	5.81	5.77	5.79	1.73	6.21	11.17	1.41	0.51	4.09	4.59	54.38
1924	5.09	3.90	2.46	7.02	3.36	2.26	5.95	2.65	8.55	0.85	0.81	5.84	48.74
1925	7.12	1.20	3.12	2.74	1.75	1.12	2.38	0.78	2.35	4.71	4.06	1.81	33.14
1926	7.73	4.58	5.17	2.08	0.25	1.86	4.29	4.06	1.44	2.46	4.63	6.56	45.11
1927	1.25	6.27	3.89	2.85	1.57	4.95	5.57	2.42	0.80	1.61	1.78	9.86	42.82
1928	2.99	3.30	4.24	5.66	4.47	4.36	7.58	13.36	3.94	1.84	0.88	1.51	54.13
1929	3.82	9.16	9.03	5.73	3.66	2.97	1.62	1.35	12.95	7.58	5.50	3.44	66.81
1930	4.18	1.24	3.51	2.58	2.27	5.08	3.76	2.65	2.74	1.45	5.82	4.60	39.88
1931	2.55	2.58	4.63	3.63	5.73	0.78	4.38	4.46	2.62	1.06	1.02	12.56	46.00
1932	6.82	3.74	5.41	2.68	2.02	4.96	3.18	2.97	2.79	12.68	3.78	10.86	61.89
1933	2.86	3.93	2.23	3.72	3.45	1.59	3.07	5.92	2.48	0.64	2.18	4.15	36.22
1934	2.66	4.34	6.00	4.27	4.51	5.07	2.92	5.00	1.72	3.22	2.96	3.41	46.08
1935	3.47	2.50	2.92	4.61	4.21	3.08	6.83	6.29	2.01	1.98	4.16	1.82	43.88
1936	9.26	4.19	4.43	8.40	0.15	2.80	4.93	4.49	10.34	6.07	1.34	5.34	61.74
1937	8.12	3.90	1.75	4.57	3.08	2.86	3.77	4.51	4.19	10.99	0.95	1.85	50.54
1938	2.49	1.15	4.14	2.14	3.83	1.75	4.26	3.01	2.77	0.41	3.11	2.58	31.64
1939	4.88	8.69	3.88	3.24	3.82	1.97	5.70	7.16	0.56	1.14	0.42	4.36	45.82
1940	2.96	3.57	4.29	1.26	1.80	2.02	4.60	9.23	0.14	2.97	3.42	2.65	38.91
1941	1.69	0.85	4.66	2.24	0.78	2.66	7.36	3.85	1.38	1.07	1.31	5.15	33.00
1942	2.84	5.04	5.93	1.00	4.02	1.83	4.73	4.87	3.50	2.37	1.39	6.01	43.53
1943	8.53	2.50	4.43	4.00	2.01	3.24	6.99	3.77	2.01	0.82	2.47	1.89	42.66
1944	1.57	6.25	7.43	5.65	1.98	2.12	2.40	5.68	4.61	2.77	3.15	1.91	45.52
1945	2.74	5.99	3.50	6.14	2.66	2.59	6.47	5.33	8.10	1.73	2.81	7.71	55.77
1946	7.37	4.83	5.12	3.52	5.11	4.19	6.02	5.56	2.33	4.29	3.39	2.11	53.84
1947	6.73	1.01	4.05	2.58	2.20	3.77	1.78	4.10	2.88	5.04	6.66	2.15	42.95
1948	3.98	4.01	8.38	1.83	7.74	3.11	2.90	4.25	2.84	1.08	12.18	4.24	56.54
1949	4.23	5.65	2.63	5.77	3.20	3.93	7.14	8.62	5.32	10.40	2.07	2.28	61.24
1950	3.09	1.49	3.89	1.02	4.44	3.11	9.02	1.74	3.67	4.47	0.70	4.50	41.14
1951	1.59	2.32	5.25	3.70	0.52	4.61	4.86	7.02	8.85	1.10	2.23	7.71	49.76
1952	3.68	4.71	11.99	3.13	1.90	2.18	3.60	7.27	1.28	1.34	1.35	4.66	47.09
1953	5.16	7.29	4.47	3.09	2.57	1.78	4.27	5.66	6.94	0.49	1.10	6.74	49.56
1954	7.35	2.14	7.08	1.19	2.90	2.02	2.89	1.49	0.52	0.77	3.08	3.62	35.05

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1955	2.74	4.01	3.15	6.03	4.46	3.27	7.00	1.01	2.42	3.72	2.73	1.05	41.59
1956	1.58	9.74	4.84	6.57	3.88	2.44	8.14	1.94	8.14	1.97	2.62	2.72	54.58
1957	5.15	4.20	3.62	4.82	2.66	3.61	0.58	3.94	7.09	2.65	7.59	3.56	49.47
1958	4.54	3.66	5.37	8.50	2.60	1.77	6.60	2.72	1.37	1.52	1.60	3.54	43.79
1959	2.74	3.08	5.53	5.88	5.63	1.41	7.04	3.55	8.20	7.32	1.64	3.28	55.30
1960	5.60	5.65	5.65	1.91	2.16	4.38	4.33	5.48	4.76	4.74	0.54	3.26	48.46
1961	2.39	8.34	4.54	4.84	2.60	4.24	5.03	8.46	1.49	0.90	2.94	10.10	55.87
1962	4.65	4.71	8.92	5.37	1.48	7.03	3.57	3.88	2.28	3.24	4.47	3.38	52.98
1963	3.93	3.25	9.66	5.95	3.06	4.73	2.46	1.16	4.68	0.24	4.19	3.78	47.09
1964	5.44	4.67	7.11	11.30	1.59	8.07	7.44	6.64	0.93	10.24	3.36	3.62	70.41
1965	2.39	5.22	7.60	4.93	1.09	8.62	3.13	3.57	2.32	3.60	2.82	0.37	45.66
1966	4.64	6.78	3.26	2.53	3.06	3.84	2.98	5.01	7.98	3.78	1.93	3.15	48.94
1967	3.97	3.32	1.98	2.36	4.97	4.87	3.86	7.51	2.05	2.35	3.50	7.40	48.14
1968	4.12	1.00	3.68	2.40	3.93	5.71	6.92	1.31	3.04	2.82	5.07	3.18	43.18
1969	3.94	5.24	4.56	7.18	1.93	9.59	3.17	6.53	3.68	2.38	2.24	4.60	55.04
1970	1.74	3.74	3.45	2.94	3.13	3.60	2.31	3.59	1.34	7.02	1.77	2.88	37.51
1971	3.33	7.43	5.52	3.09	5.72	2.19	5.64	2.44	3.28	9.51	4.22	3.79	56.16
1972	6.14	3.04	4.59	2.28	8.89	8.16	4.18	3.21	2.20	3.44	5.31	6.68	58.12
1973	4.33	4.88	8.73	4.04	5.59	3.87	3.70	2.03	7.56	0.98	1.34	7.55	54.60
1974	4.24	4.90	3.26	4.06	5.45	3.78	3.23	4.03	3.76	0.24	4.81	2.50	44.26
1975	5.42	5.78	8.64	1.14	7.81	5.39	4.79	3.21	11.65	7.45	3.98	3.07	68.33
1976	4.49	2.15	7.30	0.69	8.10	2.81	5.75	2.09	8.28	8.49	2.75	6.21	59.11
1977	3.53	2.00	8.47	3.23	2.71	2.88	0.80	4.99	9.44	6.39	4.43	3.55	52.42
1978	6.93	0.53	6.09	2.97	4.84	3.51	6.77	2.98	0.27	0.81	1.93	3.39	41.02
1979	7.19	6.11	4.19	10.15	5.69	3.74	8.66	4.34	7.50	3.33	3.91	1.25	66.06
1980	4.28	1.19	11.37	3.47	5.92	6.72	1.05	3.33	5.82	2.83	4.11	0.64	50.73
1981	0.29	3.86	3.22	0.88	4.15	1.29	5.30	1.17	2.08	4.40	1.66	7.19	35.49
1982	6.27	5.21	2.77	4.57	6.18	3.32	12.52	1.66	1.44	3.07	4.17	5.02	56.20
1983	2.70	5.26	6.26	4.66	5.80	4.67	1.13	3.27	3.59	3.05	5.29	8.45	54.13
1984	3.04	7.04	5.67	4.76	8.30	3.07	13.57	4.00	1.34	2.28	2.60	2.22	57.89
1985	4.94	4.29	1.13	1.31	2.42	2.85	6.96	5.93	1.62	4.55	7.52	1.44	44.96
1986	1.10	1.46	2.64	1.10	6.34	0.93	1.63	5.93	2.56	6.11	5.37	4.17	39.34
1987	4.65	7.33	5.01	2.30	1.31	6.68	3.58	2.79	3.33	0.37	2.81	4.62	44.78
1988	3.91	1.79	3.67	3.41	1.96	3.25	2.18	3.93	4.57	3.38	4.26	1.90	38.21
1989	1.51	4.93	4.48	3.15	3.64	6.00	5.11	4.71	5.42	3.10	3.74	4.76	50.55
1990	4.37	5.97	6.67	2.22	2.70	0.90	3.61	6.21	2.12	9.45	1.93	3.26	49.41
1991	4.72	2.24	5.82	5.65	6.37	1.72	5.74	9.02	1.44	0.24	1.39	2.90	47.25
1992	2.50	6.12	5.45	4.81	5.03	4.97	2.66	5.54	4.30	6.27	7.85	5.08	60.58
1993	7.19	3.56	10.27	2.91	3.08	0.17	0.75	0.87	1.71	2.07	3.73	2.94	39.25
1994	4.24	3.47	4.46	2.61	1.44	10.12	6.56	5.76	2.06	4.28	2.43	3.96	51.39
1995	6.42	5.08	2.30	1.58	4.53	4.84	2.69	17.37	2.13	5.96	5.13	2.05	60.08
1996	5.54	3.75	7.64	3.09	5.00	4.03	4.43	6.27	4.62	0.82	4.34	4.17	53.70
1997	4.82	6.07	2.67	4.11	3.37	6.02	6.02	0.92	3.26	4.85	3.70	4.25	50.06
1998	6.76	6.94	4.31	9.15	1.77	3.80	3.27	2.27	4.31	2.77	2.39	4.24	51.98
1999	3.84	2.84	2.33	3.95	1.37	4.67	1.95	0.79	3.04	5.86	2.67	2.62	35.93
2000	3.72	1.87	4.35	4.70	2.19	1.31	5.23	1.42	4.24	0.00	4.06	1.95	35.04
2001	3.01	2.31	6.69	1.10	2.14	3.77	6.01	1.01	6.74	3.39	1.98	2.23	40.38
2002	4.86	1.39	5.11	0.74	3.84	0.52	4.41	4.23	7.20	4.66	4.42	6.47	47.85
2003	1.91	4.02	6.71	7.13	7.64	6.24	8.03	11.34	1.72	2.07	3.64	2.66	63.11
2004	1.36	4.52	1.26	1.84	3.33	5.32	4.74	3.19	11.12	0.89	3.65	6.48	47.70
2005	1.47	3.16	5.79	3.41	3.92	9.99	8.85	3.66	0.16	4.12	3.79	4.82	53.14
2006	3.81	1.19	1.34	3.60	1.22	5.18	2.52	6.48	3.96	4.58	3.58	4.34	41.80
2007	4.67	2.42	3.70	1.82	1.56	3.21	2.99	1.78	1.31	1.58	0.89	5.15	31.08
2008	2.28	3.83	4.34	4.11	1.88	0.13	3.19	5.53					25.29
Average	4.21	4.38	5.03	3.83	3.74	4.05	4.98	4.78	3.90	3.49	3.21	4.38	49.42
Maximum	10.63	11.59	11.99	11.30	12.81	10.31	13.57	19.52	12.95	12.68	12.18	12.56	

MONTHLY PRECIPITATION GREENVILLE-SPARTANBURG AREA 1893 - Present

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1893	M	M	2.01	1.21	3.87	6.66	4.88	5.69	4.49	5.43	2.89	1.99	M
1894	M	M	M	M	M	M	M	M	M	M	M	M	M
1895	M	M	5.85	5.89	M	M	M	M	M	M	M	M	M
1896	M	4.68	M	M	5.07	4.56	11.07	2.27	3.49	2.73	9.48	2.23	M

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1897	3.45 M		7.79	4.65	2.88	3.63	5.75	3.45	2.42	3.94	4.54	2.39 M	
1898	3.54	0.80	3.42	4.51	1.50	2.18	11.20	10.10	6.31	5.26	3.35	3.29	55.46
1899	5.78	7.43	7.51	4.63	0.80	2.31	1.64	2.82	2.30	2.03	1.57	3.84	42.66
1900	2.88	9.13	7.58	7.92	1.90	9.75	2.23	1.39	3.51	2.86	4.41	3.68	57.24
1901	4.95	3.30	8.68	7.13	7.48	7.99	4.51	15.74	7.35	0.82	0.68	9.21	77.84
1902	3.02	9.35	4.52	1.94	1.47	5.34	3.41	4.49	4.42	3.39	2.39	6.38	50.12
1903	4.94	11.59	7.33	4.47	1.13	9.06	4.04	4.05	2.16	1.39	1.95	2.32	54.43
1904	2.25	3.98	3.99	2.29	1.93	3.41	2.15	12.19	2.45 T		3.70	4.90	43.24
1905	4.09	3.73	2.05	2.38	6.51	1.95	8.91	7.98	1.97	3.32	1.44	8.85	53.18
1906	10.63	0.96	7.68	1.35	3.24	4.28	10.00	4.23	10.35	3.43	1.30	5.06	62.51
1907	0.38	2.23	2.14	3.37	4.32	6.90	2.27	5.05	6.31	1.27	6.05	6.82	47.11
1908	5.31	6.65	4.24	3.77	1.45	4.56	8.77	19.52	3.82	6.14	3.09	5.18	72.50
1909	3.07	4.99	6.14	1.43	8.89	10.35	7.86	5.09	4.95	2.29	1.30	4.60	60.96
1910	3.10	4.07	2.20	1.56	12.81	6.69	3.73	3.76	3.79	2.95	0.30	4.56	49.52
1911	3.29	3.08	3.62	5.07	1.82	2.90	6.56	5.71	2.74	5.71	4.41	7.34	52.25
1912	3.91	6.39	10.29	8.17	7.14	6.58	4.89	2.65	4.30	3.03	3.62	3.16	64.13
1913	5.68	4.98	7.47	2.67	2.74	4.63	6.60	2.56	4.45	3.65	2.58	4.64	52.65
1914	1.79	4.11	2.41	5.08	1.36	0.86	3.64	5.55	2.40	4.63	3.95	9.45	45.23
1915	6.29	5.56	2.93	0.57	6.33	3.89	3.06	8.33	1.74	5.82	2.92	6.52	53.96
1916	3.10	5.96	1.29	2.41	4.59	3.75	12.12	1.25	2.63	1.58	2.01	3.23	43.92
1917	4.48	6.34	10.79	3.98	3.35	3.22	8.19	5.95	7.83	1.98	0.59	1.00	57.70
1918	7.42	2.99	2.56	4.84	5.61	5.96	2.14	3.07	4.38	11.41	3.18	7.37	60.93
1919	6.53	6.48	3.58	1.89	6.61	3.99	4.84	4.34	0.07	5.50	3.09	6.70	53.62
1920	5.83	3.42	8.26	7.18	1.62	6.11	7.90	5.96	2.65	0.53	4.52	5.39	59.37
1921	5.10	8.87	2.42	2.85	5.61	1.75	3.15	3.77	6.49	2.56	3.38	2.80	48.75
1922	5.32	7.21	5.95	4.97	6.28	6.59	5.21	0.95	0.72	4.77	0.48	6.80	55.25
1923	2.68	4.62	5.81	5.77	5.79	1.73	6.21	11.17	1.41	0.51	4.39	4.59	54.68
1924	5.09	3.90	2.46	7.02	3.36	2.26	5.95	2.65	8.55	0.85	0.81	5.84	48.74
1925	7.12	1.20	3.12	2.74	1.75	1.12	2.38	0.78	2.35	4.71	4.06	1.81	33.14
1926	7.73	4.58	5.17	2.08	0.25	1.86	4.29	4.06	1.44	2.46	4.63	6.56	45.11
1927	1.25	6.27	3.89	2.85	1.57	4.95	5.57	2.42	0.80	1.61	1.78	9.86	42.82
1928	2.99	3.30	4.24	5.66	4.47	4.36	7.58	13.36	3.94	1.84	0.88	1.51	54.13
1929	3.82	9.16	9.03	5.73	3.66	2.97	1.62	1.35	12.95	7.58	5.50	3.44	66.81
1930	4.18	1.24	3.51	2.58	2.27	5.23	3.76	2.65	2.74	1.45	5.82	4.60	40.03
1931	2.55	3.80	4.63	3.63	5.73	0.78	4.38	4.46	2.62	1.06	1.02	12.56	47.22
1932	6.82	3.74	5.41	2.68	2.02	4.96	3.18	2.97	2.79	12.68	3.78	10.86	61.89
1933	2.86	3.93	2.23	3.72	3.45	1.59	3.07	5.92	2.48	0.64	2.18	4.15	36.22
1934	2.66	4.34	6.00	4.27	4.51	5.07	2.92	5.00	1.72	3.22	2.96	3.41	46.08
1935	3.47	2.50	2.92	4.61	4.21	2.71	6.83	6.29	2.01	1.98	4.16	1.67	43.36
1936	9.26	4.19	4.43	8.40	0.15	2.80	4.93	4.49	10.34	6.07	1.34	5.34	61.74
1937	8.06	3.90	1.75	4.57	3.08	2.86	3.77	4.51	4.19	10.99	0.95	1.85	50.48
1938	2.49	1.15	4.14	2.14	3.83	1.75	4.26	3.01	2.77	0.41	3.11	2.58	31.64
1939	4.88	8.69	3.88	3.24	3.82	1.97	5.70	7.16	0.56	1.14	0.42	4.36	45.82
1940	2.85	3.57	4.29	1.26	1.80	2.02	4.60	9.23	0.14	2.97	3.42	2.65	38.80
1941	1.69	0.85	4.66	2.24	0.78	2.66	7.44	3.85	1.38	1.07	1.31	5.15	33.08
1942	2.84	5.04	5.88	1.00	4.02	1.90	4.73	4.87	3.50	2.37	1.39	6.01	43.55
1943	8.53	2.50	4.43	4.00	2.01	3.25	6.99	3.77	2.01	0.82	2.47	1.89	42.67
1944	1.57	6.25	7.43	5.65	1.98	2.12	2.40	5.68	4.61	2.77	3.15	1.91	45.52
1945	2.74	5.99	3.50	6.14	2.66	2.59	6.47	5.33	8.10	1.73	2.81	7.71	55.77
1946	7.37	4.83	5.12	3.52	5.11	4.19	6.02	5.56	2.33	4.29	3.39	2.11	53.84
1947	6.73	1.01	4.05	2.58	2.20	3.77	1.78	4.10	2.88	5.04	6.66	2.15	42.95
1948	3.76	4.01	8.38	1.83	7.74	3.11	2.90	4.25	2.84	1.08	12.18	4.24	56.32
1949	4.23	5.65	2.63	5.77	3.20	3.93	7.14	8.62	5.32	10.40	2.07	2.28	61.24
1950	3.09	1.49	3.89	1.02	4.44	3.11	9.02	1.74	3.67	4.47	0.70	4.50	41.14
1951	1.59	2.32	5.25	3.70	0.52	4.61	4.86	7.02	8.85	1.10	2.23	7.71	49.76
1952	3.68	4.71	11.99	3.13	1.90	2.18	3.60	7.27	1.28	1.34	1.35	4.66	47.09
1953	5.16	7.29	4.47	3.09	2.57	1.78	4.27	5.66	6.94	0.49	1.10	6.74	49.56
1954	7.35	2.14	7.08	1.19	2.90	2.02	2.89	1.49	0.52	0.77	3.08	3.62	35.05
1955	2.74	4.01	3.15	6.03	4.46	3.27	7.00	1.01	2.42	3.72	2.73	1.05	41.59
1956	1.58	9.74	4.84	6.57	3.88	2.44	8.14	1.94	8.14	1.97	2.62	2.72	54.58
1957	5.15	4.20	3.62	4.82	2.66	3.61	0.58	3.94	7.09	2.65	7.59	3.56	49.47
1958	4.54	3.66	5.37	8.50	2.60	1.77	6.60	2.72	1.37	1.52	1.60	3.54	43.79
1959	2.74	3.08	5.53	5.88	5.63	1.41	7.04	3.55	8.20	7.32	1.64	3.28	55.30
1960	5.60	5.65	5.65	1.91	2.16	4.38	4.33	5.48	4.76	4.74	0.54	3.26	48.46
1961	2.39	8.34	4.54	4.84	2.60	4.24	5.03	8.46	1.49	0.90	2.94	10.10	55.87
1962	4.65	4.71	8.92	5.37	1.48	7.03	3.57	3.88	2.28	3.24	4.47	3.38	52.98
1963	3.93	3.25	9.66	5.95	3.06	4.73	2.46	1.16	4.68	0.24	4.19	3.78	47.09
1964	5.44	4.67	7.11	11.30	1.59	8.07	7.44	6.64	0.93	10.24	3.36	3.62	70.41
1965	2.39	5.22	7.60	4.93	1.09	8.62	3.13	3.57	2.32	3.60	2.82	0.37	45.66
1966	4.64	6.78	3.26	2.53	3.06	3.84	2.98	5.01	7.98	3.78	1.93	3.15	48.94
1967	3.97	3.32	1.98	2.36	4.97	4.87	3.86	7.51	2.05	2.35	3.50	7.40	48.14

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	
1968	4.12	1.00	3.68	2.40	3.93	5.71	6.92	1.31	3.04	2.82	5.07	3.18	43.18	
1969	3.94	5.24	4.56	7.18	1.93	9.59	3.17	6.53	3.68	2.38	2.24	4.60	55.04	
1970	1.74	3.74	3.45	2.94	3.13	3.60	2.31	3.59	1.34	7.02	1.77	2.88	37.51	
1971	3.33	7.43	5.52	3.09	5.72	2.19	5.64	2.44	3.28	9.51	4.22	3.79	56.16	
1972	6.14	3.04	4.59	2.28	8.89	8.16	4.18	3.21	2.20	3.44	5.31	6.68	58.12	
1973	4.33	4.88	8.73	4.04	5.59	3.87	3.70	2.03	7.56	0.98	1.34	7.55	54.60	
1974	4.24	4.90	3.26	4.06	5.45	3.78	3.23	4.03	3.76	0.24	4.81	2.50	44.26	
1975	5.42	5.78	8.64	1.14	7.81	5.39	4.79	3.21	11.65	7.45	3.98	3.07	68.33	
1976	4.49	2.15	7.30	0.69	8.10	2.81	5.75	2.09	8.28	8.49	2.75	6.21	59.11	
1977	3.53	2.00	8.47	3.23	2.71	2.88	0.80	4.99	9.44	6.39	4.43	3.55	52.42	
1978	6.93	0.53	6.09	2.97	4.84	3.51	6.77	2.98	0.27	0.81	1.93	3.39	41.02	
1979	7.19	6.11	4.19	10.15	5.69	3.74	8.66	4.34	7.50	3.33	3.91	1.25	66.06	
1980	4.28	1.19	11.37	3.47	5.92	6.72	1.05	3.33	5.82	2.83	4.11	0.64	50.73	
1981	0.29	3.86	3.22	0.88	4.15	1.29	5.30	1.17	2.08	4.40	1.66	7.19	35.49	
1982	6.27	5.21	2.77	4.57	6.18	3.32	12.52	1.66	1.44	3.07	4.17	5.02	56.20	
1983	2.70	5.26	6.26	4.66	5.80	4.67	1.13	3.27	3.59	3.05	5.29	8.45	54.13	
1984	3.04	7.04	5.67	4.76	8.30	3.07	13.57	4.00	1.34	2.28	2.60	2.22	57.89	
1985	4.94	4.29	1.13	1.31	2.42	2.85	6.96	5.93	1.62	4.55	7.52	1.44	44.96	
1986	1.10	1.46	2.64	1.10	6.34	0.93	1.63	5.93	2.56	6.11	5.37	4.17	39.34	
1987	4.65	7.33	5.01	2.30	1.31	6.68	3.58	2.79	3.33	0.37	2.81	4.62	44.78	
1988	3.91	1.79	3.67	3.41	1.96	3.25	2.18	3.93	4.57	3.38	4.26	1.90	38.21	
1989	1.51	4.93	4.48	3.15	3.64	6.00	5.11	4.71	5.42	3.10	3.74	4.76	50.55	
1990	4.37	5.97	6.67	2.22	2.70	0.90	3.61	6.21	2.12	9.45	1.93	3.26	49.41	
1991	4.72	2.24	5.82	5.65	6.37	1.72	5.74	9.02	1.44	0.24	1.39	2.90	47.25	
1992	2.50	6.12	5.45	4.81	5.03	4.97	2.66	5.54	4.30	6.27	7.85	5.08	60.58	
1993	7.19	3.56	10.27	2.91	3.08	0.17	0.75	0.87	1.71	2.07	3.73	2.94	39.25	
1994	4.24	3.47	4.46	2.61	1.44	10.12	6.56	5.76	2.06	4.28	2.43	3.96	51.39	
1995	6.42	5.08	2.30	1.58	4.53	4.84	2.69	17.37	2.13	5.96	5.13	2.05	60.08	
1996	5.54	3.75	7.64	3.09	5.00	4.03	4.43	6.27	4.62	0.82	4.34	4.17	53.70	
1997	4.82	6.07	2.67	4.11	3.37	6.02	6.02	0.92	3.26	4.85	3.70	4.25	50.06	
1998	6.76	6.94	4.31	9.15	1.77	3.80	3.27	2.27	4.31	2.77	2.39	4.24	51.98	
1999	3.84	2.84	2.33	3.95	1.37	4.67	1.95	0.79	3.04	5.86	2.67	2.62	35.93	
2000	3.72	1.87	4.35	4.70	2.19	1.31	5.23	1.42	4.24	0.00	4.06	1.95	35.04	
2001	3.01	2.31	6.69	1.10	2.14	3.77	6.01	1.01	6.74	3.39	1.98	2.23	40.38	
2002	4.86	1.39	5.11	0.74	3.84	0.52	4.41	4.23	7.20	4.66	4.42	6.47	47.85	
2003	1.91	4.02	6.71	7.13	7.64	6.24	8.03	11.34	1.72	2.07	3.64	2.66	63.11	
2004	1.36	4.52	1.26	1.84	3.33	5.32	4.74	3.19	11.12	0.89	3.65	6.48	47.70	
2005	1.47	3.16	5.79	3.41	3.92	9.99	8.85	3.66	0.16	4.12	3.79	4.82	53.14	
2006	3.81	1.19	1.34	3.60	1.22	5.18	2.52	6.48	3.96	4.58	3.58	4.34	41.80	
2007	4.67	2.42	3.70	1.82	1.56	3.21	2.99	1.78	1.31	1.58	0.89	5.15	31.08	
2008	2.28	3.83	4.34	4.11	1.88	0.13	3.19	5.53						
WET	10.63	11.59	11.99	11.30	12.81	10.35	13.57	19.52	12.95	12.68	12.18	12.56	77.84	1901
DRY	0.29	0.53	1.13	0.57	0.15	0.13	0.58	0.78	0.07	0.00	0.30	0.37	31.08	2007

From: NOAA Website, MONTHLY PRECIPITATION GREENVILLE-SPARTANBURG AREA 1893 - Present

http://www.erh.noaa.gov/gsp/climate/gsppcp.htm Last Accessed 10/6/2008

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-004

NRC RAI:

Explain how effective porosity was determined. Define the terms used and identify the raw data or references such that an independent determination can be made. Corroborate values determined for the Lee site with published values used to represent similar settings elsewhere in the Piedmont region.

Duke Energy Response:

Site-specific soils in the area surrounding Units 1 and 2 include fill, residual soil, saprolite, and partially weathered rock (PWR). For the fill, residual soil, and saprolite, effective porosity was assumed equivalent to specific yield, which was determined based on sand, silt, and clay fractions of fill material, residual soil, and saprolite. This process is outlined in a Duke Energy calculation and excerpts are provided below.

The definition of effective (kinematic) porosity is linked to the concept of pore fluid displacement rather than to the percentage of the volume occupied by the pore spaces. In an unconfined aquifer, such as the Piedmont aquifer system, the effective porosity of a material is assumed equivalent to its specific yield.

Equation 1 $n = Sr + Sy$
$ne \sim Sy$

Where: n = total porosity, percentage or decimal
Sr = specific retention, decimal
Sy = specific yield, decimal
ne = effective porosity, percentage or decimal

Under natural conditions, saturated materials drain under the influence of gravity, approaching the specific retention of the material. The water drained from the material represents the material released from the effective porosity. The quantity of water that will drain from a rock or soil material depends on the length of time the rock or soil is allowed to drain; the temperature and the mineral composition of the water (which affect its surface tension, viscosity, and specific gravity); and the various physical characteristics of the rock or soil under consideration. Particle-size analysis can be used to estimate specific yield by presenting the sand, silt, and clay fractions of a soil on a trilinear graph.

For the Lee Nuclear Site, geotechnical analyses were conducted to characterize soil particle fractions and trilinear graphs were used to estimate specific yield based on sand, silt, and clay fractions of fill material, residual soil, and saprolite.

Trilinear graphs were used to determine effective porosity as follows:

1. Obtain sand, silt, and clay fraction data from FSAR Table 2.5.4-211.
2. Draw a line on the corresponding percentage for sand, silt, and clay.
3. The intersection of these lines or the center of the resulting triangle marks the approximate specific yield, or effective porosity, as shown on the graph. The minimum effective porosity is approximated by identifying the lowest effective porosity value observed within the triangle.

As shown in Table 2.5.4-204, 21 borings were drilled to support the design of the groundwater monitoring wells. Note that some of these borings are offset holes but an evaluation by well grouping strongly suggests that partially weathered rock varies in thickness across the site and that the tested samples appropriately define the grain size distribution. An evaluation of grain size test by material type using FSAR Table 2.5.4-211 reveals the following: a total of 8 partially weathered rock samples were analyzed which is less than samples classified as 'all fill samples' and 'saprolite' but is more than samples classifies as 'test fill only samples' and closely approximates samples classified as 'remolded fill samples'. Therefore, the number of PWR samples analyzed is consistent with the distribution of material types observed in the groundwater monitoring well borings.

The minimum effective porosity was estimated by converting the weight of the water lost by gravity drainage from a saturated material (specific yield) to a representative volume. Pore water is assumed to have a unit weight of 62.4 pounds per cubic foot (pcf). The saturated unit weight of soil is the weight of the soil plus the weight of water per unit volume when 100% of pore space is filled with water. Wet unit weight is assumed to approximate the weight of the material with a portion of the mobile water freely drained by gravity. Therefore, the unit weight difference between the saturated PWR and the wet, freely drained soil represents the unit weight of the water drained from the material, a gravimetric measurement of water that filled the effective pore space. Converting this gravimetric value to a volumetric value provides an approximate specific yield, or effective porosity. Thus, given wet unit weight, and saturated unit weight, effective porosity can be derived as follows:

Equation 2a $\gamma wg = \gamma s - \gamma m$
Equation 2b $ne = \gamma wg / \gamma w$

Where γwg = the unit weight of water drained by gravity from the saturated sample (pcf)
γs = the unit weight of saturated soil (pcf)
γm = the unit weight of wet (moist) soil (pcf)
γw = the unit weight of water (62.4 pcf)

Equations 2a and 2b are used to determine effective porosity for PWR. The general process followed is:

1. Obtain data for saturated unit weight and wet unit weight from FSAR Table 2.5.4-211.
2. Subtract the wet unit weight from the saturated unit weight to determine the unit weight of water drained by gravity by Equation 2a.

3. Assume water has a unit weight of 62.4 pcf and density of 1.00 gram per cubic centimeter (g/cc).
4. Determine the minimum effective porosity using Equation 2b.

In the Piedmont Province, soil porosity and specific yield were evaluated for soil samples collected from the Catawaba Nuclear Station Site[1], located approximately 35 miles east-northeast of the Lee Nuclear Station Site. The information presented below allows comparison of the mean hydraulic conductivity and mean effective porosity values determined for soil/saprolite and PWR at the Catawba Nuclear Site and Lee Nuclear Site.

	Average Hydraulic Conductivity (cm/sec)	Mean Effective Porosity
Catawba Nuclear Site		
Soil/Saprolite	3.27E-4	26%
PWR/Fractured Rock	1.48E-4	5.5%
Lee Nuclear Site		
Soil/Saprolite	2.73E-4	20%
PWR	8.09E-4	8%

The above data indicate that the mean hydraulic conductivity and mean effective porosity values determined for soil/saprolite and PWR at the Lee Nuclear Site are comparable to those at the Catawba Nuclear Site.

FSAR Tables 2.4.12-203 and 2.4.12-204 are revised by this RAI response in Attachments 1 and 2 to provide additional soil data. The identified changes will be incorporated in a future revision of the Final Safety Analysis Report.

Associated Revisions to the Lee Nuclear Station Final Safety Analysis Report:

1) FSAR Table 2.4.12-203
2) FSAR Table 2.4.12-204

Attachments:

1) Replacement FSAR Table 2.4.12-203
2) Replacement FSAR Table 2.4.12-204
3) Supporting Information for Effective Porosity Calculations

[1] S&ME, 2008 Project 1264-07-064. Site Characterization Report, Groundwater Protection Initiative, Duke Energy Catawba Nuclear Station, York, South Carolina. April 28, 2008.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-004

Replacement FSAR Table 2.4.12-203

Enclosure No. 4
Duke Letter Dated: December 11, 2008

TABLE 2.4.12-203
SOIL CHARACTERISTICS AT THE LEE NUCLEAR SITE

(Reported values are mean ± one standard deviation)

		All Fill Samples(a)			Test Fill Only	Remolded Fill(b)	Residual Soil			Saprolite			PWR
		$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$10 < N_{60} \le 30$ ($8 < N \le 23$)(c)	N/A (N/A)	$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$N_{60} > 100$ ($N > 75$)(c)
Percent gravel(d)	%	0(e) [1]	4 ± 6 [36]	6 ± 8 [6]	10 ± 7 [6]	3 ± 7 [9]	0 [1]	0 [4]	0 [1]	3 ± 3 [8]	3 ± 7 [20]	1 ± 1 [11]	9 ± 14 [8]
Percent sand(d)	%	42(e) [1]	34 ± 8 [36]	47 ± 19 [6]	33 ± 11 [6]	34 ± 12 [9]	57(e) [1]	46 ± 15 [4]	40(e) [1]	44 ± 11 [8]	52 ± 12 [20]	52 ± 13 [11]	55 ± 19 [8]
Percent fines (<#200 sieve)(d)	%	58(e) [1]	62 ± 11 [36]	47 ± 21 [6]	57 ± 15 [6]	64 ± 12 [9]	43(e) [1]	54 ± 14 [4]	60(e) [1]	54 ± 13 [8]	46 ± 15 [20]	47 ± 13 [11]	36 ± 22 [8]
Percent silt	%	-	41 ± 9 [13]	42(e) [1]	37 ± 8 [6]	-	-	55(e) [1]	56(e) [1]	53(e) [2]	41 ± 10 [3]	34(e) [1]	-
Percent clay (<5μm)	%	-	18 ± 9 [13]	19(e) [1]	20 ± 11 [6]	-	-	19(e) [1]	4(e) [1]	6(e) [2]	5 ± 2 [3]	8(e) [1]	-
Specific gravity, G_s		-	2.71 ± .06 [20]	2.68(e) [1]	2.72 ± .09 [6]	2.72 ± 0.02 [9]	-	2.72(e) [2]	2.70(e) [1]	2.72 ± 0.04 [6]	2.71 ± .04 [11]	2.69 ± .04 [4]	-
Dry unit weight, γ_{dry}	pcf	-	101 ± 8 [13]	-	101 ± 2 [6]	90 ± 5 [5]	-	88(e) [2]	-	93 ± 11 [4]	94 ± 15 [8]	93(e) [2]	-
Wet unit weight, γ_t	pcf	-	122 ± 5 [13]	-	122 ± 3 [6]	110 ± 3 [5]	-	113(e) [2]	-	116 ± 11 [4]	117 ± 7 [8]	114(e) [2]	135(f)
Saturated unit weight, γ_{sat}	pcf	-	125 ± 5 [13]	-	126 ± 2 [6]	119 ± 3 [5]	-	118(e) [2]	-	121 ± 7 [4]	124 ± 7 [7]	121(e) [2]	140(f)
Hydraulic conductivity (g), k	ft/yr	-	-	-	-	29 ± 11 [5]	-	-	-	-	-	-	-
Total Porosity	%	-	40	-	40	47	-	48	-	45	44	45	-
Effective Porosity	%	-	9 ± 2 (h)	12 ± 2 (h)	7 ± 2 (h)	-	-	15 ± 6 (h)	19	20 ± 1 (h)	22 ± 1 (h)	18 ± 2 (h)	8

a) All fill includes samples classified as fill on boring logs, including test fill samples, but does not include remolded fill samples.
b) Remolded soil samples compacted to 95% of Standard Proctor maximum dry density at optimum moisture content.
c) Field SPT-N values to correlate to N60-values are computed using the average energy transfer ratio (ETR) of 80.0%. N=N60(60/80.0).
d) Three samples of alluvium were tested for moisture content and two underwent grain-size analysis; the results are not shown in this table.
e) Insufficient data to determine standard deviation.
f) These values are from PSAR, Table 2D-3 and Table 2A-1 (Reference 201 in the PSAR).
g) 1 ft/year * 9.67 x 10^{-7} = 1 cm/sec.
h) Range of values.
i) Minimum effective porosity based on estimate from saturated and wet unit weights.
Note: The number in brackets is the count, [Number].
Weighted Average dependent upon the limiting number of samples for each result.
pcf- pounds per cubic foot

	Weighted Average
Fill Samples (in place)	
Total Porosity	40%
Effective Porosity	9%
Residual Soil and Saprolite	
Total Porosity	45%
Effective Porosity	20%
Partially Weathered Rock (PWR)	
Total Porosity	NM
Effective Porosity	8%

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.04.12-004

Replacement FSAR Table 2.4.12-204

Enclosure No. 4
Duke Letter Dated: December 11, 2008

WLS COL 2.4-4

TABLE 2.4.12-204 ~~(Sheet 1 of 2)~~
AQUIFER CHARACTERISTICS

Material	Hydraulic Conductivity (K) Minimum	~~Geometric Mean~~	Median	Conservative Estimate	Maximum	Source
Saprolite/Soil K_v	2.45×10^{-8}	~~2.91×10^{-6}~~	2.10×10^{-6}	4.4×10^{-5}	2.55×10^{-4}	1973 i~~I~~nvestigation laboratory analyses.
Saprolite/Soil K_h	9.67×10^{-7}	~~5.52×10^{-6}~~	6.38×10^{-6}	3.2×10^{-4}	2.26×10^{-3}	1973 investigation field tests and 2006 slug tests.
Bedrock - PWR K_h	9.67×10^{-7}	~~9.36×10^{-5}~~	1.54×10^{-4}	1.4×10^{-3}	9.89×10^{-3}	1973 investigation packer tests and 2006 slug, aquifer, and packer tests.
Unconsolidated Material	2.21×10^{-4}	~~8.61×10^{-4}~~	4.10×10^{-4}	2.6×10^{-3}	3.90×10^{-3}	1973 aquifer tests and 2006 pumping well.
Fill Material	4.22×10^{-5}	~~2.26×10^{-4}~~	1.81×10^{-4}	6.2×10^{-4}	1.03×10^{-3}	2006 slug tests.

Units are in centimeters per second (cm/sec).
PWR – Partially weathered rock.
K_v – Vertical hydraulic conductivity.
K_h - ~~Horizontial~~ Horizontal hydraulic conductivity.

Conservative Estimate - The geometric mean of samples exceeding the median ~~used to calculate groundwater velocities below~~.
Conservative Estimate for Bedrock K_h was obtained from results of 2006 pump test.
Conservative Estimates - These numbers were used below to calculate the groundwater velocity.
Unconsolidated ~~material~~ Material - ~~fill~~ Fill material, soil, saprolite, and partially weathered rock.

~~TABLE 2.4.12-204 (Sheet 2 of 2)~~
~~AQUIFER CHARACTERISTICS~~

Material	Hydraulic Conductivity K (cm/s)	Effective Porosity n_e (%)	Groundwater Gradient dh/dl (ft/ft)	Groundwater Velocity V (ft/yr)	Groundwater Exposure Travel Time
Fill Material	6.2×10^{-4}	~~31~~9	0.~~034~~040	~~70~~285	A release at the base of the Liquid Radwaste Tank #2 containment structure (elevation 556.5 ft. above msl) preferentially migrates through the layer of partially weathered rock ~~is the pathway with~~ as it exhibits the shortest travel time (2.8 years) to a point of exposure (i.e., the Broad River at a distance of 1935 ft.). ~~, of 6.7 years. Other likely pathways~~ Four other analyzed pathways ~~through soil and saprolite and fill are shorter, (1340 ft. to Hold Up Pond A), but take a longer travel time of 20.3 years~~ suggested travel times ranging from 7.2 to 53 years to a point of exposure.
Saprolite/Soil	3.2×10^{-4}	20	0.~~034~~040	~~56~~66	
Bedrock - PWR	1.4×10^{-3}	~~1~~8	0.~~036~~038	~~290~~692	

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.04.12-004

Supporting Information for Effective Porosity Calculations

Enclosure No. 4
Duke Letter Dated: December 11, 2008

Supporting Information for Effective Porosity Calculations

Enclosure No. 4
Duke Letter Dated: December 11, 2008

Used to estimate effective porosity (see Trilinear Diagrams on following pages)

Used to calculate total porosity (Eq. 1)

Used to estimate minimum effective porosity for PWR (Eq. 2b)

TABLE 2.5.4-211 (Sheet 1 of 2)
AVERAGE ENGINEERING PROPERTIES OF SOIL

(Reported Values are Mean ± One Standard Deviation)

		All Fill Samples(a)			Test Fill Only	Remolded Fill(b)	Residual Soil			Saprolite			PWR
WLS COL 2.5-6		$N_{60} < 10$ $(N \le 8)$(c)	$11 < N_{60} < 30$ $(8 < N \le 23)$(c)	$31 < N_{60} < 100$ $(23 < N \le 75)$(c)	$10 < N_{60} < 30$ $(8 < N \le 23)$(c)	N/A (N/A)	$N_{60} < 10$ $(N \le 8)$(c)	$11 < N_{60} < 30$ $(8 < N \le 23)$(c)	$31 < N_{60} < 100$ $(23 < N \le 75)$(c)	$N_{60} < 10$ $(N \le 8)$(c)	$11 < N_{60} \le 30$ $(8 < N \le 23)$(c)	$31 < N_{60} < 100$ $(23 < N \le 75)$(c)	$N_{60} > 100$ $(N > 75)$(c)
N_{60}-value(d)		21 ± 8 [75]			17 ± 3 [11]	N/A	25 ± 26 [14]			28 ± 23 [64]			-
Corrected tip resistance, qc	tsf	46.6 ± 31.4 [1,646]			50.1 ± 30.7 [719]	N/A	62.5 ± 41.1 [330]			69.3 ± 61.2 [367]			-
Friction ratio, FR	ft/sec	5.4 ± 1.7 [1,646]			4.9 ± 1.4 [719]	N/A	3.5 ± 1.5 [330]			4.0 ± 2.0 [367]			-
Percent gravel(e)	%	0(f) [1]	4 ± 6 [36]	6 ± 8 [6]	10 ± 7 [6]	3 ± 7 [9]	0 [1]	0 [4]	0 [1]	3 ± 3 [8]	3 ± 7 [20]	1 ± 1 [11]	9 ± 14 [8]
Percent sand(e)	%	42(f) [1]	34 ± 8 [36]	47 ± 19 [6]	33 ± 11 [6]	34 ± 12 [9]	57(f) [1]	46 ± 15 [4]	40(f) [1]	44 ± 11 [8]	52 ± 12 [20]	52 ± 13 [11]	55 ± 19 [8]
Percent fines (<#200 sieve)(e)	%	58(f) [1]	62 ± 11 [36]	47 ± 21 [6]	57 ± 15 [6]	64 ± 12 [9]	43(f) [1]	54 ± 14 [4]	60(f) [1]	54 ± 13 [8]	46 ± 15 [20]	47 ± 13 [11]	36 ± 22 [8]
Percent silt	%	-	41 ± 9 [13]	42(f) [1]	37 ± 8 [6]	-	-	55(f) [1]	56(f) [1]	53(f) [2]	41 ± 10 [3]	34(f) [1]	-
Percent clay (<5μm)	%	-	18 ± 9 [13]	19(f) [1]	20 ± 11 [6]	-	-	19(f) [1]	4(f) [1]	6(f) [2]	5 ± 2 [3]	8(f) [1]	-
Plasticity index, PI	%	-	NP [20]	NP [1]	NP [6]	NP [9]	-	NP [2]	-	NP [5]	NP [10]	NP [5]	NP [1]
Liquid limit, LL	%	-	NV [20]	NV [1]	NV [6]	NV [9]	-	NV [2]	-	NV [5]	NV [10]	NV [5]	NV [1]
Water content(e), w	%	33(f) [1]	23 ± 6 [59]	21 ± 10 [9]	20 ± 4 [6]	24 ± 5 [9]	22(f) [1]	32 ± 6 [9]	28 ± 10 [3]	32 ± 6 [15]	30 ± 12 [27]	20 ± 6 [16]	14 ± 4 [9]
Initial void ratio, e_o		-	0.69 ± .17 [13]	-	0.68 ± .06 [6]	0.90 ± .12(b) [5]	-	0.94(f) [2]	-	0.84 ± 0.23 [4]	0.84 ± 0.33 [8]	0.83(f) [2]	-
Specific gravity, G_s		-	2.71 ± .06 [20]	2.68(f) [1]	2.72 ± .09 [6]	2.72 ± 0.02 [9]	-	2.72(f) [2]	2.70(f) [1]	2.72 ± 0.04 [6]	2.71 ± .04 [11]	2.69 ± .04 [4]	-
Dry unit weight, γ_{dry}	pcf	-	101 ± 8 [13]	-	101 ± 2 [6]	90 ± 5 [5]	-	88(f) [2]	-	93 ± 11 [4]	94 ± 15 [8]	93(f) [2]	-
Wet unit weight, γ_t	pcf	-	122 ± 5 [13]	-	122 ± 3 [6]	110 ± 3 [5]	-	113(f) [2]	-	116 ± 11 [4]	117 ± 7 [8]	114(f) [2]	135(g)
Saturated unit weight, γ_{sat}	pcf	-	125 ± 5 [13]	-	126 ± 2 [6]	119 ± 3 [5]	-	118(f) [2]	-	121 ± 7 [4]	124 ± 7 [7]	121(f) [2]	140(g)
Overconsolidation ratio(h), OCR		4.9 ± 2.8(i) [11]			4.2 ± 2.4 [6]	N/A	-	1.6(f) [1]	-	4.2 ± 2.4 [3]	3.5 ± 2.0 [7]	2.4(f) [2]	-
Preconsolication pressure(h), σ_p'	ksf	8.8 ± 1.6(i) [11]			8.5 ± 1.5 [6]	(j)		10.0(f) [1]		10.0 ± 1.5 [3]	9.4 ± 2.0 [7]	8.9(f) [2]	-
Compression index(h), C_c		0.19 ± 0.09(i) [11]			0.17 ± 0.02 [6]	0.35 ± 0.10 [5]	-	0.34(f) [1]	-	0.29 ± 0.03 [3]	0.33 ± 0.22 [7]	0.19(f) [2]	-
Re-compression index(h), C_r		0.024 ± 0.015(i) [11]			0.025 ± 0.010 [6]	0.018 ± 0.007 [5]	-	0.030 (f) [1]	-	0.024 ± 0.016 [3]	0.027 ± 0.012 [7]	0.026(f) [2]	-
Consolidation coefficient(h), C_v	ft²/day	5.6 ± 2.2(i) [11]			6.3 ± 1.8 [6]	6.8 ± 1.5 [5]	-	6 (f) [1]	-	6.3 ± 0.6 [3]	5.1 ± 2.3 [7]	7(f) [2]	-
Total cohesion(h), c	psf	1,887 ± 178(i) [13]			1,508(f) [3]	1,174(f) [6]	224 ± 61 (k)	1,243 ± 346 (k)	1,406 (k)	224 ± 61 [4]	1,243 ± 346 [6]	1,406(f) [2]	1,000(g)
Total friction angle(h), ϕ	deg	20 ± 2(i) [13]			21(f) [3]	13(f) [6]	27 ± 5 (k)	20 ± 5 (k)	19 (k)	27 ± 5 [4]	20 ± 5 [6]	19(f) [2]	45(g)

Units: tsf = tons per square foot (tons/ft²); pcf = pounds per cubic foot (lbs/ft³); ksf = kips per square foot (kips/ft²)

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psf = pounds per square foot (lbs/ft^2)

TABLE 2.5.4-211 (Sheet 2 of 2)
AVERAGE ENGINEERING PROPERTIES OF SOIL

(Reported Values are Mean ± One Standard Deviation)

		All Fill Samples[a]			Test Fill Only	Remolded Fill[b]	Residual Soil			Saprolite			PWR
WLS COL 2.5-6		$N_{60} \le 10$ ($N \le 8$)[c]	$11 < N_{60} \le 30$ ($8 < N \le 23$)[c]	$31 < N_{60} \le 100$ ($23 < N \le 75$)[c]	$10 < N_{60} \le 30$ ($8 < N \le 23$)[c]	N/A (N/A)	$N_{60} \le 10$ ($N \le 8$)[c]	$11 < N_{60} \le 30$ ($8 < N \le 23$)[c]	$31 < N_{60} \le 100$ ($23 < N \le 75$)[c]	$N_{60} \le 10$ ($N \le 8$)[c]	$11 < N_{60} \le 30$ ($8 < N \le 23$)[c]	$31 < N_{60} \le 100$ ($23 < N \le 75$)[c]	$N_{60} > 100$ ($N > 75$)[c]
Effective cohesion[h][l], c'	psf	276 ± 49[i] [14]			353[f] [3]	255 ± 22 [15]	-	130 [f] [3]	-	0 [4]	439 ± 94 [6]	230[f] [2]	1,000[g]
Effective friction angle[h][l], ϕ'	deg	28 ± 4 [i] [14]			25[f] [3]	29 ± 2 [15]	-	30 [f] [3]	-	31 ± 4 [4]	23 ± 5 [6]	28[f] [2]	45[g]
Hydraulic conductivity [m], k	ft/year	-	-	-	-	29 ± 11 [5]	-	-	-	-	-	-	-

a) All Fill includes samples classified as fill on boring logs, including Test Fill samples, but does not include Remolded Fill samples.

b) Remolded soil samples compacted to 95% of Standard Proctor maximum dry density at optimum moisture content.

c) Field SPT-N values to correlate to N_{60}-values are computed using the average enery transfer ratio (ETR) of 80.0 percent. $N = N_{60}(60/80.0)$.

d) N_{60}- value is obtained from field values corrected to Energy Transfer Ratios of 60%.

e) Three samples of alluvium were tested for moisture content and two underwent grain size analysis; the results are not shown in this table.

f) Insufficient data to determine standard deviation.

g) These values are from PSAR, Table 2D-3 and Table 2A-1 (Reference 201).

h) The design engineer (i.e., engineer that will use data for design) must give careful consideration to compressibility and strength parameters based on test data, and the values reported in this table are estimates.

i) Samples tested were all in the $11 < N_{60} \le 30$ range. The resulting consolidation and shear parameters may be applied to existing fill regardless of N_{60}.

j) Preconsolidation pressure is not reported for laboratory remolded specimens because the values from undisturbed samples of existing fills are more indicative of in-situ conditions.

k) Insufficient data to determine total strength parameters; strength parameters have been assigned same as for saprolite having similar N_{60}. Little residual soil remains.

l) For consolidated-undrained triaxial tests on undisturbed specimens, failure was said to occur at peak pore pressure.

m) 1 ft/year * 9.67 x 10^{-7} = 1 cm/sec.

Note: The number in brackets is the number of samples in the data set, [Number].

POROSITY AND EFFECTIVE POROSITY

Project: **William States Lee Nuclear Station COLA (DUK010)**

Material: **Fill Material** **$11<N_{60}\leq 30$**
(see FSAR Table 2.5.4-211)

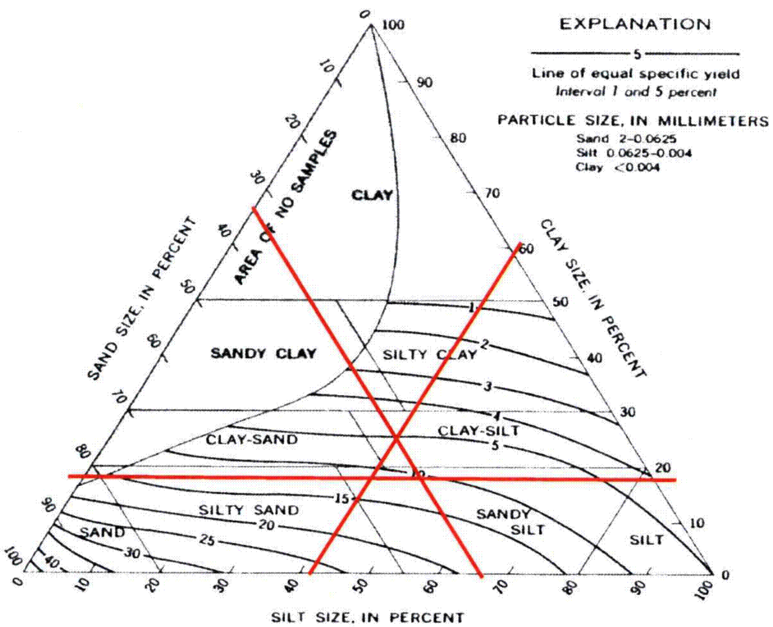
Data Inputs

Dry Unit Weight	γ_s	101	pcf
Unit Weight of Water	γ_w	62.4	pcf
Specific Gravity of Water	G_w	1.0	g/cc
Particle Density of Soil	G_s	2.71	g/cc
Percent gravel		4	%
Percent sand		34	%
Percent fines		62	%
Percent silt		41	%
Percent clay		18	%

$n = 1 - (\gamma_s / \gamma_w \cdot G_w / G_s)$

TOTAL POROSITY (n):	40%

Porosity
(1) The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium (after ASTM, 1980).



Soil classification triangle showing relation between particle size and specific yield
Johnson, A.I., USGS Water -Supply Paper 1662-D, 1967, Specific Yield - Compilation of Specific Yields for Various Materials.

ESTIMATED SPECIFIC YIELD or EFFECTIVE POROSITY (n_e):	9 ± 2%

Specific Yield
The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium (Lohman and others, 1972).

Effective Porosity
The ratio of the volume of the voids of a soil or rock mass that can be drained by gravity to the total volume of the mass (ASTM, 1980).

While recognized that specific yield and effective porosity are not identical, in practice, they may be estimated to be approximately equal in value.

POROSITY AND EFFECTIVE POROSITY

Project: **William States Lee Nuclear Station COLA (DUK010)**

Material: **Fill Material** **$31<N_{60}\leq100$**
(see FSAR Table 2.5.4-211)

Data Inputs

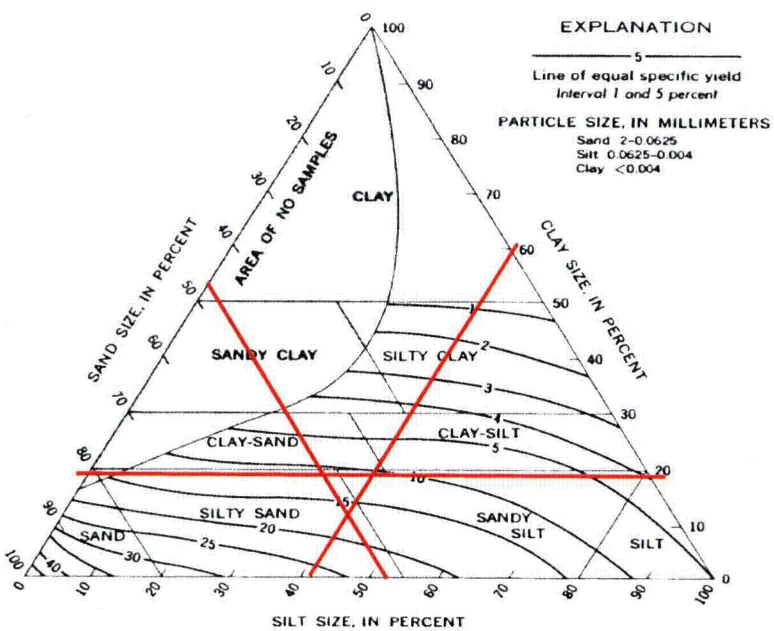
Dry Unit Weight	γ_s	NM	pcf
Unit Weight of Water	γ_w	62.4	pcf
Specific Gravity of Water	G_w	1.0	g/cc
Particle Density of Soil	G_s	2.68	g/cc
Percent gravel		6	%
Percent sand		47	%
Percent fines		47	%
Percent silt		42	%
Percent clay		19	%

$n = 1 - (\gamma_s / \gamma_w * G_w / G_s)$

TOTAL POROSITY (n):	**NM**

Porosity
(1) The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium (after ASTM, 1980).

ESTIMATED SPECIFIC YIELD or EFFECTIVE POROSITY (n_e):	**12 ± 2%**



Soil classification triangle showing relation between particle size and specific yield
Johnson, A.I., USGS Water -Supply Paper 1662-D, 1967, Specific Yield - Compilation of Specific Yields for Various Materials.

Specific Yield
The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium (Lohman and others, 1972).

Effective Porosity
The ratio of the volume of the voids of a soil or rock mass that can be drained by gravity to the total volume of the mass (ASTM, 1980).

While recognized that specific yield and effective porosity are not identical, in practice, they may be estimated to be approximately equal in value.

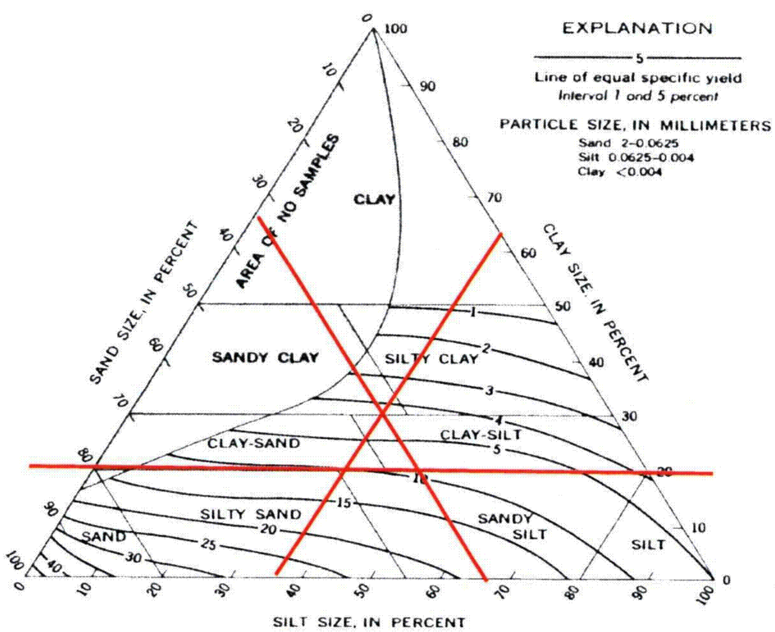
POROSITY AND EFFECTIVE POROSITY

Project: **William States Lee Nuclear Station COLA (DUK010)**

Material: **Test Fill Only** **$10 < N_{60} \le 30$**
(see FSAR Table 2.5.4-211)

Data Inputs

Dry Unit Weight	γ_s	101	pcf
Unit Weight of Water	γ_w	62.4	pcf
Specific Gravity of Water	G_w	1.0	g/cc
Particle Density of Soil	G_s	2.72	g/cc
Percent gravel		10	%
Percent sand		33	%
Percent fines		57	%
Percent silt		37	%
Percent clay		20	%



Soil classification triangle showing relation between particle size and specific yield
Johnson, A.I., USGS Water -Supply Paper 1662-D, 1967, Specific Yield - Compilation of Specific Yields for Various Materials.

$$n = 1 - (\gamma_s / \gamma_w \cdot G_w / G_s)$$

TOTAL POROSITY (n):	**40%**

Porosity
(1) The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium (after ASTM, 1980).

ESTIMATED SPECIFIC YIELD or EFFECTIVE POROSITY (n_e):	**7 ± 2%**

Specific Yield
The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium (Lohman and others, 1972).

Effective Porosity
The ratio of the volume of the voids of a soil or rock mass that can be drained by gravity to the total volume of the mass (ASTM, 1980).

While recognized that specific yield and effective porosity are not identical, in practice, they may be estimated to be approximately equal in value.

POROSITY AND EFFECTIVE POROSITY

Project: **William States Lee Nuclear Station COLA (DUK010)**

Material: **Remolded Fill** **N/A**
(see FSAR Table 2.5.4-211)

Data Inputs

Dry Unit Weight	γ_s	90	pcf
Unit Weight of Water	γ_w	62.4	pcf
Specific Gravity of Water	G_w	1.0	g/cc
Particle Density of Soil	G_s	2.72	g/cc
Percent gravel			%
Percent sand			%
Percent fines			%
Percent silt			%
Percent clay			%

$n = 1 - (\gamma_s / \gamma_w \cdot G_w / G_s)$

TOTAL POROSITY (n):	**47%**

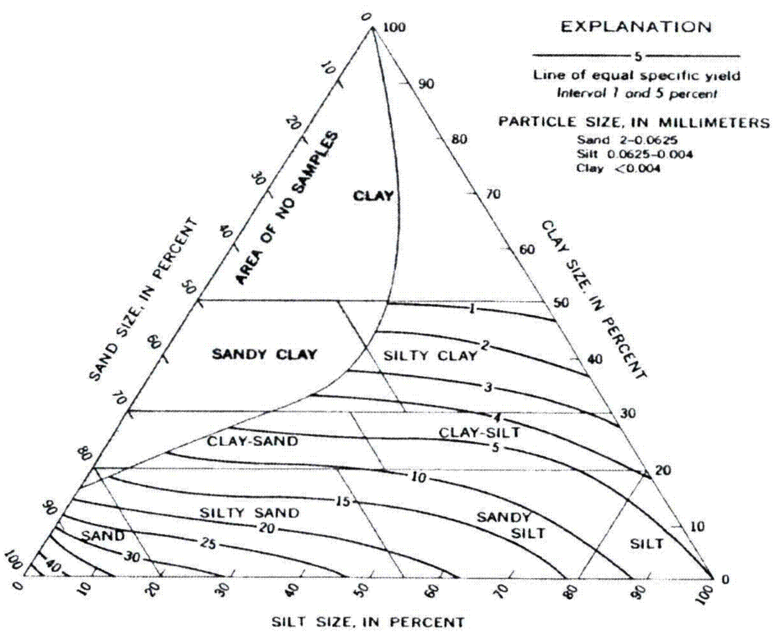
Porosity
(1) The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium (after ASTM, 1980).

ESTIMATED SPECIFIC YIELD or EFFECTIVE POROSITY (n_e):	**NM**

Specific Yield
The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium (Lohman and others, 1972).

Effective Porosity
The ratio of the volume of the voids of a soil or rock mass that can be drained by gravity to the total volume of the mass (ASTM, 1980).

While recognized that specific yield and effective porosity are not identical, in practice, they may be estimated to be approximately equal in value.



Soil classification triangle showing relation between particle size and specific yield
Johnson, A.I., USGS Water -Supply Paper 1662-D, 1967, Specific Yield - Compilation of Specific Yields for Various Materials.

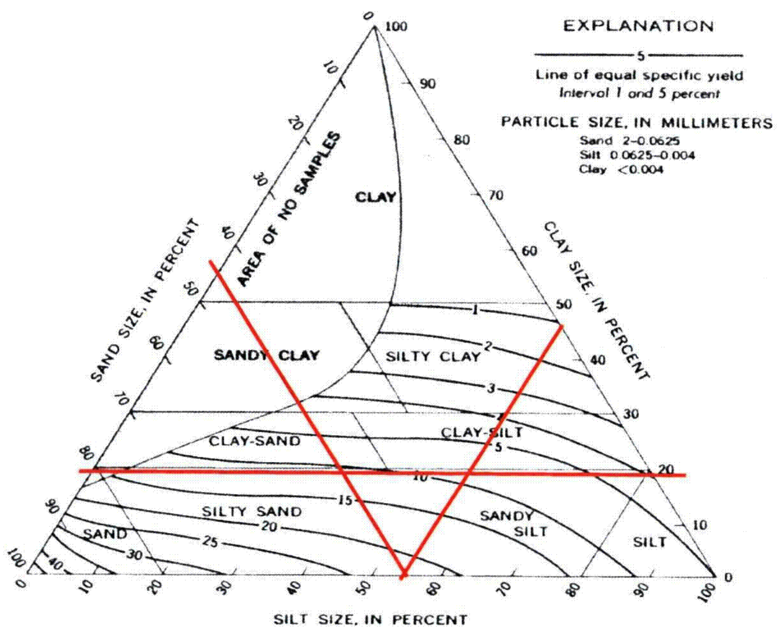
POROSITY AND EFFECTIVE POROSITY

Project: William States Lee Nuclear Station COLA (DUK010)

Material: Residual Soil **$11<N_{60}\leq30$**
(see FSAR Table 2.5.4-211)

Data Inputs

Dry Unit Weight	γ_s	88	pcf
Unit Weight of Water	γ_w	62.4	pcf
Specific Gravity of Water	G_w	1.0	g/cc
Particle Density of Soil	G_s	2.72	g/cc
Percent gravel		0	%
Percent sand		46	%
Percent fines		54	%
Percent silt		55	%
Percent clay		19	%



Soil classification triangle showing relation between particle size and specific yield
Johnson, A.I., USGS Water -Supply Paper 1662-D, 1967, Specific Yield - Compilation of Specific Yields for Various Materials.

$$n = 1 - (\gamma_s / \gamma_w \cdot G_w / G_s)$$

TOTAL POROSITY (n):	48%

Porosity

(1) The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium (after ASTM, 1980).

ESTIMATED SPECIFIC YIELD or EFFECTIVE POROSITY (n_e):	15 ± 6%

Specific Yield

The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium (Lohman and others, 1972).

Effective Porosity

The ratio of the volume of the voids of a soil or rock mass that can be drained by gravity to the total volume of the mass (ASTM, 1980).

While recognized that specific yield and effective porosity are not synonymous, in practice, they may be estimated to be approximately equal in value

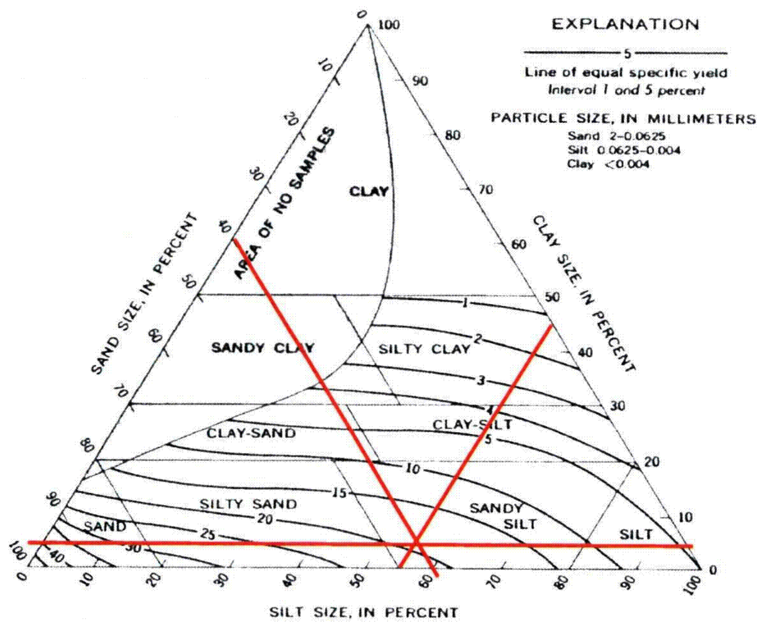
POROSITY AND EFFECTIVE POROSITY

Project: **William States Lee Nuclear Station COLA (DUK010)**

Material: **Residual Soil** **$31<N_{60}\leq100$**
(see FSAR Table 2.5.4-211)

Data Inputs

Dry Unit Weight	γ_s	NM	pcf
Unit Weight of Water	γ_w	62.4	pcf
Specific Gravity of Water	G_w	1.0	g/cc
Particle Density of Soil	G_s	2.7	g/cc
Percent gravel		0	%
Percent sand		40	%
Percent fines		60	%
Percent silt		56	%
Percent clay		4	%



Soil classification triangle showing relation between particle size and specific yield
Johnson, A.I., USGS Water -Supply Paper 1662-D, 1967, Specific Yield - Compilation of Specific Yields for Various Materials.

$$n = 1 - (\gamma_s / \gamma_w \cdot G_w / G_s)$$

TOTAL POROSITY (n):	**NM**

Porosity
(1) The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium (after ASTM, 1980).

ESTIMATED SPECIFIC YIELD or EFFECTIVE POROSITY (n_e):	**19%**

Specific Yield
The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium (Lohman and others, 1972).

Effective Porosity
The ratio of the volume of the voids of a soil or rock mass that can be drained by gravity to the total volume of the mass (ASTM, 1980).

While recognized that specific yield and effective porosity are not identical, in practice, they may be estimated to be approximately equal in value.

POROSITY AND EFFECTIVE POROSITY

Project: **William States Lee Nuclear Station COLA (DUK010)**

Material: **Saprolite** **$N_{60} \leq 10$**
(see FSAR Table 2.5.4-211)

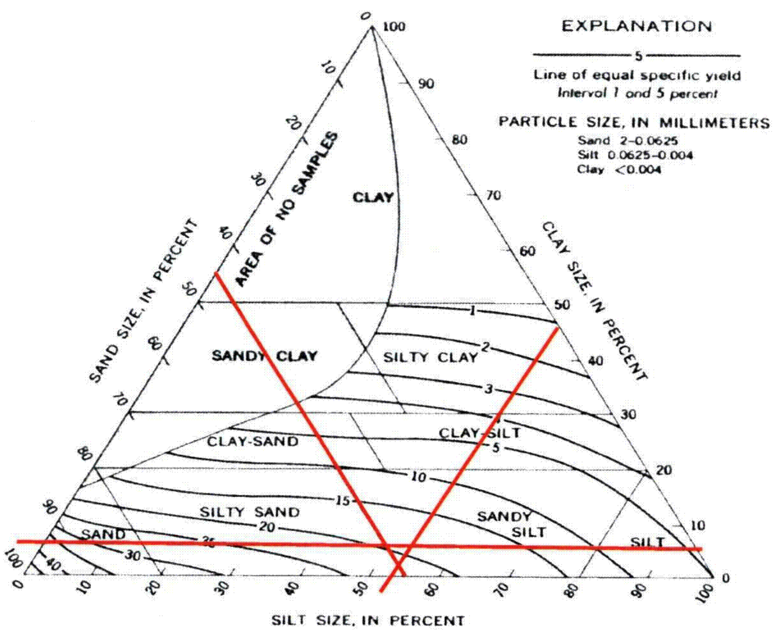
Data Inputs

Dry Unit Weight	γ_s	93	pcf
Unit Weight of Water	γ_w	62.4	pcf
Specific Gravity of Water	G_w	1.0	g/cc
Particle Density of Soil	G_s	2.72	g/cc
Percent gravel		3	%
Percent sand		44	%
Percent fines		54	%
Percent silt		53	%
Percent clay		6	%

$n = 1 - (\gamma_s / \gamma_w \cdot G_w / G_s)$

TOTAL POROSITY (n):	**45%**

Porosity
(1) The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium (after ASTM, 1980).



Soil classification triangle showing relation between particle size and specific yield
Johnson, A.I., USGS Water -Supply Paper 1662-D, 1967, Specific Yield - Compilation of Specific Yields for Various Materials.

ESTIMATED SPECIFIC YIELD or EFFECTIVE POROSITY (n_e):	**20 ± 1%**

Specific Yield
The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium (Lohman and others, 1972).

Effective Porosity
The ratio of the volume of the voids of a soil or rock mass that can be drained by gravity to the total volume of the mass (ASTM, 1980).

While recognized that specific yield and effective porosity are not identical, in practice, they may be estimated to be approximately equal in value.

POROSITY AND EFFECTIVE POROSITY

Project: **William States Lee Nuclear Station COLA (DUK010)**

Material: **Saprolite** **$11<N_{60}\leq 30$**
(see FSAR Table 2.5.4-211)

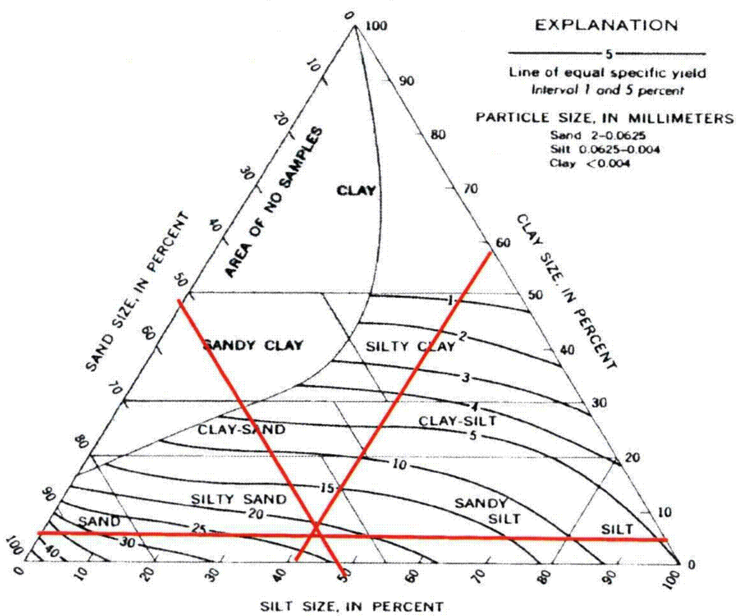
Data Inputs

Dry Unit Weight	γ_s	94	pcf
Unit Weight of Water	γ_w	62.4	pcf
Specific Gravity of Water	G_w	1.0	g/cc
Particle Density of Soil	G_s	2.71	g/cc
Percent gravel		3	%
Percent sand		52	%
Percent fines		46	%
Percent silt		41	%
Percent clay		5	%

$n = 1 - (\gamma_s / \gamma_w \cdot G_w / G_s)$

TOTAL POROSITY (n):	**44%**

Porosity
(1) The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium (after ASTM, 1980).



Soil classification triangle showing relation between particle size and specific yield
Johnson, A.I., USGS Water -Supply Paper 1662-D, 1967, Specific Yield - Compilation of Specific Yields for Various Materials.

ESTIMATED SPECIFIC YIELD or EFFECTIVE POROSITY (n_e):	**22 ± 1%**

Specific Yield
The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium (Lohman and others, 1972).

Effective Porosity
The ratio of the volume of the voids of a soil or rock mass that can be drained by gravity to the total volume of the mass (ASTM, 1980).

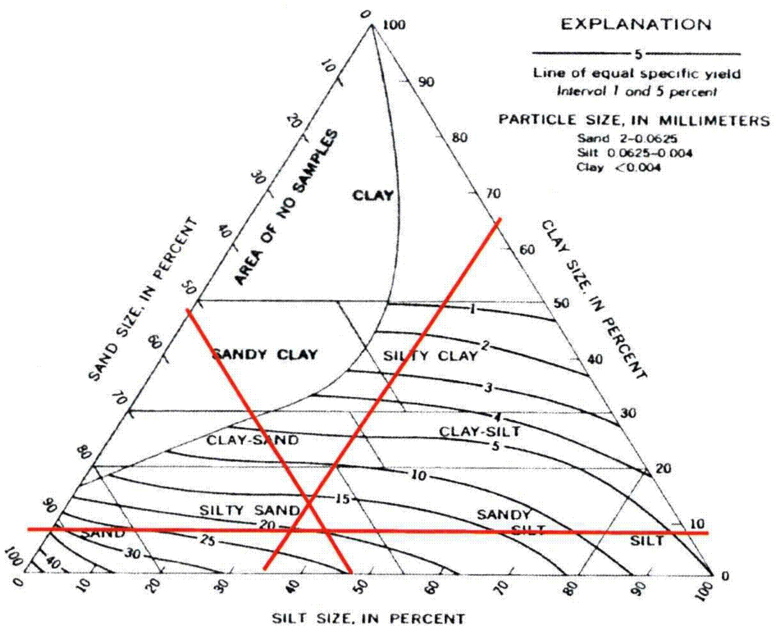
While recognized that specific yield and effective porosity are not identical, in practice, they may be estimated to be approximately equal in value.

POROSITY AND EFFECTIVE POROSITY

Project: **William States Lee Nuclear Station COLA (DUK010)**

Material: **Saprolite** **$31<N_{60}\leq 100$**
(see FSAR Table 2.5.4-211)

Data Inputs			
Dry Unit Weight	γ_s	93	pcf
Unit Weight of Water	γ_w	62.4	pcf
Specific Gravity of Water	G_w	1.0	g/cc
Particle Density of Soil	G_s	2.69	g/cc
Percent gravel		1	%
Percent sand		52	%
Percent fines		47	%
Percent silt		34	%
Percent clay		8	%



Soil classification triangle showing relation between particle size and specific yield
Johnson, A.I., USGS Water -Supply Paper 1662-D, 1967, Specific Yield - Compilation of Specific Yields for Various Materials.

$$n = 1 - (\gamma_s / \gamma_w \cdot G_w / G_s)$$

TOTAL POROSITY (n):	**45%**

Porosity
(1) The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium (after ASTM, 1980).

ESTIMATED SPECIFIC YIELD or EFFECTIVE POROSITY (n_e):	**18 ± 2%**

Specific Yield
The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium (Lohman and others, 1972).

Effective Porosity
The ratio of the volume of the voids of a soil or rock mass that can be drained by gravity to the total volume of the mass (ASTM, 1980).

While recognized that specific yield and effective porosity are not identical, in practice, they may be estimated to be approximately equal in value.

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Duke Letter Dated: December 11, 2008

TABLE 2.4.12-203
SOIL CHARACTERISTICS AT THE LEE NUCLEAR SITE

(Reported values are mean ± one standard deviation.)

		All Fill Samples(a)			Test Fill Only	Remolded Fill(b)	Residual Soil			Saprolite			PWR
		$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$10 < N_{60} \le 30$ ($8 < N \le 23$)(c)	N/A (N/A)	$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$N_{60} > 100$ ($N > 75$)(c)
Percent gravel(d)	%	0(e) [1]	4 ± 6 [36]	6 ± 8 [6]	10 ± 7 [6]	3 ± 7 [9]	0 [1]	0 [4]	0 [1]	3 ± 3 [8]	3 ± 7 [20]	1 ± 1 [11]	9 ± 14 [8]
Percent sand(d)	%	42(e) [1]	34 ± 8 [36]	47 ± 19 [6]	33 ± 11 [6]	34 ± 12 [9]	57(e) [1]	46 ± 15 [4]	40(e) [1]	44 ± 11 [8]	52 ± 12 [20]	52 ± 13 [11]	55 ± 19 [8]
Percent fines (<#200 sieve)(d)	%	58(e)[1]	62 ± 11 [36]	47 ± 21 [6]	57 ± 15 [6]	64 ± 12 [9]	43(e) [1]	54 ± 14 [4]	60(e) [1]	54 ± 13 [8]	46 ± 15 [20]	47 ± 13 [11]	36 ± 22 [8]
Percent silt	%	-	41 ± 9 [13]	42(e) [1]	37 ± 8 [6]	-	-	55(e) [1]	56(e) [1]	53(e) [2]	41 ± 10 [3]	34(e) [1]	-
Percent clay (<5μm)	%	-	18 ± 9 [13]	19(e) [1]	20 ± 11 [6]	-	-	19(e) [1]	4(e) [1]	6(e) [2]	5 ± 2 [3]	8(e) [1]	-
Specific gravity, G_s		-	2.71 ± .06 [20]	2.68(e) [1]	2.72 ± .09 [6]	2.72 ± 0.02 [9]	-	2.72(e) [2]	2.70(e) [1]	2.72 ± 0.04 [6]	2.71 ± .04 [11]	2.69 ± .04 [4]	-
Dry unit weight, γ_{dry}	pcf	-	101 ± 8 [13]	-	101 ± 2 [6]	90 ± 5 [5]	-	88(e) [2]	-	93 ± 11 [4]	94 ± 15 [8]	93(e) [2]	-
Wet unit weight, γ_t	pcf	-	122 ± 5 [13]	-	122 ± 3 [6]	110 ± 3 [5]	-	113(e) [2]	-	116 ± 11 [4]	117 ± 7 [8]	114(e) [2]	135(f)
Saturated unit weight, γ_{sat}	pcf	-	125 ± 5 [13]	-	126 ± 2 [6]	119 ± 3 [5]	-	118(e) [2]	-	121 ± 7 [4]	124 ± 7 [7]	121(e) [2]	140(f)
Hydraulic conductivity (g), k	ft/yr	-	-	-	-	29 ± 11 [5]	-	-	-	-	-	-	-
Total Porosity	%	-	40	-	40	47	-	48	-	45	44	45	-
Effective Porosity	%	-	9 ± 2 (h)	12 ± 2 (h)	7 ± 2 (h)	-	-	15 ± 6 (h)	19	20 ± 1 (h)	22 ± 1 (h)	18 ± 2 (h)	8

a) All fill includes samples classified as fill on boring logs, including test fill samples, but does not include remolded fill samples.
b) Remolded soil samples compacted to 95% of Standard Proctor maximum dry density at optimum moisture content.
c) Field SPT-N values to correlate to N60-values are computed using the average energy transfer ratio (ETR) of 80.0%. N=N60(60/80.0).
d) Three samples of alluvium were tested for moisture content and two underwent grain-size analysis; the results are not shown in this table.
e) Insufficient data to determine standard deviation.
f) These values are from PSAR, Table 2D-3 and Table 2A-1 (Reference 201 in the PSAR).
g) 1 ft/year * 9.67 x 10^{-7} = 1 cm/sec.
h) Range of effective porosity values as determined from trilinear diagrams. Results are in the format of x ± y, where "x" is the centerpoint value and "y" is the potential deviation from the centerpoint value.

i) Minimum effective porosity based on estimate from saturated and wet unit weights.
Note: The number in brackets is the number of samples in the data set, [Number].
Weighted Average dependent upon the limiting number of samples for each result.

Weighted Average calculations

	Weighted Average	
Fill Samples (in place, excluding remolded fill)		
Total Porosity	40%	1 value
Effective Porosity	9%	((9*13)+(12*1))/14
Residual Soil and Saprolite		
Total Porosity	45%	((48*2)+(45*4)+(44*8)+(45*2))/(2+4+8+2)
Effective Porosity	20%	((15*1)+(19*1)+(20*2)+(22*3)+(18*1))/(1+1+2+3+1)
Partially Weathered Rock (PWR)		
Total Porosity	Not Measured	
Effective Porosity	8%	1 value

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-005

NRC RAI:

Identify in Table 2.4.12-203 which parameters were measured and which were estimated. Provide data traceability for all parameters. Provide clarification of the methods used to estimate parameters.

Duke Energy Response:

Duke Energy has performed additional analysis of groundwater at the Lee site. This has resulted in a complete revision of FSAR Table 2.4.12-203. Boring information is addressed in FSAR Subsection 2.5.4 and is no longer repeated in the Table 2.4.12-203.

For clarity, "measurement" is the dimension, quantity, or capacity determined by measuring. An "estimate" is an approximate judgment or calculation as to the value, amount, time, size, or weight of something.

Measured parameters used within Table 2.4.12-203 include the following:

- Grain size distribution (sieve + hydrometer and sieve) of gravel, sand, silt, and clay fractions, ASTM D 422-63 (2002) and ASTM D 6913-04.
- Specific gravity, ASTM D 854-06.
- Unit weight of soil, ASTM D 5084 -03 (Sections 5.7 – 5.9 and 8.1; Subsection 11.3.2), as discussed in FSAR Subsection 2.5.4.2.3.
- Hydraulic conductivity, ASTM D 5084-03.

Derived (estimated) parameters in Table 2.4.12-203 include:

- Total porosity, which was calculated using the measured dry unit weight and specific gravity of soil and the standard unit weight of water (Subsection 2.4.12.2.4.1).
- Effective porosity, which was assumed to be equivalent to the specific yield of the sample. Effective porosity was estimated for samples that had measured grain-size distribution data for sand, silt, and clay fractions. The grain-size distribution data were used to estimate the effective porosity by interpolation of the sample data using trilinear graphs.
- Effective porosity for partially weathered rock (PWR), which was estimated based on the assumption that the difference between the saturated and wet unit weights of the sample represents the loss of water due to natural gravity drainage.

Further explanation on the method used to derive the porosity values can be found in the response to FSAR RAI 02.04.12-004 (this letter).

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Table 2.4.12-203

Attachment:

1) Replacement FSAR Table 2.4.12-203 and Table 2.4.12-203 Annotated

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-005

Replacement FSAR Table 2.4.12-203

And

Table 2.4.12-203 Annotated

TABLE 2.4.12-203
SOIL CHARACTERISTICS AT THE LEE NUCLEAR SITE

(Reported values are mean ± one standard deviation)

		All Fill Samples (a)			Test Fill Only	Remolded Fill (b)	Residual Soil			Saprolite			PWR
		$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$10 < N_{60} \le 30$ ($8 < N \le 23$)(c)	N/A (N/A)	$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$N_{60} > 100$ ($N > 75$)(c)
Percent gravel (d)	%	0(e) [1]	4 ± 6 [36]	6 ± 8 [6]	10 ± 7 [6]	3 ± 7 [9]	0 [1]	0 [4]	0 [1]	3 ± 3 [8]	3 ± 7 [20]	1 ± 1 [11]	9 ± 14 [8]
Percent sand (d)	%	42(e) [1]	34 ± 8 [36]	47 ± 19 [6]	33 ± 11 [6]	34 ± 12 [9]	57(e) [1]	46 ± 15 [4]	40(e) [1]	44 ± 11 [8]	52 ± 12 [20]	52 ± 13 [11]	55 ± 19 [8]
Percent fines (<#200 sieve) (d)	%	58(e) [1]	62 ± 11 [36]	47 ± 21 [6]	57 ± 15 [6]	64 ± 12 [9]	43(e) [1]	54 ± 14 [4]	60(e) [1]	54 ± 13 [8]	46 ± 15 [20]	47 ± 13 [11]	36 ± 22 [8]
Percent silt	%	-	41 ± 9 [13]	42(e) [1]	37 ± 8 [6]	-	-	55(e) [1]	56(e) [1]	53(e) [2]	41 ± 10 [3]	34(e) [1]	-
Percent clay (<5μm)	%	-	18 ± 9 [13]	19(e) [1]	20 ± 11 [6]	-	-	19(e) [1]	4(e) [1]	6(e) [2]	5 ± 2 [3]	8(e) [1]	-
Specific gravity, G_s		-	2.71 ± .06 [20]	2.68(e) [1]	2.72 ± .09 [6]	2.72 ± 0.02 [9]	-	2.72(e) [2]	2.70(e) [1]	2.72 ± 0.04 [6]	2.71 ± .04 [11]	2.69 ± .04 [4]	-
Dry unit weight, γ_{dry}	pcf	-	101 ± 8 [13]	-	101 ± 2 [6]	90 ± 5 [5]	-	88(e) [2]	-	93 ± 11 [4]	94 ± 15 [8]	93(e) [2]	-
Wet unit weight, γ_t	pcf	-	122 ± 5 [13]	-	122 ± 3 [6]	110 ± 3 [5]	-	113(e) [2]	-	116 ± 11 [4]	117 ± 7 [8]	114(e) [2]	135(f)
Saturated unit weight, γ_{sat}	pcf	-	125 ± 5 [13]	-	126 ± 2 [6]	119 ± 3 [5]	-	118(e) [2]	-	121 ± 7 [4]	124 ± 7 [7]	121(e) [2]	140(f)
Hydraulic conductivity (g), k	ft/yr	-	-	-	-	29 ± 11 [5]	-	-	-	-	-	-	-
Total Porosity	%	-	40	-	40	47	-	48	-	45	44	45	-
Effective Porosity	%	-	9 ± 2 (h)	12 ± 2 (h)	7 ± 2 (h)	-	-	15 ± 6 (h)	19	20 ± 1 (h)	22 ± 1 (h)	18 ± 2 (h)	8

a) All fill includes samples classified as fill on boring logs, including test fill samples, but does not include remolded fill samples.
b) Remolded soil samples compacted to 95% of Standard Proctor maximum dry density at optimum moisture content.
c) Field SPT-N values to correlate to N60-values are computed using the average energy transfer ratio (ETR) of 80.0%. N=N60(60/80.0).
d) Three samples of alluvium were tested for moisture content and two underwent grain-size analysis; the results are not shown in this table.
e) Insufficient data to determine standard deviation.
f) These values are from PSAR, Table 2D-3 and Table 2A-1 (Reference 201 in the PSAR).
g) 1 ft/year * 9.67×10^{-7} = 1 cm/sec.
h) Range of values.
i) Minimum effective porosity based on estimate from saturated and wet unit weights.
Note: The number in brackets is the count, [Number].
Weighted Average dependent upon the limiting number of samples for each result.
pcf- pounds per cubic foot

	Weighted Average
Fill Samples (in place)	
Total Porosity	40%
Effective Porosity	9%
Residual Soil and Saprolite	
Total Porosity	45%
Effective Porosity	20%
Partially Weathered Rock (PWR)	
Total Porosity	NM
Effective Porosity	8%

Measured parameters (see FSAR Table 2.5.4-211)

TABLE 2.4.12-203
SOIL CHARACTERISTICS AT THE LEE NUCLEAR SITE

(Reported values are mean ± one standard deviation)

		All Fill Samples (a)			Test Fill Only	Remolded Fill (b)	Residual Soil			Saprolite			PWR
		$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$10 < N_{60} \le 30$ ($8 < N \le 23$)(c)	N/A (N/A)	$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$N_{60} \le 10$ ($N \le 8$)(c)	$11 < N_{60} \le 30$ ($8 < N \le 23$)(c)	$31 < N_{60} \le 100$ ($23 < N \le 75$)(c)	$N_{60} > 100$ ($N > 75$)(c)
Percent gravel (d)	%	0(e) [1]	4 ± 6 [36]	6 ± 8 [6]	10 ± 7 [6]	3 ± 7 [9]	0 [1]	0 [4]	0 [1]	3 ± 3 [8]	3 ± 7 [20]	1 ± 1 [11]	9 ± 14 [8]
Percent sand (d)	%	42(e) [1]	34 ± 8 [36]	47 ± 19 [6]	33 ± 11 [6]	34 ± 12 [9]	57(e) [1]	46 ± 15 [4]	40(e) [1]	44 ± 11 [8]	52 ± 12 [20]	52 ± 13 [11]	55 ± 19 [8]
Percent fines (<#200 sieve) (d)	%	58(e) [1]	62 ± 11 [36]	47 ± 21 [6]	57 ± 15 [6]	64 ± 12 [9]	43(e) [1]	54 ± 14 [4]	60(e) [1]	54 ± 13 [8]	46 ± 15 [20]	47 ± 13 [11]	36 ± 22 [8]
Percent silt	%	-	41 ± 9 [13]	42(e) [1]	37 ± 8 [6]	-	-	55(e) [1]	56(e) [1]	53(e) [2]	41 ± 10 [3]	34(e) [1]	-
Percent clay (<5μm)	%	-	18 ± 9 [13]	19(e) [1]	20 ± 11 [6]	-	-	19(e) [1]	4(e) [1]	6(e) [2]	5 ± 2 [3]	8(e) [1]	-
Specific gravity, G_s		-	2.71 ± .06 [20]	2.68(e) [1]	2.72 ± .09 [6]	2.72 ± 0.02 [9]	-	2.72(e) [2]	2.70(e) [1]	2.72 ± 0.04 [6]	2.71 ± .04 [11]	2.69 ± .04 [4]	-
Dry unit weight, γ_{dry}	pcf	-	101 ± 8 [13]	-	101 ± 2 [6]	90 ± 5 [5]	-	88(e) [2]	-	93 ± 11 [4]	94 ± 15 [8]	93(e) [2]	-
Wet unit weight, γ_t	pcf	-	122 ± 5 [13]	-	122 ± 3 [6]	110 ± 3 [5]	-	113(e) [2]	-	116 ± 11 [4]	117 ± 7 [8]	114(e) [2]	135(f)
Saturated unit weight, γ_{sat}	pcf	-	125 ± 5 [13]	-	126 ± 2 [6]	119 ± 3 [5]	-	118(e) [2]	-	121 ± 7 [4]	124 ± 7 [7]	121(e) [2]	140(f)
Hydraulic conductivity (g), k	ft/yr	-	-	-	-	29 ± 11 [5]	-	-	-	-	-	-	-
Total Porosity	%	-	40	-	40	47	-	48	-	45	44	45	-
Effective Porosity	%	-	9 ± 2 (h)	12 ± 2 (h)	7 ± 2 (h)	-	-	15 ± 6 (h)	19	20 ± 1 (h)	22 ± 1 (h)	18 ± 2 (h)	8

a) All fill includes samples classified as fill on boring logs, including test fill samples, but does not include remolded fill samples.
b) Remolded soil samples compacted to 95% of Standard Proctor maximum dry density at optimum moisture content.
c) Field SPT-N values to correlate to N60-values are computed using the average energy transfer ratio (ETR) of 80.0%. N=N60(60/80.0).
d) Three samples of alluvium were tested for moisture content and two underwent grain-size analysis; the results are not shown in this table.
e) Insufficient data to determine standard deviation.
f) These values are from PSAR, Table 2D-3 and Table 2A-1 (Reference 201 in the PSAR).
g) 1 ft/year * 9.67 x 10^{-7} = 1 cm/sec.
h) Range of values.
i) Minimum effective porosity based on estimate from saturated and wet unit weights.
Note: The number in brackets is the count, [Number].
Weighted Average dependent upon the limiting number of samples for each result.
pcf- pounds per cubic foot

Estimated

	Weighted Average
Fill Samples (in place)	
Total Porosity	40%
Effective Porosity	9%
Residual Soil and Saprolite	
Total Porosity	45%
Effective Porosity	20%
Partially Weathered Rock (PWR)	
Total Porosity	NM
Effective Porosity	8%

Estimated: With the exception of PWR, trilinear diagrams were used to analyze grain size distribution (see diagrams in FSAR RAI 2.4.12-4). Not applicable without hydrometer measurements to differentiate clay and silt.

PWR effective porosity is estimated assuming the difference between saturated and wet unit weights are equivalent to the specific yield resulting from gravity drainage. While the effective porosity may actually be greater than this value, it is no lower than this value. This value is as a conservative estimate of effective porosity used for calculating groundwater velocity.

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-006

NRC RAI:

The high-water mark in the excavation (579 ft) was proposed as an indicator of the maximum groundwater height that would be expected. Being able to use that mark depends, in part, on understanding the historical conditions that affected the water level. Specify in which month and year pumping ceased at the former Cherokee Nuclear site and in which month and year pumping resumed at the Lee Nuclear Site. For the interval when pumping did not occur, provide the annual precipitation amounts for each year and their deviation from normal. Describe what is known about whether the site owners altered the water levels in the excavation. Section 2.5.4.6.1 states that the long term groundwater elevation is expected to fluctuate over time between 584 and 574, i.e., 579 +/- 5 ft. Also, 579 ft will be 10.5 ft below final grade of 589.5 ft. Figure 2.4.12-203 shows that some wells with groundwater within 10-15 ft of the surface responded up to 5 ft during a six-month period in 2007. Explain whether a similar seasonal response is or is not expected in the vicinity of the nuclear island. Explain how such seasonal variations alter groundwater flow paths and how those variable flow paths were evaluated with respect to the transport calculations that support Section 2.4.13.

Duke Energy Response:

From 1977 to 1982, construction activities at the Cherokee Nuclear Site resulted in significant alterations to site topography. Dewatering of Cherokee Units 1, 2, and 3 is believed to have been maintained during that time, although a precise timeline of dewatering activities is not available. Following cessation of dewatering, the water level in the excavation is believed to have rebounded naturally. It is unknown if the water level was altered by the interim property owners as no long-term monitoring of the impoundment was performed. In December 2005, pumping resumed at the Lee Nuclear Site Units 1 and 2, and the excavation was dewatered and pressure washed to restore the conditions of the original excavation during the Cherokee construction project.

Water levels in the impoundment were also compared against available aerial photographs, using the historic containment building as the point of reference. Comparing the apparent water level in this impoundment as shown on the February 1994 and February 2005 aerial photographs (Attachment 3) with the topographic survey conducted in 2006, indicates that water levels of the impoundment ranged from around 574 ft. msl (1994) to 579 ft. msl (2005). Precipitation data at the time of these photographs did not identify abnormal conditions, suggesting the aerial photographs show typical impoundment levels.

Annual precipitation totals were available from the National Oceanic and Atmospheric Administration (NOAA) collected at the Greenville-Spartanburg (GSP) Airport, located approximately 45 miles west of the Lee Nuclear Site, for the period from January 1950 through

May 2008, as shown in Attachment 2. During that period, the average annual precipitation was 49.18 inches.

As discussed in the response to FSAR RAI 2.4.12-003 (this letter), precipitation is relatively evenly distributed throughout the year. However, groundwater levels do show a general seasonal trend, indicating that other factors influence groundwater levels as well. Water levels appear to rise in winter, reaching peaks around April – May, then decline through summer and fall, reaching their lowest levels in October – November. The average annual water level fluctuation observed in wells located outside of the lateral area of influence of the dewatering was approximately 4.5 ft. Similar seasonal responses are expected to occur across the site. By using the highest projected groundwater gradient, transport calculations account for seasonal groundwater variations. Thus, the design groundwater elevation is 579 ± 5 ft msl, allowing for a 5 ft seasonal variation over the high water mark level.

FSAR Subsections 2.4.12.2.3 and 2.4.12.5 are revised by this RAI response to discuss the variation in groundwater levels. The identified changes will be incorporated in a future revision of the Final Safety Analysis Report.

Associated Revisions to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsections 2.4.12.2.3 and 2.4.12.5

Attachments:

1) Revised FSAR Subsections 2.4.12.2.3 and 2.4.12.5
2) Precipitation Data from the National Oceanic and Atmospheric Administration (NOAA)
3) Aerial Photographs from February 1994 and February 2005

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-006

Revised FSAR Subsections 2.4.12.2.3 and 2.4.12.5

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.2.3, first paragraph, will be revised as follows:

In March 2006, the current groundwater investigation was initiated as part of the subsurface study to evaluate hydrogeologic conditions for the Lee Nuclear Site. The dewatering of the existing excavation preceded the subsurface investigation, thus returning the site to hydrogeologic conditions similar to those of the previous construction phase. Approximately 740 million gal. of water were removed from the excavation from December 19, 2005, through September 7, 2006. The apparent high-water-level mark (elev. 578.72 ft. msl), as indicated by stains observed on the concrete structures, was measured in 2006 following the dewatering of the site. Comparing the apparent water level in this impoundment as shown on the February 1994 and February 2005 aerial photographs with the topographic survey conducted in 2006, indicates that water levels of the impoundment ranged from around 574 ft. msl (1994) to 579 ft. msl (2005). Precipitation data at the time of these photographs did not identify abnormal conditions, suggesting the aerial photographs captured typical impoundment levels. Since no long-term monitoring of the full impoundment was performed, the high-water-level mark observed on the structures appears~~ed~~ to be a reasonable estimate of ~~the~~ a typical high-water elevation for ~~of~~ the impoundment, and a relatively conservative ~~the best~~ indicator of hydrostatic equilibrium. ~~steady-state conditions.~~ Maintenance dewatering activities are expected to end following construction activities. Construction dewatering of the excavation is within the capacity of the current on-site pumps.

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.2.3, sixth paragraph, will be revised as follows:

~~Both regionally and locally, surface topography plays a dominant role in groundwater occurrence.~~ Under natural conditions the topography of the water table within the Piedmont mimics the topography of the land surface, but has less relief. Cross-sections of the Lee Nuclear Site are presented in Figure 2.4.12-205, Sheets 1 - 4. These figures depict the relationship between groundwater beneath the site and the surface water bodies surrounding the site. Groundwater flow in the Piedmont province is typically restricted to the topographic area underlying the slope that extends from a divide to an adjacent stream. ~~Ultimately, groundwater is discharged to the Broad River, the groundwater sink for the site, and the surrounding area.~~

Both regionally and locally, surface topography plays a dominant role in groundwater occurrence. Post-construction topography was observed to affect groundwater conditions such that cuts in topography induce a lowered water table and fill induces a raised water table. Field evidence for this is based on comparison between the Cherokee water table map (Figure 2.4.12-201) and the maps developed from the Lee Nuclear Site investigation (Figure 2.4.12-204, Sheet 1-7). For example, MW-1204, located on the Unit #2 Cooling Tower Pad, is where construction fill was placed during Cherokee construction, resulting in a significantly higher land surface elevation (approximately 610 ft. msl compared to its pre-grading elevation of around 560 ft. msl). Consequently, the water table elevation is higher in MW-1204: groundwater elevation of approximately 570 ft. msl compared with the former groundwater elevation of less than 550 ft. msl. Another example includes MW-1200, located west-northwest of Unit #1, and is where Cherokee construction cuts resulted in a significantly lower land surface elevation: approximately 590 ft. msl compared to its pre-grading elevation of approximately 670 ft. msl. Consequently, the water table elevation has lowered: groundwater elevation of 565 ft. msl compared with the former groundwater elevation of more than 585 ft. msl.

The topography of the water table during operation, post-dewatering, is expected to mimic land surface, consistent with slope-aquifer conditions of the Piedmont physiographic province. The projected post-dewatering water table conditions are illustrated in Figure 2.4.12-204, Sheet 8. The potentiometric conditions shown in Figure 2.4.12-204, Sheet 8 affect the directions of groundwater flow surrounding the Lee Nuclear Station. Each of the ponds serves as constant head flow boundaries. The crests of the water table undulations serve as groundwater divides within the slope-aquifer system and are expected to contain the movement of groundwater. The low areas between the topographic divides serve as flow compartments that are open-ended down slope, where, ultimately, groundwater is discharged to the Broad River, the groundwater sink for the site and the surrounding area. The potentiometric surface beneath Lee Units 1 and 2 is expected to rebound to an elevation near the observed pre-dewatering high water level mark. Based on an annual average water level fluctuation observed in monitoring wells outside the apparent dewatering lateral area of influence of 4.5 ft., a maximum high groundwater elevation is not expected to vary more than 5 ft. of that high water mark (i.e., 578.72 + 5 ft. above msl). Therefore, the high groundwater elevation at Lee Nuclear Station is expected to be approximately 584 ft. msl.

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.5, first paragraph, will be revised as follows:

According to the AP1000 Design Control Document (DCD), the design maximum groundwater elevation is 2 ft. below yard grade elevation. The Lee Nuclear Station plant elevation is 590.0 ft. above msl and the yard grade is 589.5 ft. above msl, therefore, the design maximum groundwater elevation is 587.5 ft. above msl. The maximum static groundwater level anticipated in the vicinity of Units 1 and 2 power blocks during operations is expected to be around ~~579~~ 584 ft. above msl (Figure 2.4.12-204, Sheet 8). The hydrostatic loading is not expected to exceed design criteria since ~~approximately 8.5~~at least 5 ft. of unsaturated interval are expected below the design basis groundwater elevation. The installation and operation of a permanent dewatering system is not expected.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.04.12-006

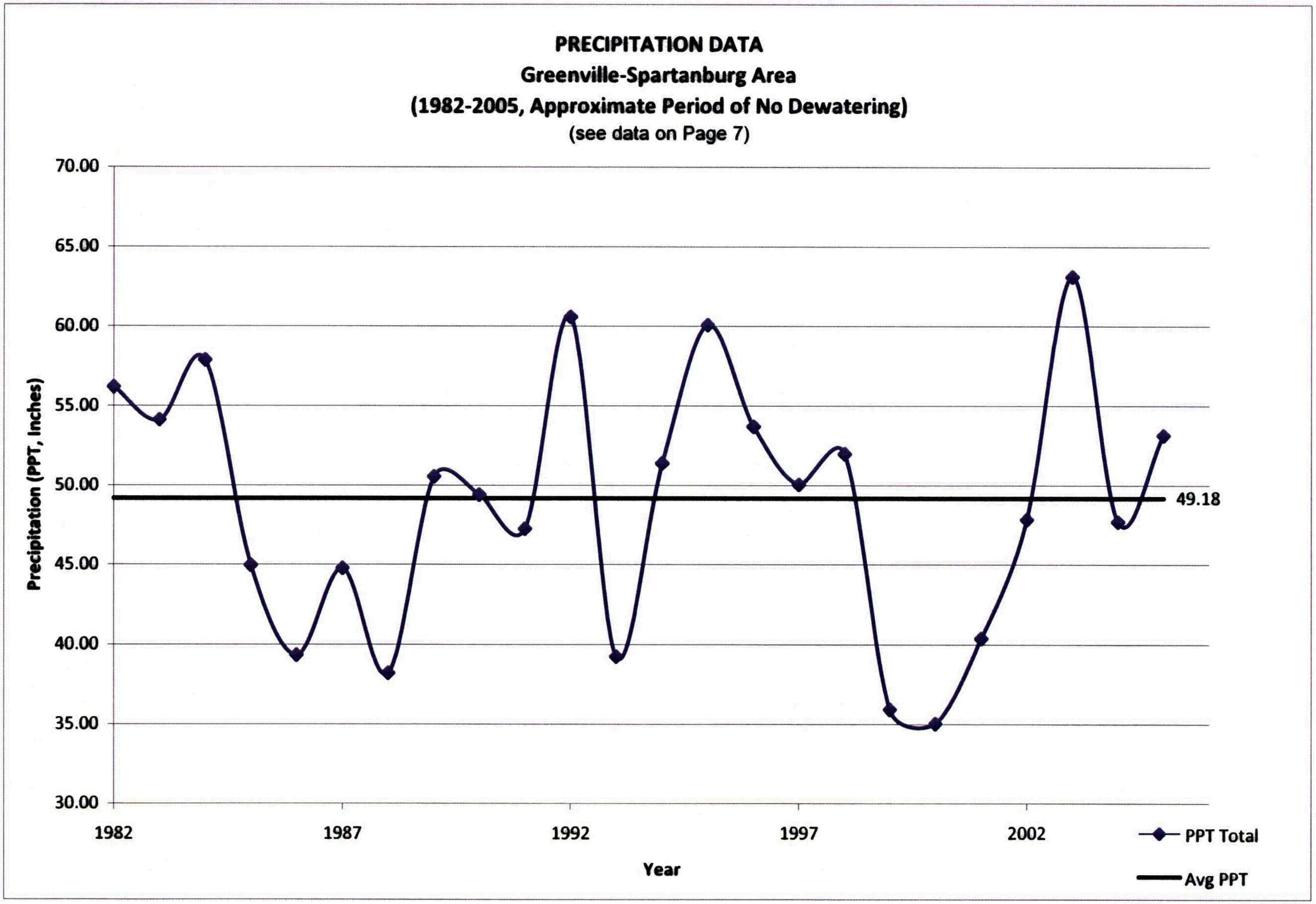
Precipitation Data from the National Oceanic and Atmospheric Administration (NOAA)

MONTHLY PRECIPITATION GREENVILLE SPARTANBURG AREA (1950 - May 2008)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	3.09	1.49	3.89	1.02	4.44	3.11	9.02	1.74	3.67	4.47	0.70	4.50	41.14
1951	1.59	2.32	5.25	3.70	0.52	4.61	4.86	7.02	8.85	1.10	2.23	7.71	49.76
1952	3.68	4.71	11.99	3.13	1.90	2.18	3.60	7.27	1.28	1.34	1.35	4.66	47.09
1953	5.16	7.29	4.47	3.09	2.57	1.78	4.27	5.66	6.94	0.49	1.10	6.74	49.56
1954	7.35	2.14	7.08	1.19	2.90	2.02	2.89	1.49	0.52	0.77	3.08	3.62	35.05
1955	2.74	4.01	3.15	6.03	4.46	3.27	7.00	1.01	2.42	3.72	2.73	1.05	41.59
1956	1.58	9.74	4.84	6.57	3.88	2.44	8.14	1.94	8.14	1.97	2.62	2.72	54.58
1957	5.15	4.20	3.62	4.82	2.66	3.61	0.58	3.94	7.09	2.65	7.59	3.56	49.47
1958	4.54	3.66	5.37	8.50	2.60	1.77	6.60	2.72	1.37	1.52	1.60	3.54	43.79
1959	2.74	3.08	5.53	5.88	5.63	1.41	7.04	3.55	8.20	7.32	1.64	3.28	55.30
1960	5.60	5.65	5.65	1.91	2.16	4.38	4.33	5.48	4.76	4.74	0.54	3.26	48.46
1961	2.39	8.34	4.54	4.84	2.60	4.24	5.03	8.46	1.49	0.90	2.94	10.10	55.87
1962	4.65	4.71	8.92	5.37	1.48	7.03	3.57	3.88	2.28	3.24	4.47	3.38	52.98
1963	3.93	3.25	9.66	5.95	3.06	4.73	2.46	1.16	4.68	0.24	4.19	3.78	47.09
1964	5.44	4.67	7.11	11.30	1.59	8.07	7.44	6.64	0.93	10.24	3.36	3.62	70.41
1965	2.39	5.22	7.60	4.93	1.09	8.62	3.13	3.57	2.32	3.60	2.82	0.37	45.66
1966	4.64	6.78	3.26	2.53	3.06	3.84	2.98	5.01	7.98	3.78	1.93	3.15	48.94
1967	3.97	3.32	1.98	2.36	4.97	4.87	3.86	7.51	2.05	2.35	3.50	7.40	48.14
1968	4.12	1.00	3.68	2.40	3.93	5.71	6.92	1.31	3.04	2.82	5.07	3.18	43.18
1969	3.94	5.24	4.56	7.18	1.93	9.59	3.17	6.53	3.68	2.38	2.24	4.60	55.04
1970	1.74	3.74	3.45	2.94	3.13	3.60	2.31	3.59	1.34	7.02	1.77	2.88	37.51
1971	3.33	7.43	5.52	3.09	5.72	2.19	5.64	2.44	3.28	9.51	4.22	3.79	56.16
1972	6.14	3.04	4.59	2.28	8.89	8.16	4.18	3.21	2.20	3.44	5.31	6.68	58.12
1973	4.33	4.88	8.73	4.04	5.59	3.87	3.70	2.03	7.56	0.98	1.34	7.55	54.60
1974	4.24	4.90	3.26	4.06	5.45	3.78	3.23	4.03	3.76	0.24	4.81	2.50	44.26
1975	5.42	5.78	8.64	1.14	7.81	5.39	4.79	3.21	11.65	7.45	3.98	3.07	68.33
1976	4.49	2.15	7.30	0.69	8.10	2.81	5.75	2.09	8.28	8.49	2.75	6.21	59.11
1977	3.53	2.00	8.47	3.23	2.71	2.88	0.80	4.99	9.44	6.39	4.43	3.55	52.42
1978	6.93	0.53	6.09	2.97	4.84	3.51	6.77	2.98	0.27	0.81	1.93	3.39	41.02
1979	7.19	6.11	4.19	10.15	5.69	3.74	8.66	4.34	7.50	3.33	3.91	1.25	66.06
1980	4.28	1.19	11.37	3.47	5.92	6.72	1.05	3.33	5.82	2.83	4.11	0.64	50.73
1981	0.29	3.86	3.22	0.88	4.15	1.29	5.30	1.17	2.08	4.40	1.66	7.19	35.49
1982	6.27	5.21	2.77	4.57	6.18	3.32	12.52	1.66	1.44	3.07	4.17	5.02	56.20
1983	2.70	5.26	6.26	4.66	5.80	4.67	1.13	3.27	3.59	3.05	5.29	8.45	54.13
1984	3.04	7.04	5.67	4.76	8.30	3.07	13.57	4.00	1.34	2.28	2.60	2.22	57.89
1985	4.94	4.29	1.13	1.31	2.42	2.85	6.96	5.93	1.62	4.55	7.52	1.44	44.96
1986	1.10	1.46	2.64	1.10	6.34	0.93	1.63	5.93	2.56	6.11	5.37	4.17	39.34
1987	4.65	7.33	5.01	2.30	1.31	6.68	3.58	2.79	3.33	0.37	2.81	4.62	44.78
1988	3.91	1.79	3.67	3.41	1.96	3.25	2.18	3.93	4.57	3.38	4.26	1.90	38.21
1989	1.51	4.93	4.48	3.15	3.64	6.00	5.11	4.71	5.42	3.10	3.74	4.76	50.55
1990	4.37	5.97	6.67	2.22	2.70	0.90	3.61	6.21	2.12	9.45	1.93	3.26	49.41
1991	4.72	2.24	5.82	5.65	6.37	1.72	5.74	9.02	1.44	0.24	1.39	2.90	47.25
1992	2.50	6.12	5.45	4.81	5.03	4.97	2.66	5.54	4.30	6.27	7.85	5.08	60.58
1993	7.19	3.56	10.27	2.91	3.08	0.17	0.75	0.87	1.71	2.07	3.73	2.94	39.25
1994	4.24	3.47	4.46	2.61	1.44	10.12	6.56	5.76	2.06	4.28	2.43	3.96	51.39
1995	6.42	5.08	2.30	1.58	4.53	4.84	2.69	17.37	2.13	5.96	5.13	2.05	60.08
1996	5.54	3.75	7.64	3.09	5.00	4.03	4.43	6.27	4.62	0.82	4.34	4.17	53.70
1997	4.82	6.07	2.67	4.11	3.37	6.02	6.02	0.92	3.26	4.85	3.70	4.25	50.06
1998	6.76	6.94	4.31	9.15	1.77	3.80	3.27	2.27	4.31	2.77	2.39	4.24	51.98
1999	3.84	2.84	2.33	3.95	1.37	4.67	1.95	0.79	3.04	5.86	2.67	2.62	35.93
2000	3.72	1.87	4.35	4.70	2.19	1.31	5.23	1.42	4.24	0.00	4.06	1.95	35.04
2001	3.01	2.31	6.69	1.10	2.14	3.77	6.01	1.01	6.74	3.39	1.98	2.23	40.38
2002	4.86	1.39	5.11	0.74	3.84	0.52	4.41	4.23	7.20	4.66	4.42	6.47	47.85
2003	1.91	4.02	6.71	7.13	7.64	6.24	8.03	11.34	1.72	2.07	3.64	2.66	63.11
2004	1.36	4.52	1.26	1.84	3.33	5.32	4.74	3.19	11.12	0.89	3.65	6.48	47.70
2005	1.47	3.16	5.79	3.41	3.92	9.99	8.85	3.66	0.16	4.12	3.79	4.82	53.14
2006	3.81	1.19	1.34	3.60	1.22	5.18	2.52	6.48	3.96	4.58	3.58	4.34	41.80
2007	4.67	2.42	3.70	1.82	1.56	3.21	2.99	1.78	1.31	1.58	0.89	5.15	31.08
2008	2.28	3.83	4.34	4.11	1.88								
Avg Since 1950	**4.00**	**4.14**	**5.25**	**3.82**	**3.79**	**4.19**	**4.76**	**4.20**	**4.04**	**3.52**	**3.33**	**4.05**	**49.18**

All values in inches

From: NOAA Website, MONTHLY PRECIPITATION GREENVILLE-SPARTANBURG AREA 1893 - Present
http://www.erh.noaa.gov/gsp/climate/gsppcp.htm Last Accessed 8/15/2008


PRECIPITATION DATA
Greenville-Spartanburg Area
(1982-2005, Approximate Period of No Dewatering)
(see data on Page 7)
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
Precipitation (PPT, Inches)
1982
1987
1992
1997
2002
Year
49.18
PPT Total
Avg PPT

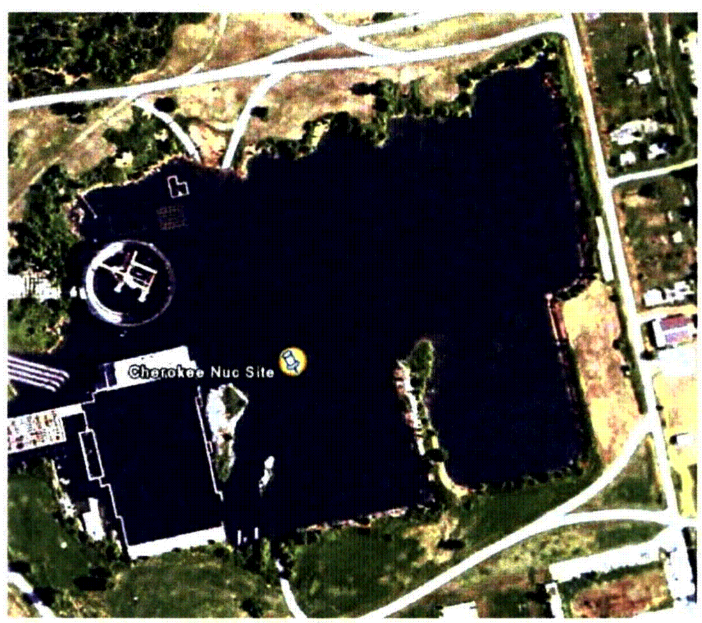
Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.04.12-006

Aerial Photographs from February 1994 and February 2005

1994 Aerial Photograph:
Water stage elevation appears lower than that shown on 2005 aerial. Based on topographic map the water lever appears to be around 574 ft. msl.

2005 Aerial Photograph:
Water stage elevation is approximately 579 ft. msl based on the comparison with topographic map discussed above



Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-007

NRC RAI:

Figure 2.4.12-202 shows the radius of influence of Cherokee construction dewatering. Specify which years of groundwater data were used to establish this zone. Identify the location of the [ ]^{SRI} well. If it is not in the figure, describe in the text where it is located (distance and direction) relative to the excavation. Identify the maximum depth of the [ ]^{SRI} well, the screened zone interval, and the geologic condition of the screened zone.

Duke Energy Response:

Data from 1976-1985, the time of the Cherokee Nuclear Station dewatering event, were used to develop Figure 2.4.12-202; these data are included in Attachment 2. Revisions to FSAR Subsection 2.4.12.2.2 are provided in Attachment 1. These text revisions are proposed to clarify the discussion of the [ ]^{SRI} well pertaining to the Cherokee construction dewatering. The identified changes will be incorporated in a future revision of the Final Safety Analysis Report.

The [ ]^{SRI} well is shown on Figure 2.4.12-202 (Attachment 3), and is located approximately 5,000 ft south of the center of the excavation on the north side of McKowns Mountain Rd. Drilling records are not available for this well. In the Piedmont, virtually all materials above the continuous bedrock, including partially weathered rock (PWR), saprolite, residual soil, and fill materials, where encountered, are porous and permeable. There were no confining beds within the Piedmont aquifer to vertically separate zones from each other. Thus, it is anticipated that the [ ]^{SRI} well produces water from zones similar to those across the WLS site. The lowest recorded water level for the [ ]^{SRI} well indicates that the well was at least 80 ft deep, but the completion depth, as well as the screened interval for this well was not available.

Associated Revisions to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.4.12.2.2

FSAR Figure 2.4.12-202

Attachments:

1) Revised FSAR Subsection 2.4.12.2.2
2) Duke Power Company, "Table 2B-6 – Groundwater Levels in Offsite Observation Wells," In *Project 81 Preliminary Safety Analysis Report*, Volume IV, Appendix 2B, Groundwater Hydrology-Cherokee, no date
3) Revised FSAR Figure 2.4.12-202

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-007

Mark-up of Part 2 FSAR Subsection 2.4.12.2.2

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.2.2, fourth paragraph will be revised as follows:

Construction activities for the Cherokee Nuclear Station began in the late 1970s, resulting in significant alterations to on-site topography. Because of the relationship between topography and depth to water, changes to the potentiometric surface were monitored with a network of observation wells across the site. A review of historical data identified groundwater levels in observation wells prior to and during the construction. Based on water level data, construction dewatering from the site excavation was indicated around January 1977. Between November 1977 and March 1978, approximately 5.74 million gal. of water were reportedly pumped from the water table aquifer through dewatering wells over the 5-month period. These wells were pumped at average rates ranging from 38 to 65 gpm with well depths from 200 to 280 ft. below ground surface. The effect of construction dewatering was assessed on the basis of historical groundwater measurements collected across the site and in the nearest residential well during construction dewatering activities. The apparent drawdown in the observation wells, caused by the cumulative dewatering activities, is shown on Figure 2.4.12-202. The dewatering activities did not affect observation wells outside the area shown. In addition, the nearest residential well, the [ ][SRI] well was not affected by construction dewatering activities (References 215 and 218). The [ ][SRI] well is completed in the Piedmont Aquifer and is located approximately 5000 ft. south of the center of the excavation on the north side of McKowns Mountain Road. ~~Five~~Several wells located ~~on-site and adjacent to the site~~adjacent to the excavation, around the site, and at a nearby residence (the [ ][SRI] well) were gauged on a monthly basis between 1976 and 1985, providing limited-term historical water level data. Only observation wells nearest the excavation, as shown in Figure 2.4.12-202, appeared to be affected by the Cherokee site dewatering activities. ~~No distinct trends were observed from groundwater observation data collected between 1976 and 1985, except for the dewatering activities discussed above.~~

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.04.12-007

Duke Power Company

Table 2B-6 – Groundwater Levels in Offsite Observation Wells

***Project 81 Preliminary Safety Analysis Report*, Volume IV, Appendix 2B, Groundwater Hydrology-Cherokee, no date**

2B GROUNDWATER HYDROLOGY – CHEROKEE

PROJECT 81
PRELIMINARY SAFETY ANALYSIS REPORT
VOLUME IV
1 OF 2
(One section out of volume IV)

✓ wells monitored beyond mid 1975

Enclosure No. 7
Duke Letter Dated: December 11, 2008

TABLE 2B-6
GROUNDWATER LEVELS
IN OFFSITE OBSERVATION WELLS
CHEROKEE NUCLEAR STATION

BORING NUMBER	GROUND SURFACE ELEVATION	WATER SURFACE ELEVATION	DATE MEASURED
BW-1	646.4	599	10-2-73
BW-2	621.5	597	10-2-73
BW-3	556.3	531	10-23-73
BW-4	578.7	550	10-23-73
BW-5	572.8	553	10-23-73
BW-6	606.9	558	10-23-73
BW-7	605.9	565	10-23-73
✓ BW-8	622.5	575	10-23-73
BW-9	624.5	567	10-23-73
BW-10	599.5	566	10-23-73
BW-11	573.9	546	10-23-73
2 ✓ BW-12	586.1	556	10-23-73
BW-13	546.0	541	10-23-73
✓ BW-14	584.8	545	10-23-73
BW-15	551.0	545	10-23-73
BW-16	569.5	543	10-23-73
BW-17	585.3	555	10-23-73
BW-18	574	524	11-9-73
BW-19	672	628	11-9-73
BW-20	578	527	11-16-73

Enclosure No. 7
Duke Letter Dated: December 11, 2008

TABLE 2B-6 (CONT'D.)
GROUNDWATER LEVELS
IN OFFSITE OBSERVATION WELLS
CHEROKEE NUCLEAR STATION

BORING NUMBER	GROUND SURFACE ELEVATION	WATER SURFACE ELEVATION	DATE MEASURED
BW-21	676	639	11-9-73
BW-22	684	635	11-9-73
BW-23	664	633	11-9-73
BW-24	634	574	12-6-73
BW-25	607	562	11-9-73
BW-26	587	552	11-9-73
BW-27	586	546	11-9-73
BW-28	619	584	11-9-73
BW-29	667	641	11-9-73
BW-30	657	633	11-9-73
BW-31	634	586	11-9-73
BW-32	605	558	11-9-73
BW-33	629	588	11-9-73
BW-34	587	577	11-9-73
BW-35	559	521	12-14-73
BW-36	567	517	12-14-73
BW-37	622	572	12-6-73
BW-38	640	603	12-6-73

2

Enclosure No. 7
Duke Letter Dated: December 11, 2008

Withheld From Public Disclosure Under 10 CFR 2.390(a)(6) and 2.390(a)(9)

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

Location of Observation Wells

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.04.12-007

Revised Part 2 FSAR Figure 2.4.12-202

Enclosure No. 7
Duke Letter Dated: December 11, 2008

Withheld From Public Disclosure Under 10 CFR 2.390(a)(6) and 2.390(a)(9)

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

Radius of Influence of Cherokee
Nuclear Site Construction Dewatering

FIGURE 2.4.12-202 Rev 1

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-008

NRC RAI:

Explain how Figure 2.4.12-204 (sheet 8), was produced. Because there are no groundwater level data for conditions uninfluenced by dewatering, there is significant uncertainty regarding the exact nature of the future groundwater surface. Therefore, identify alternative conceptual models of the future groundwater surface that bracket the possible worst case conditions that would cause flow to proceed in at least four directions: north to Holdup Pond A and the river; east to Makeup Pond A and the river; west to Holdup Pond B, its dam, and the river; and due north of Unit 1 toward the river (along a path to the west of Holdup Pond A. Identify the groundwater transport pathway for each combination of flow direction and Unit and calculate the groundwater gradient, velocity, and travel time. If the future groundwater surface is to be managed, such as through the use of surface features, monitoring, and conduits, explain how such management will occur and what the goals of such management will be.

Duke Energy Response:

Figure 2.4.12-204, Sheet 8 was produced by projecting post-dewatering water table elevations based upon knowledge of the current water table and the 1973 water table. The water table elevations are projected to generally conform to the surface topography and reflect a north-south trending groundwater divide historically located west of the reactor area and east of Make-Up Pond B. As discussed in Subsection 2.4.12.2.2, initial potentiometric surface data collected from 1973, prior to construction activities, indicated site-specific groundwater flows were primarily to the north and east from the reactor area, which generally mimicked the preconstruction site topography (Figure 2.4.12-201). Additional discussion on the groundwater divides is provided in the RAI 02.04.12-014 response (this letter). A new FSAR figure (Figure 2.4.12-208) has been added to show the five alternate groundwater flow paths analyzed for the projected water table. This flow path evaluation is presented in the RAI 02.04.12-001 response (this letter). The pathways were evaluated to determine the most conservative travel pathway from potential points of release to exposure points (i.e., the fastest travel time between these points) based on hydrogeologic conditions. These groundwater transport pathways and estimated travel times are:

Pathway Number	Route	Distance (ft)	Velocity (ft/yr)	Time (years)	Gradient (ft/ft)
1	Unit 2 to Hold-Up Pond A	1250	173.6	7.2	0.040
2	Unit 2 to Broad River	1935	691.1	2.8	0.038
3	Unit 2 to Make-Up Pond A	1950	84.8	23	0.019
4	Unit 1 to Non-Jurisdictional Wetland Area	1110	20.9	53	0.013
5	Unit 1 to Make-Up Pond B	1630	166.3	9.8	0.009

The groundwater flow pathway from Unit 1 to the Make-Up Pond B dam is similar to Pathway #4, and the pathway due north of Unit 1 toward the river (along a path to the west of Hold-Up Pond A) is similar to Pathway # 2. The distances for these similar pathways are longer than the distances for Pathway # 2 and Pathway # 4, respectively. The longer distances result in longer travel times given similar subsurface conditions. Therefore, Pathway # 2 and Pathway #4 are expected to conservatively represent the alternative groundwater pathways for these groundwater flow directions.

Plans for storm water management include removal of existing drain lines that run north from the power block to Hold-Up Pond A at depths that intercept the water table and installation of ditches to divert storm water away from the Lee Nuclear Station (FSAR Subsection 2.4.12.2.3). The planned features are shallow enough that they should not interfere with groundwater flow. The groundwater surface may actually be lower than what has been projected due to less infiltration after completion of the Lee Nuclear Station.

FSAR Subsection 2.4.12.2.3 is revised by this RAI response to augment the discussion on groundwater pathways. The identified changes will be incorporated in a future revision of the Final Safety Analysis Report.

Associated Revisions to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.4.12.2.3

FSAR Subsections 2.4.12.3.1 and 2.4.12.3.2 as shown in response to FSAR RAI 02.04.12-001, Attachment 1 (this letter)

FSAR Subsections 2.4.12.2.3 and 2.4.12.5 as shown in response to FSAR RAI 02.04.12-006, Attachment 1 (this letter)

Attachment:

1) Revision to FSAR Subsection 2.4.12.2.3

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-008

Revision to FSAR Subsection 2.4.12.2.3

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.2.3, fourth paragraph, will be revised as follows:

Potentiometric surface maps developed from water level data showed that during the recent construction dewatering and site investigation, groundwater surrounding the excavation is drawn toward the excavation as shown on the potentiometric surface maps (Figure 2.4.12-204, Sheets 1 - 7). During the dewatering activities, continuous decline of water levels in areas downgradient of the excavation was observed, as recharge entering the power block area from the south was intercepted by the excavation and discharged to Make-Up Pond B. ~~Following the completion of construction dewatering, the potentiometric surface beneath the reactor buildings is expected to rebound to equilibrium conditions.~~

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.2.3, add the following paragraphs to the end of this subsection immediately following the paragraphs inserted by Attachment 1 of RAI 02.04.12-006 (this letter):

Based on site observations, a network of storm drains and buried piping was partially installed during the Cherokee project to manage surface water runoff. While no as-built drawings for the existing storm drain system for the former Cherokee Nuclear Station exist, a review of stormwater plans was conducted to assess the drain system's potential affect on groundwater movement. Storm drains located upgradient (south) of the excavation appear to intercept the water table and allow movement of water toward the make-up ponds. Other storm drains appear to be above the water table and would not affect the movement of groundwater. One exception is a storm drain originally designed to transfer stormwater from the Cherokee power block area to Hold-Up Pond A. The depth of this storm drain pipe appears to be below the projected water table and, thus, if left as is could locally affect groundwater movement when groundwater recovers from the dewatering. The potential effect on groundwater movement can be mitigated by engineering controls or by removal and replacement with less permeable materials.

The Lee Nuclear Station stormwater drainage system (DRS) is designed to facilitate and control the runoff of precipitation along surface water flow paths, diverting surface runoff away from the power block area and reducing the potential for flooding. The site grading and drainage plan is shown in Figure 2.4.2-202. The site is relatively flat; however, the site is graded such that overall runoff will drain away from safety-related structures to Make-Up Pond B, Make-Up Pond A, or directly to the Broad River. The DRS is not expected to alter the preferential groundwater flow pathway.

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number(s): 02.04.12-009

NRC RAI:

Update the Figure 2.4.12-201 to include an outline of the Lee Nuclear Island (for reference purposes) and the locations of springs and seeps. Differentiate between the springs and seeps that existed before the original Cherokee construction and the current springs and seeps.

Duke Energy Response:

Duke Energy has prepared a figure showing the locations of current springs and seeps and those observed during the original Cherokee construction. The power block is included on this figure for reference, overlaid on the existing FSAR Figure 2.4.12-201. This figure is provided for NRC's use and will not result in a change to the Final Safety Analysis Report.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

None

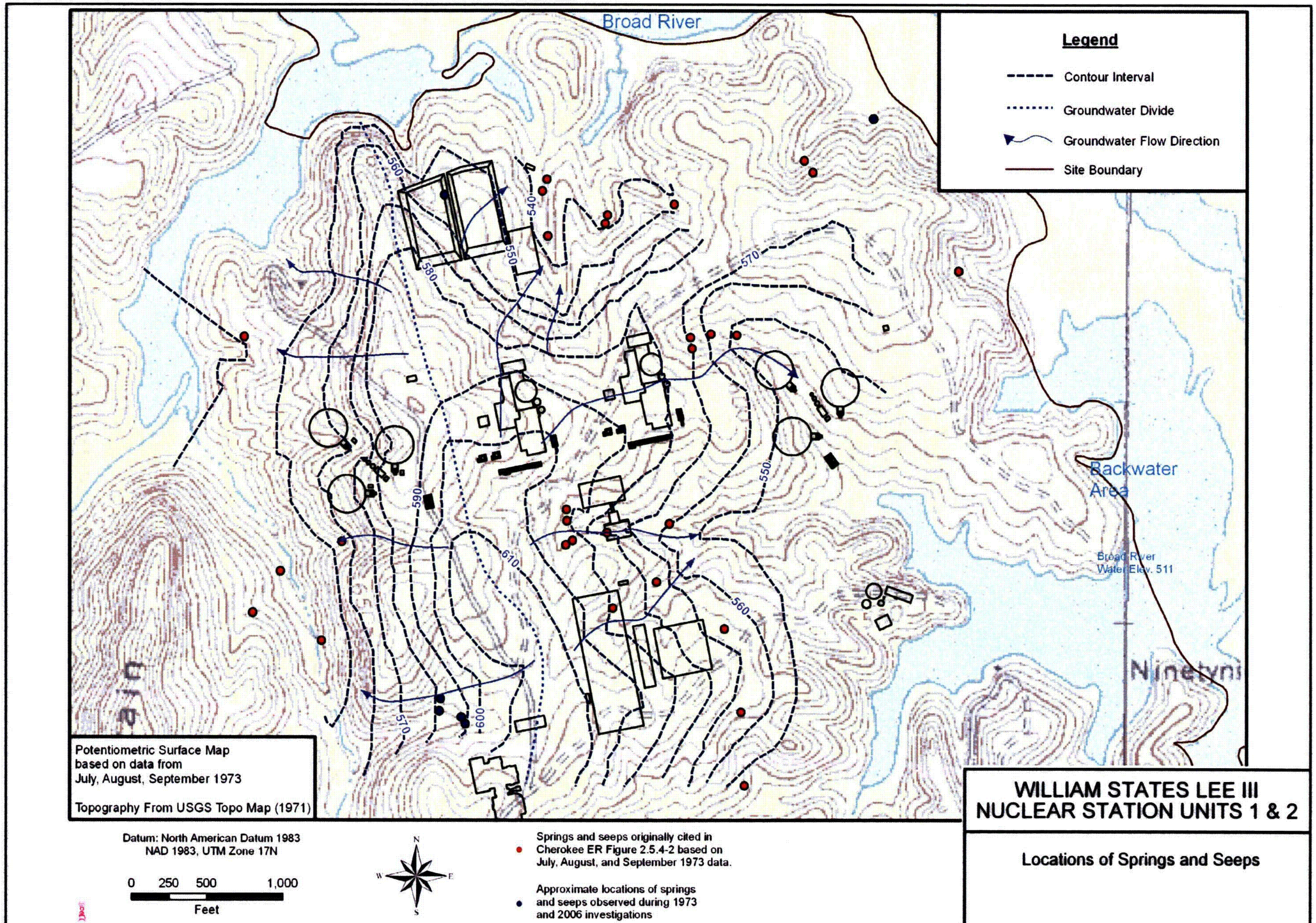
Attachment:

1) Figure - Locations of Springs and Seeps

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-009

Figure - Locations of Springs and Seeps



WILLIAM STATES LEE III NUCLEAR STATION UNITS 1 & 2

Locations of Springs and Seeps

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-010

NRC RAI:

FSAR Figure 2.4.12-207 displays conductivity data as a function of depth. The figure combines data from two separate time periods (1970s and 2006) that have distinctly different surface elevations (and thus different depths) because of the geoengineering of the site. Describe how the depth data have been adjusted or rectified to reflect the correct elevation in the figure for the conductivity data points. Explain any added "noise" and "bias" to the K versus depth comparison caused by the depth differences.

Duke Energy Response:

The data from 1970 and 2006 were not modified to adjust for changes between pre-Cherokee construction era elevations and the current elevations, but it is recognized that the 2006 data and 1970s data do not share a constant datum (i.e., 1970s surface grade elevations do not equal the 2006 surface grade elevations). The upper ranges of 2006 hydraulic conductivity (K) data are consistent with the upper ranges of 1970s K values relative to lithology (e.g., higher values of K values determined in 2006 for partially weathered rock (PWR) were generally consistent with PWR K values determined in the 1970s and are in range of 1E-03 to 1E-02). While the depths of the samples collected in areas of cut and fill have changed, the soil and rock characteristics have not. Therefore, the depth changes add "noise" to Figure 2.4.12-207. Separating the 1970s and 2006 data sets allowed independent comparisons of K versus depth (Attachment 2). Both comparisons showed the hydraulic conductivities decrease with depth as PWR transitions to continuous rock.

Potential "bias" in the 2006 K data may exist because one goal of the groundwater investigation was to identify preferential flow paths. Using Cherokee investigation data, an attempt was made to explore for areas with relatively higher Ks than those in other areas of the site. This exploration approach would potentially bias the 2006 results to higher K values than the 1970s K values. A revision of the Final Safety Analysis Report Subsection 2.4.12.2.4.2 text is provided as Attachment 1 to clarify the discussion of hydraulic conductivity. The identified changes will be incorporated in a future revision of the Final Safety Analysis Report.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.4.12.2.4.2

Attachments:

1) Revision to FSAR Subsection 2.4.12.2.4.2
2) Hydraulic Conductivity (K) vs Depth for 1970s and 2006 Data Sets

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-010

Revision to FSAR Subsection 2.4.12.2.4.2

COLA Part 2, FSAR Chapter 2, Subsection 2.4.12.2.4.2, will be revised as follows:

During the Cherokee investigation in the early 1970's, 135 field and laboratory tests were conducted to characterize soil and rock permeability. Fifty-five packer tests were conducted in soil and rock intervals in 17 soil borings across the site. An additional 42 field and 38 laboratory tests were performed to evaluate soil permeability. The recent investigation supplements the above investigation with the performance of an additional 11 packer tests in bedrock materials, 16 slug-out tests across the site, and one multiwell aquifer pump test performed within the groundwater preferential flow path from the nuclear island area toward the Broad River to the north. ~~A summary of the various test results is presented in Table 2.4.12-204 and Figure 2.4.12-207.~~

Based on results from the 1973 investigation, packer tests, multiwell pumping tests, geotechnical laboratory analyses, and field tests (combined with the results of the 2006 slug tests, packer tests, and multiwell pumping tests), the following conclusions are made regarding aquifer permeability at the Lee Nuclear Site, noting that maintenance dewatering is ongoing and may have affected the recent aquifer test results:

- Reported vertical soil hydraulic conductivit~~y~~ies (Kv) of soil and saprolite ranges from 2.45 x 10^{-8} cm/s to a maximum value of 2.55 x 10^{-4} cm/s ~~and exhibits a geometric mean of 2.91 x 10^{-6} cm/s and~~ with a median of 2.10 x 10^{-6} cm/s. For samples exceeding the median hydraulic conductivity of the data set, the geometric mean (4.4 x 10^{-5} cm/s) represents a conservative vertical hydraulic conductivity value for the residuum. For the purpose of permeability analysis, a conservative value is one that increases the rate of water movement. Vertical hydraulic conductivity generally increases with depth.
- Reported horizontal hydraulic conductivities~~y~~ (Kh) of soil and saprolite ranges from 9.67 x 10^{-7} cm/s (i.e., the lower limit of the test range) to a maximum value of 2.26 x 10^{-3} cm/s with ~~a geometric mean of 5.52 x 10^{-5} cm/s and~~ a median of 6.38 x 10^{-5} cm/s. For samples exceeding the median hydraulic conductivity of the data set, the geometric mean (3.2 x 10^{-4} cm/s) represents a conservative hydraulic conductivity value for the residuum.
- Reported hydraulic conductivities measured in the partially weathered rock (PWR), or transition zone, range from approximately 9.67 x 10^{-7} cm/s to a maximum value of 9.89 x 10^{-3} cm/s with ~~a geometric mean value of 9.36 x 10^{-5} cm/s and~~ a median of 1.54 x 10^{-4} cm/s. For samples exceeding the median hydraulic conductivity of the data set, the geometric mean (1.0 x 10^{-3} cm/s) represents a conservative hydraulic conductivity value for the transition zone at the top of the weathered rock for samples collected across the site. A value of 1.4 x 10^{-3} cm/s was obtained from aquifer tests in 2006 for an area believed to best represent the preferential groundwater flow path, and is used for the Kh for PWR. Figure 2.4.12-207 includes three PWR samples that were subsequently excavated in the area of the reactors. ~~Higher hydraulic conductivities are generally reported in moderately hard, closely-jointed felsic gneiss with weathered zones, with the highest hydraulic conductivities observed in intervals of metaquartzd iorite.~~
- Reported hydraulic conductivities representing the upper 100 ft. of the unconsolidated saturated interval comprised of ~~fill material,~~ residual soil, saprolite, and partially weathered rock range from 2.21 x 10^{-4} cm/s to 3.90 x 10^{-3} cm/s with ~~a geometric mean of 8.61 x 10^{-4} cm/s and~~ a median hydraulic conductivity for the unconsolidated material of

4.10 x 10^{-4} cm/s. For samples exceeding the median hydraulic conductivity of the data set, the geometric mean (2.6 x 10^{-3} cm/s) represents a conservative hydraulic conductivity value for the unconsolidated materials.

- Fill materials placed in former valleys during site grading are currently groundwater aquifer materials in some areas. Slug tests conducted in 2006 and 2007 characterized these materials to have hydraulic conductivities ranging from 4.22 x 10^{-5} cm/s to 1.03 x 10^{-3} cm/s. The ~~geometric mean is 2.26 x 10^{-4} cm/s, and the~~ median hydraulic conductivity for the fill material is 1.81 x 10^{-4} cm/s. For samples equal to and greater than the median hydraulic conductivity of the data set, the geometric mean (6.2 x 10^{-4} cm/s) represents a conservative hydraulic conductivity value for the fill materials.

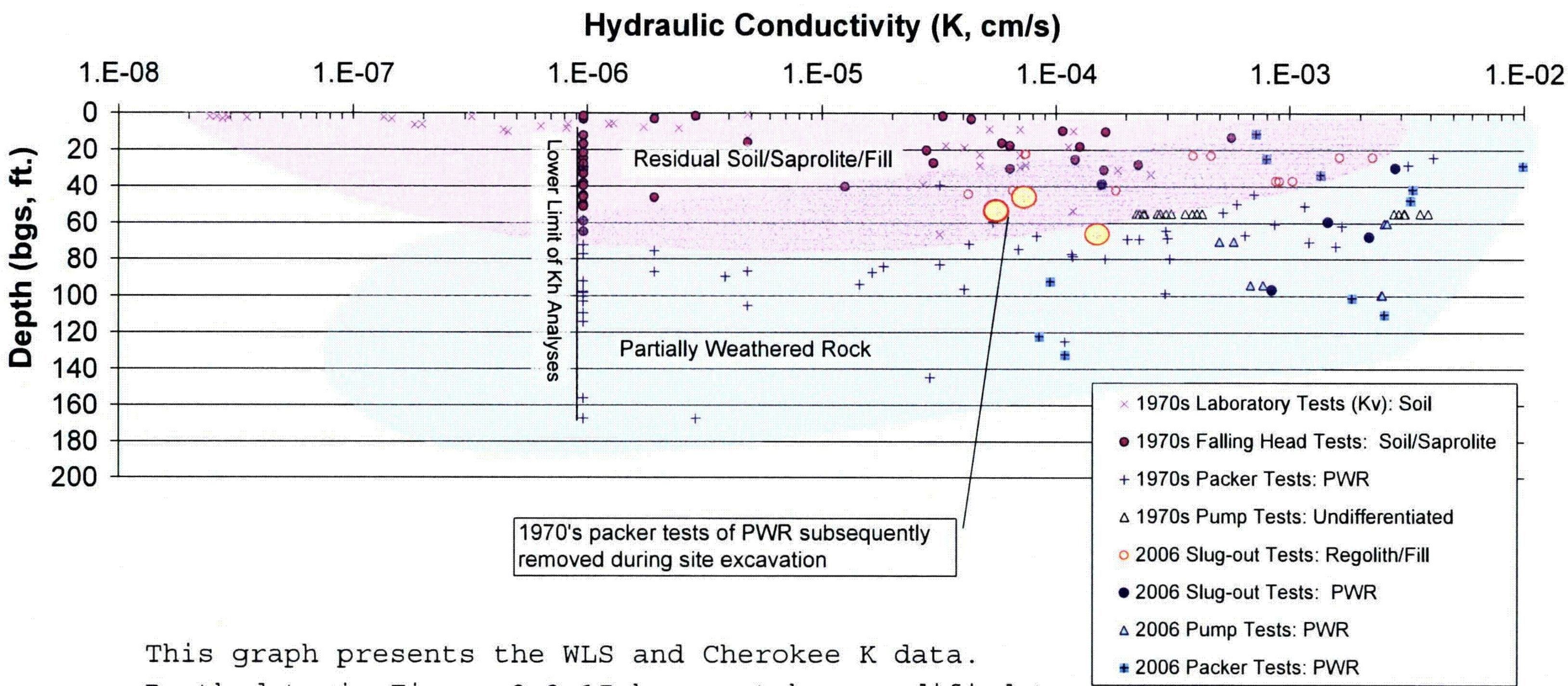
A summary of the various test results is presented in Table 2.4.12-204. Figure 2.4.12-207 depicts the distribution of hydraulic conductivities with depth. This figure shows the wide variability of hydraulic conductivities observed across the site during both the Cherokee and Lee site investigations. Hydraulic conductivities generally decrease with depth as partially weathered rock transitions to continuous rock. Figure 2.4.12-207 includes the results for partially weathered rock samples that were subsequently removed during excavation for the Cherokee Nuclear Station reactor buildings.

Lee Nuclear Station Response to Request for Additional Information (RAI)

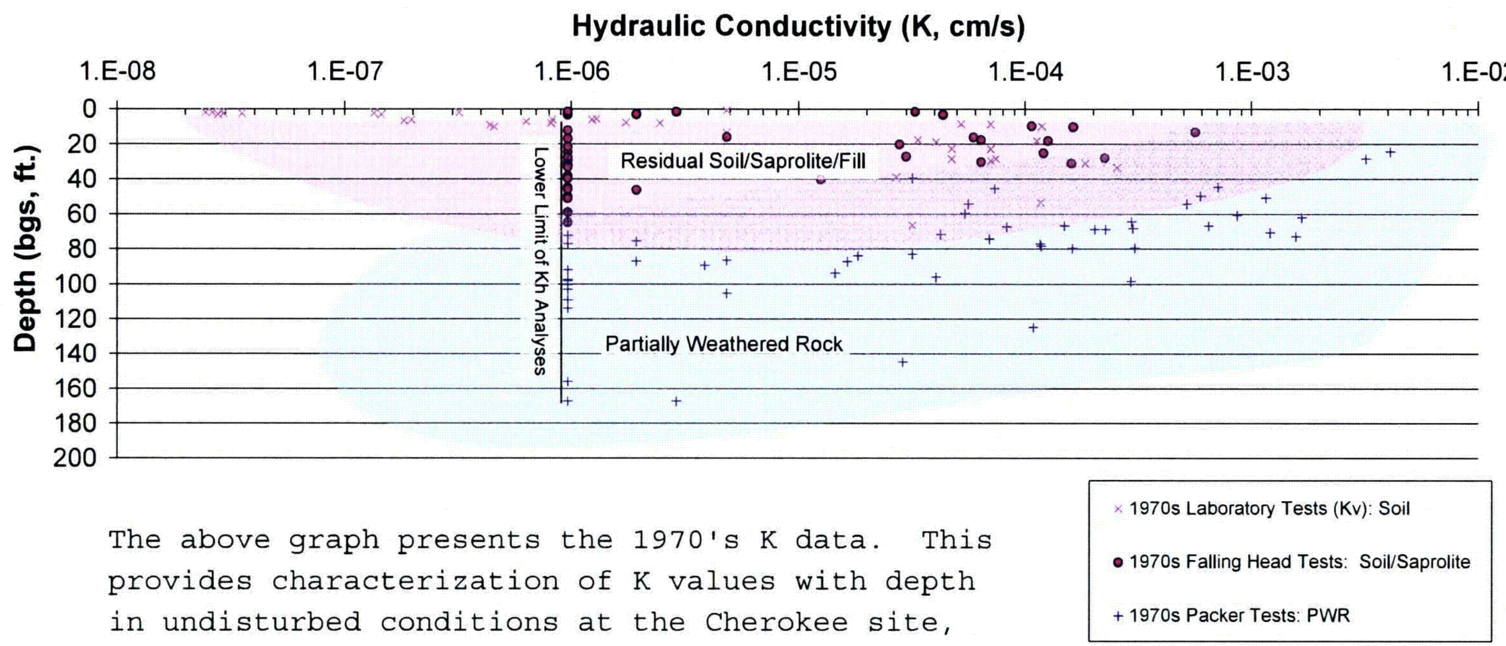
Attachment 2 to RAI 02.04.12-010

K vs Depth for 1970s and 2006 Data Sets

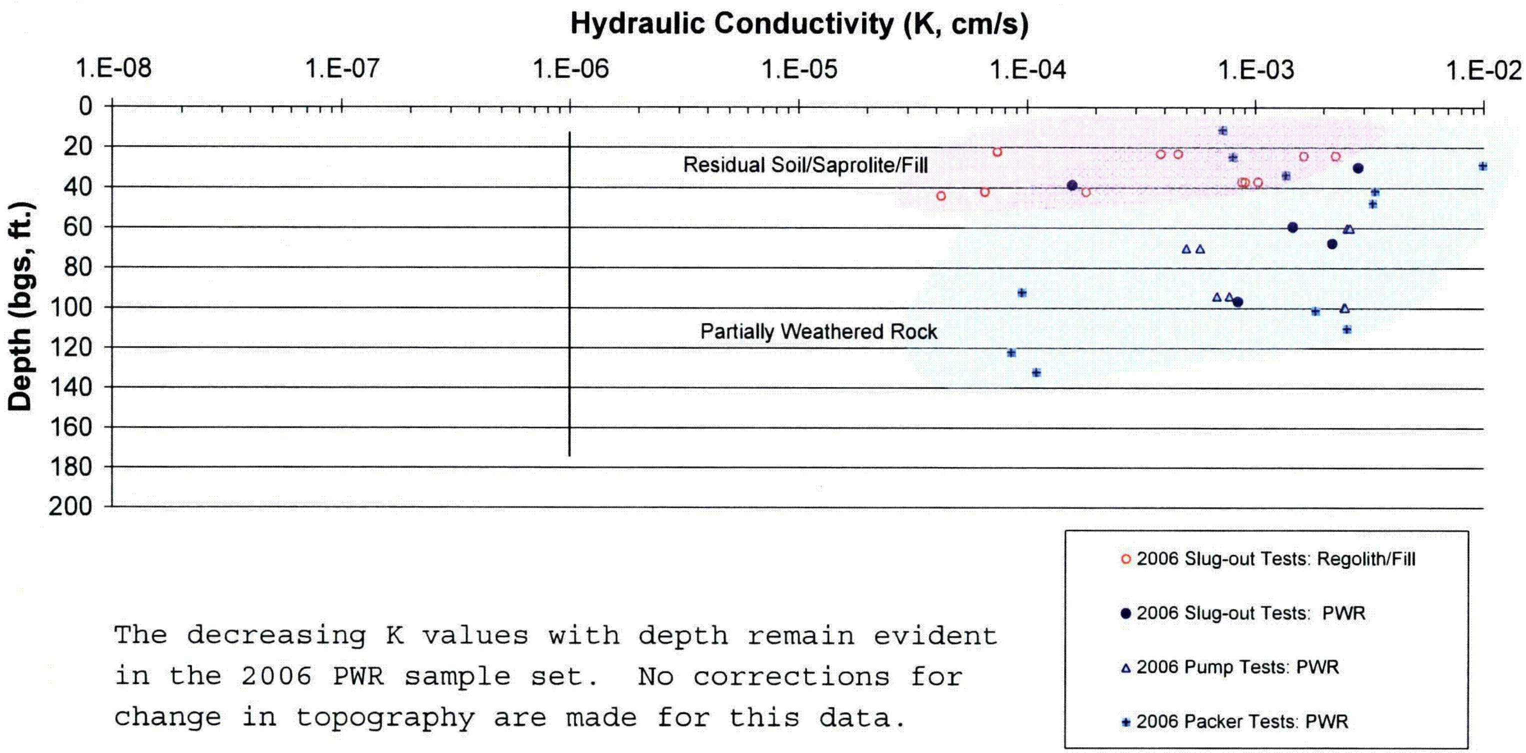
Enclosure No. 10
Duke Letter dated: December 11, 2008



This graph presents the WLS and Cherokee K data. Depth data in Figure 2.3-17 have not been modified to adjust for changes between pre-Cherokee construction era depths and the current depths. Areas of cut would result in a 2006 K value appearing shallower than the same location in the 1970's. Similarly, a 2006 fill area sample would yield an apparently deeper K value than a 1970's sample. 2006 data was collected to verify the findings of the Cherokee investigation,and both data sets support the apparent decrease in K with increasing depth for partially weathered rock (see Pages 2 and 3 of RAI-10-1). Depth is measured in feet below ground surface (bgs).



The above graph presents the 1970's K data. This provides characterization of K values with depth in undisturbed conditions at the Cherokee site, prior to construction activities.



The decreasing K values with depth remain evident in the 2006 PWR sample set. No corrections for change in topography are made for this data.

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number(s): 02.04.12-011

NRC RAI:

Provide a discussion of the post-operational monitoring plan. Include in that discussion how the plan will be designed to reduce uncertainties in the groundwater flow paths used for Section 2.4.13 of the FSAR.

Duke Energy Response:

Duke Energy will implement the Radiological Groundwater Protection Initiative (RGP Initiative), currently implemented at Duke's other three nuclear stations, upon completion of construction. Additional information concerning the RGP Initiative is contained in the answer to 2.4.12-014. The well network that will be installed will consist of wells whose location and depths will be selected to ensure that groundwater conditions are appropriately monitored and potential contaminants are detected. The network will include near-field and far-field wells. The placement of wells will allow monitoring within the preferential groundwater flow path and plausible conceptual pathways. The development of conceptual model is discussed in RAI 02.04.12-001 (this letter). To reduce the uncertainties in the projected groundwater flow paths, evaluation of well data, particularly analysis of water elevation data used to refine the potentiometric surface maps, will be performed intermittently as part of the groundwater monitoring program. Periodic chemical and radiological monitoring will be conducted in accordance with station procedures.

The post construction water monitoring program is summarized in FSAR 12AA.5.4.13 "Groundwater Monitoring Program." The groundwater monitoring program will be established prior to plant startup.

FSAR Subsection 2.4.12.4 is revised by this RAI response to augment the discussion on groundwater monitoring. The identified changes will be incorporated in a future revision of the Final Safety Analysis Report.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.4.12.4

Attachment:

1) Revision to FSAR Subsection 2.4.12.4

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 2.4.12-011

Revision to FSAR Subsection 2.4.12.4

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.4, will be revised as follows:

2.4.12.4 Monitoring or Safeguard Requirements

There are two potential sources for radiological impacts to groundwater: (1) leaks from radioactive waste tanks and (2) leaks from the spent fuel pool. To minimize the potential for contact of radioactive material with groundwater, the Lee Nuclear Site is equipped with a water barrier around the building foundation up to 1 ft. above grade. The water barrier is installed to prevent water from seeping into the auxiliary building that holds the liquid radioactive waste (LRW) tanks. In addition, groundwater monitoring will be conducted at the Lee Nuclear Site. The groundwater monitoring program will be consistent with the guidance in "Generic FSAR Template Guidance for Life Cycle Minimization of Contamination" (NEI 08-08). The groundwater monitoring program will include a network of wells for early detection (near-field wells) and for verification of no off-site migration (far-field wells). Wells will be installed in proximity to plant systems that may be a source of radiological releases, and/or in nearby plausible down-gradient flow direction from such sources. Both shallow and deep wells will be utilized as needed to monitor the location closest to the potential release area. The laboratory analyses of groundwater samples will include gamma isotopes and tritium.

The ~~G~~groundwater monitoring program~~s~~ is~~are~~ described in Subsection 12AA.5.4.13. Accident effects are discussed in Subsection 2.4.13. Additionally, analysis of the relationship of the Lee Nuclear Site groundwater to seismicity and the potential for related soil liquefaction and the potential for undermining of safety-related structures is discussed in Section 2.5.

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017
NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-012

NRC RAI:

One potential groundwater flow pathway is along the top of the groundwater surface, particularly if the leaked solution is buoyant or neutrally buoyant. Under these conditions, flow would occur laterally through the fill to a point where it could exit directly into a surface water body or along one of the slopes above the water bodies. If this scenario is not valid, explain why. Otherwise, add this pathway(s) to the list of alternative pathways to be considered in Section 2.4.13.

Duke Energy Response:

Five alternative pathways have been evaluated and are shown in revised Subsection 2.4.12.3.2 as presented in the response to RAI 2.4.12-001 (this letter). These pathways include:

- Pathway 1: Unit 2 to Hold-Up Pond A through soil/saprolite (240 ft.) and fill (1010 ft.)
- Pathway 2: Unit 2 to the Broad River through partially weathered rock (PWR) (1935 ft.)
- Pathway 3: Unit 2 to Make-Up Pond A through soil/saprolite (390 ft.) and fill (1560 ft.)
- Pathway 4: Unit 1 to a non-jurisdictional wetland/ former spring through soil/saprolite (1110 ft.)
- Pathway 5: Unit 1 to Make-Up Pond B through PWR (1630 ft.).

Pathway 1, toward Hold-Up Pond A, is similar to the pathway described in NRC RAI 2.4.12-012 (above) and is the pathway for groundwater movement in the event the release exhibits buoyant characteristics. While this pathway has the closest point of exposure and greater hydraulic gradient, hydraulic conductivities of the soil/saprolite and fill material result in slower groundwater velocities than the preferential pathway (Pathway 2). Information on the gradient and velocities of each pathway is included in the response to RAI 2.4.12-008 (this letter).

While the release has the potential to exhibit some buoyant characteristics due to elevated temperatures of the effluent, dilution effects and heat dissipation are expected to neutralize temperature gradients relatively quickly compared to the travel time of the plume. Pathway 1 has a travel time of approximately 7.2 years. As presented in the revised Subsection 2.4.12.3.2, Pathway 2 is the most conservative pathway with the shortest travel time of approximately 2.8 years. Thus, Pathway 2, plume movement through PWR to the Broad River, remains the focus of Section 2.4.13.

Associated Revisions to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsections 2.4.12.3.1 and 2.4.12.3.2 as shown in FSAR RAI 02.04.12-001, Attachment 1

FSAR Subsections 2.4.12.2.3 as shown in FSAR RAI 02.04.12-008, Attachment 1

Attachment:

None

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017
NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-013

NRC RAI:

Figure 2.4.12-205 shows estimates of groundwater gradients (0.034 and 0.036) that are slightly different than values (0.033 and 0.035) calculated from the reported measurements (i.e., max groundwater elevation 579 ft; holdup pond A 535 ft; river 511 ft; distance to holdup pond A 1340 ft; distance to river 1935 ft). Confirm which values are correct.

Duke Energy Response:

The basis of the estimated groundwater gradients shown on Figure 2.4.12-205 (Sheet 3 of 4) changed following the submittal of the FSAR document. The estimated maximum groundwater elevation increased from 579 to 584 ft msl. The 579 ft msl elevation was based upon the surveyed elevation of the observed high water level mark (578.72 ft msl) on the Cherokee power block structures. The 584 ft msl is derived assuming water levels would be unlikely to exceed 5 ft. above the observed high water mark. In addition, flowpath distances were revised to reflect the shortest distance between the edges of the respective water bodies, rather than the respective center points. The resultant groundwater gradients allow for more conservative calculations of other hydraulic properties, such as groundwater travel time. The correct values are as follows:

- Groundwater gradient of 0.040 ft/ft for soil, saprolite, and fill material
- Groundwater gradient of 0.038 ft/ft for weathered rock
- Maximum groundwater elevation of 584 ft. msl
- Distance from Unit 2 to Hold-Up Pond A of 1250 ft.
- Distance from Unit 2 to the Broad River of 1935 ft.

The FSAR revisions to Subsection 2.4.12.3.2 in the response to RAI 02.04.12-001 (this letter), Subsection 2.4.12.5 in the response to RAI 02.04-006 (this letter), and Table 2.4.12-204 in the response to RAI 02.04.12-004 (this letter) reflect the corrected groundwater gradients. Attachment 1 contains a replacement for Figure 2.4.12-205 (Sheets 2, 3, and 4).

Associated Revisions to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.4.12.3.2 as shown in Attachment 1 to FSAR RAI 02.04.12-001 (this letter)

FSAR Subsection 2.4.12.5 as shown in Attachment 1 to FSAR RAI 02.04.12-006 (this letter)

FSAR Table 2.4.12-204 as shown in Attachment 2 to FSAR RAI 02.04.12-004 (this letter)

FSAR Figure 2.4.12-205 (Sheets 2, 3, and 4 of 4)

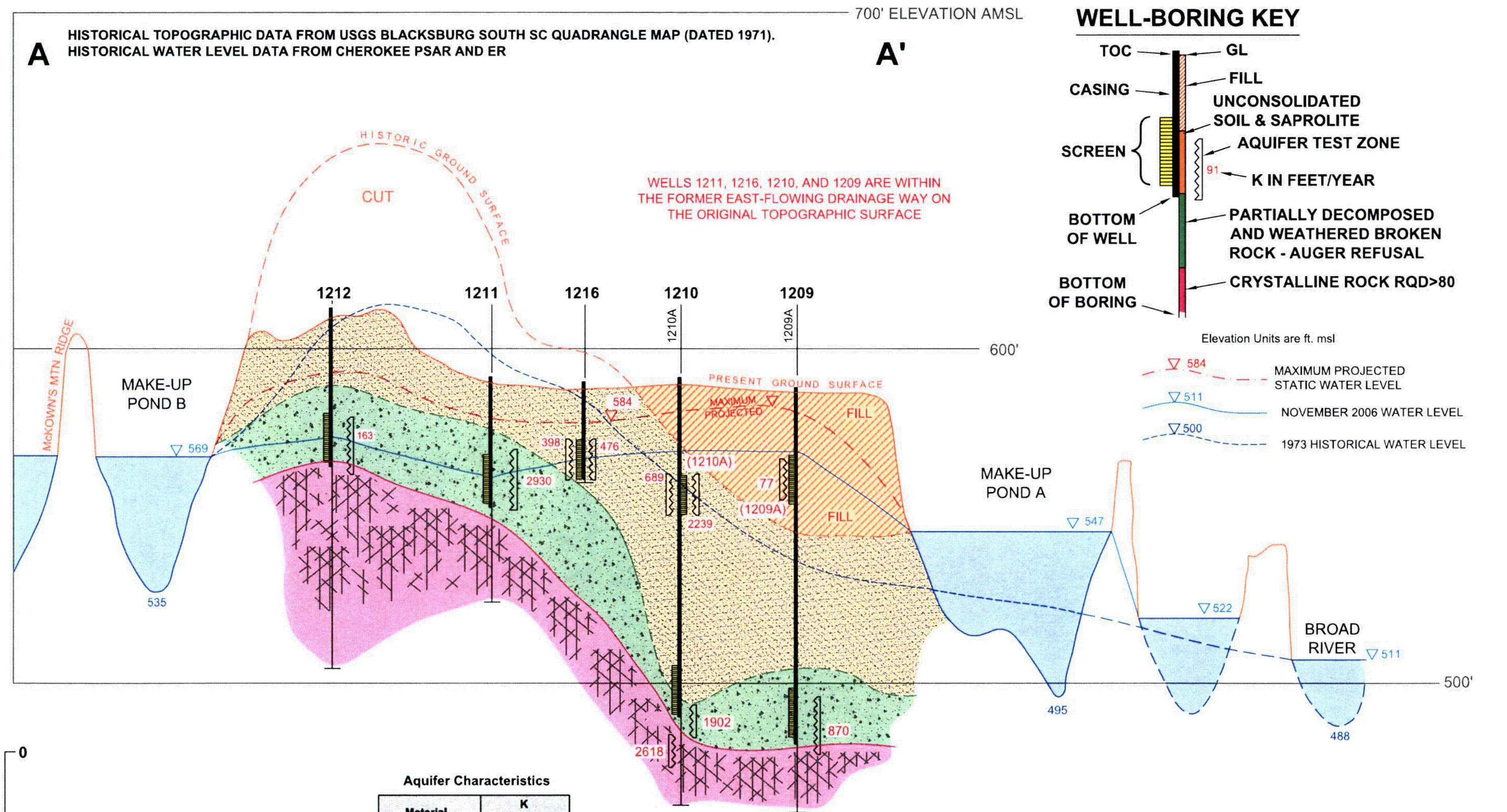
Attachments:

Replacement for Figure 2.4.12-205 (Sheets 2, 3, and 4 of 4)

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.04.12-013

Replacement for Figure 2.4.12-205 (Sheets 2, 3, and 4 of 4)



Aquifer Characteristics

	Material	K (cm/s)
	Fill Material	6.2×10^{-4}
	Soil and Saprolite	3.2×10^{-4}
	Partly Weathered Rock	1.4×10^{-3}

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

Cross Sections of Lee Nuclear Site:
A - A'

FIGURE 2.4.12-205
Sheet 2 of 4

Rev 1

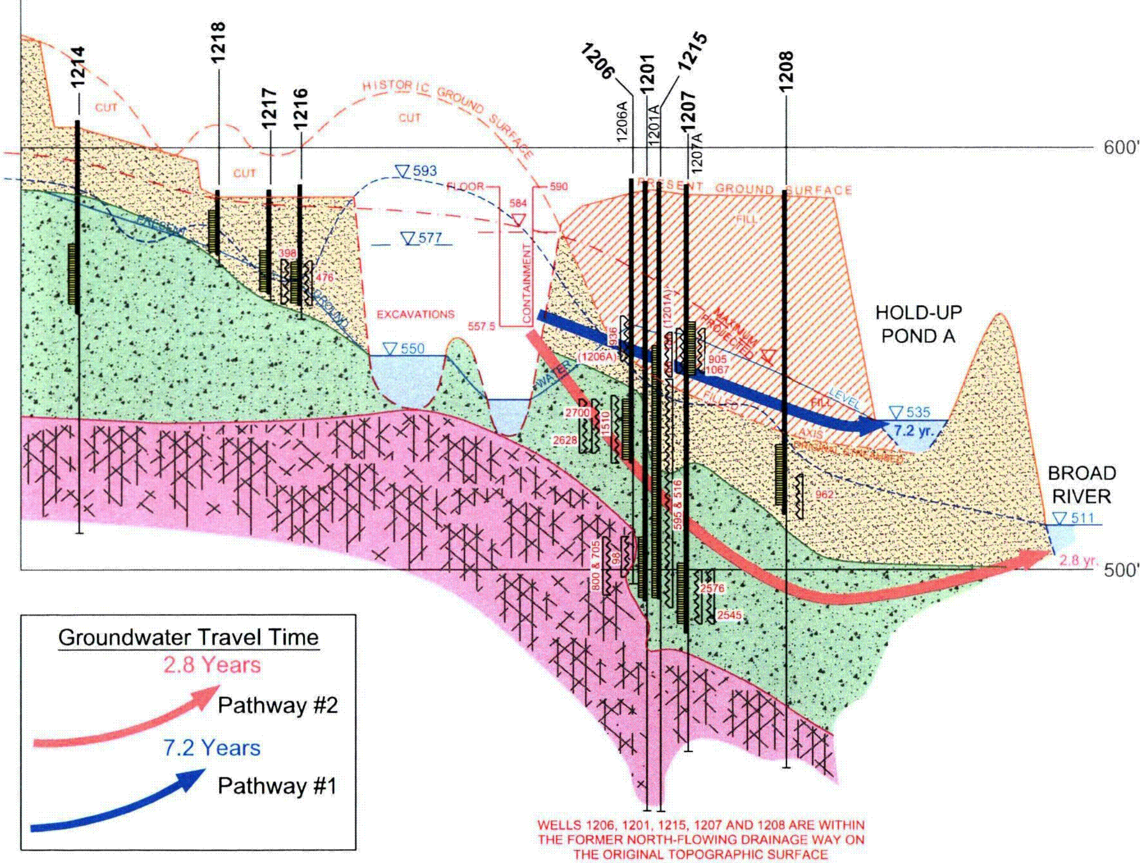
700' ELEVATION AMSL

B **B'**

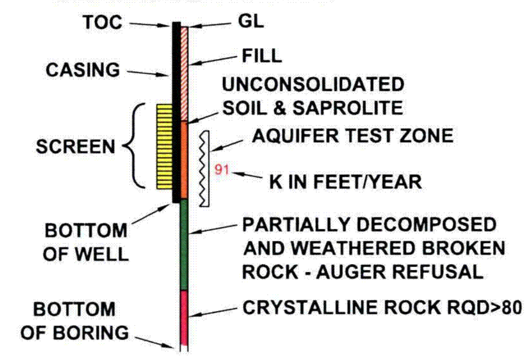
Aquifer Characteristics

Material	K (cm/s)	Effective Porosity	GW Gradient (ft/ft)	GW Velocity (ft/yr)	Time (yr) to Exposure Pt.
Fill Material	6.2×10^{-4}	9%	0.040	285	7.2
Soil and Saprolite	3.2×10^{-4}	20%	0.040	66	
Partially Weathered Rock	1.4×10^{-3}	8%	0.038	692	2.8

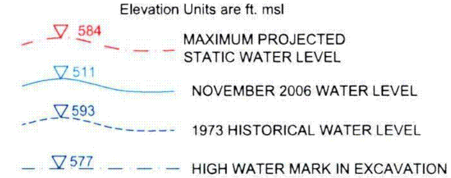
HISTORICAL TOPOGRAPHIC DATA FROM USGS BLACKSBURG SOUTH SC QUADRANGLE MAP (DATED 1971).
HISTORICAL WATER LEVEL DATA FROM CHEROKEE PSAR AND ER

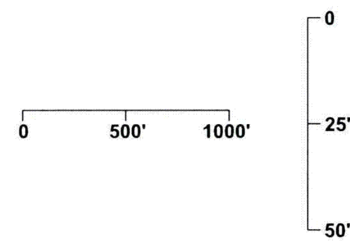


WELL-BORING KEY



Elevation Units are ft. msl





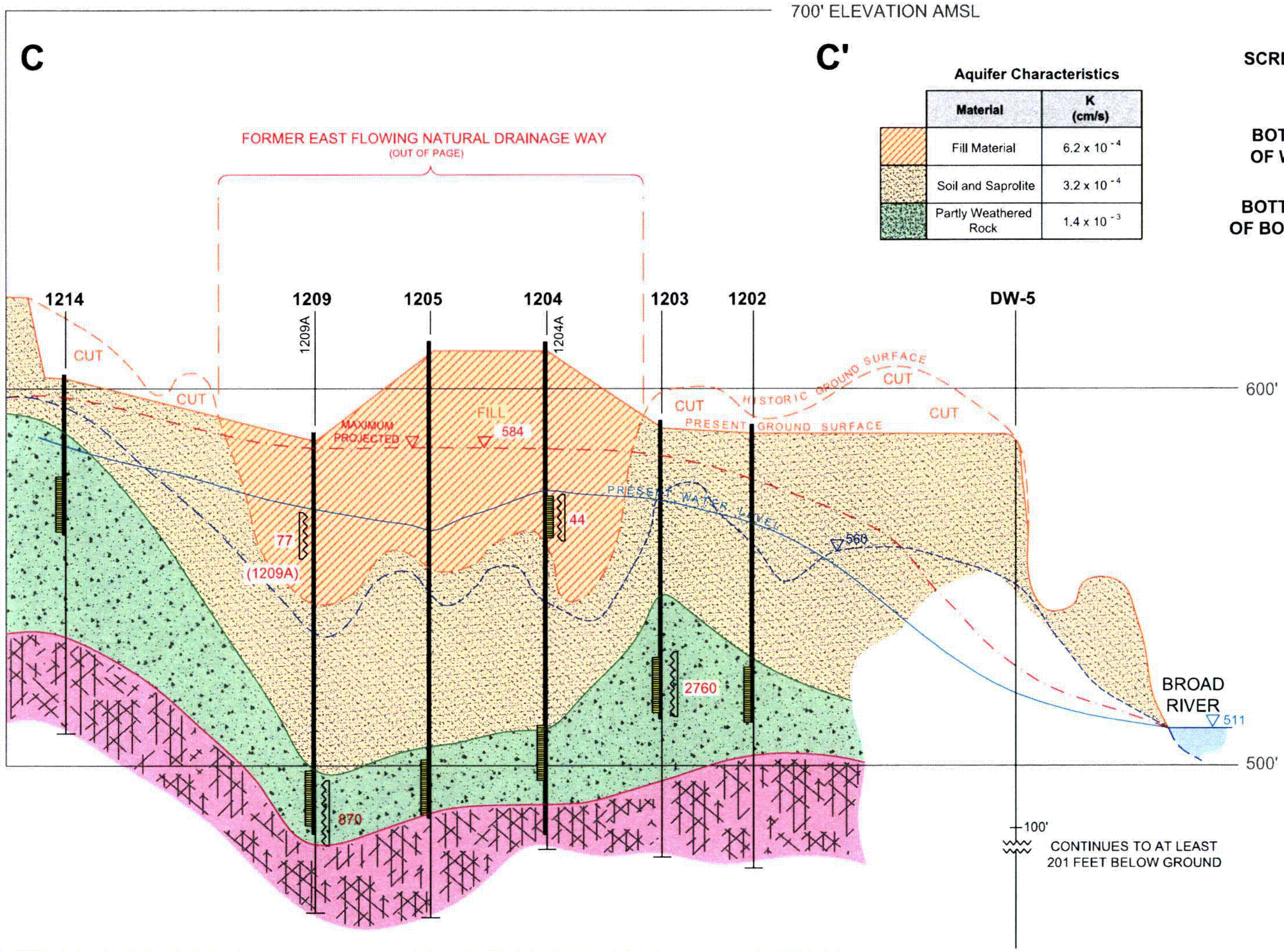
WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

Cross Sections of Lee Nuclear Site:
B - B'

FIGURE 2.4.12-205
Sheet 3 of 4

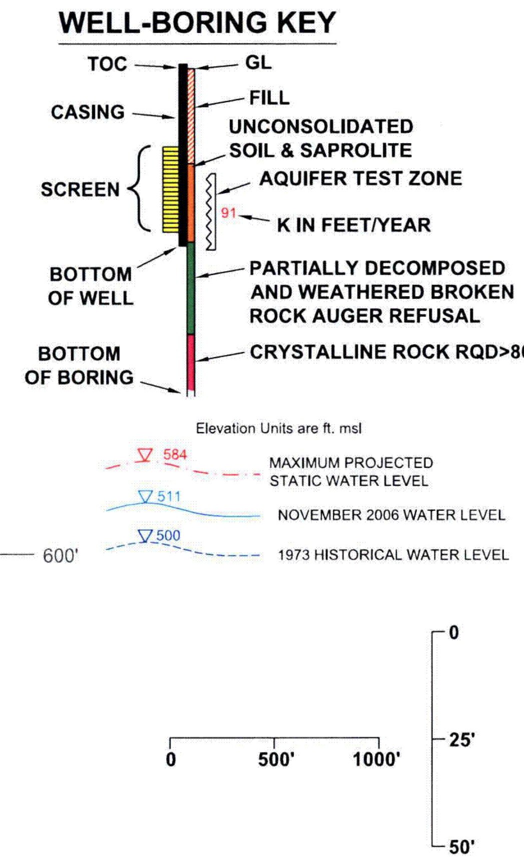
Rev 1

HISTORICAL TOPOGRAPHIC DATA FROM USGS BLACKSBURG SOUTH SC QUADRANGLE MAP (DATED 1971).
HISTORICAL WATER LEVEL DATA FROM CHEROKEE PSAR AND ER



Aquifer Characteristics

Material	K (cm/s)
Fill Material	6.2×10^{-4}
Soil and Saprolite	3.2×10^{-4}
Partly Weathered Rock	1.4×10^{-3}



WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

Cross Sections of Lee Nuclear Site:
Index Map

FIGURE 2.4.12-205
Sheet 4 of 4

Rev 1

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 017

NRC Technical Review Branch: Hydrologic Engineering Branch (RHEB)

Reference NRC RAI Number: 02.04.12-014

NRC RAI:

FSAR Figure 2.4.12-204, Sheet 8, shows the projected post-development water table. This water table is dominated by two groundwater divides, one west and one east of the planned nuclear power units and trending generally north and south. These divides apparently diverge from a groundwater high at a point about 2,500 feet south of Unit 1. Between the divides, the projected water table implies that groundwater flows generally northward and converges on Hold-Up Pond A. Groundwater conditions were, however, significantly different before construction associated with the Cherokee Nuclear Station. According to the Cherokee Nuclear Station Environmental Report, Vol. 1 (1974), the pre-construction water table (Figure 2.5.4-2) had a western groundwater divide whose location was similar to that of the western groundwater divide projected for the Lee plant (FSAR Figure 2.4.12-204). A second groundwater divide diverged from the western divide at a point located about 800 feet south-southwest of the proposed Lee Unit 1 reactor containment. This second divide ran to the northeast between the locations of the proposed Lee Units 1 and 2. The difference between the Cherokee (pre-construction) and Lee (post-construction) groundwater configurations is potentially highly significant. For example, if the actual configuration were more like the Cherokee case, then a release to groundwater at Lee Unit 2 would flow southeastward toward Make-Up Pond A rather than northward as is hypothesized in the Lee FSAR. Please provide a detailed discussion of the projected post-development water table, the factors that govern its configuration, and why the post-construction water table is expected to differ significantly from the observed pre-construction water table. Staff believes that hydrogeological modeling will be necessary to examine these issues in sufficient detail; if modeling is not used, its omission should be clearly justified. To the extent that the discussion is based on the similarity of the projected water table to the post-construction topography, provide a detailed discussion, with appropriate analysis and literature references, to support this approach.

Duke Energy Response:

As discussed in the RAI 02.04.12-008 response (this letter), the post-dewatering water table elevations shown in Figure 2.4.12-204, Sheet 8, are based on knowledge of the current water table as shown in Figure 2.4.12-204, Sheets 1 through 7, and the 1973 water table, Figure 2.4.12-201. The water table elevations are projected to generally conform to the surface topography and reflect a north-south trending groundwater divide historically located west of the reactor area and east of Make-Up Pond B. Under natural conditions the topography of the water table is similar to that of the land surface, but has less relief (Reference 285 in FSAR Subsection 2.4.16). At the Lee Nuclear Site, changes to pre-construction topography appear to have resulted in similar changes to water table elevations. Based on water level observations during the Lee investigation, areas of surficial cut and fill have correlative changes in water table elevations relative to "natural conditions." For example, prior to Cherokee construction, the hydraulic head between the area that would become Cherokee Unit #3/Lee Unit #2 to the area that would become Make-Up Pond A was 69 ft (580 feet mean sea level (ft msl) at Lee Unit #2 to 511 ft msl at the Broad River). With the changes made during Cherokee construction, the hydraulic head along the same path was decreased to 33 ft (580 ft msl at Unit #2 to 547 ft msl Make-Up Pond A elevation). Furthermore, the construction of the Lee Unit #2 cooling tower pad created an apparent recharge mound; the water table elevation was less than 550 ft msl prior to construction activities. In 2006 the groundwater level was observed at an approximate elevation of 570 ft msl (MW-1214). The mounding effect appears to impede the southeastwardly flow of the second groundwater divide referenced above.

Similarly, areas of cut exhibit lowered water table elevations during the Lee investigation relative to the pre-Cherokee construction investigation. For example, the surface elevation in the area of the current well MW-1200 (located west-northwest of Lee Unit #1) prior to Cherokee construction was approximately 670 ft msl, compared to the post-grading surface elevation of approximately 590 ft msl; consequently, the water table elevation has lowered (2006 investigation groundwater elevation of 565 ft msl compared with pre-Cherokee construction groundwater elevation of more than 585 ft msl). These are similar site water level observations, and professional experience aided in the characterization of how water table conditions were impacted due to Cherokee construction.

Five plausible groundwater pathways have been identified and characterized, as discussed in the response to FSAR RAI 02.04.12-001 (this letter).

A numerical model is not recommended for Lee Nuclear at this time due to site conditions, the influence of the current dewatered excavation on groundwater flow, and future construction activities. Duke Energy expects to implement a groundwater monitoring program at Lee Nuclear upon completion of construction and expects that program to include development of a groundwater model similar to those voluntarily developed for Duke's existing nuclear stations. A conceptual site model containing hydrogeologic information, an interpretation of historical and current groundwater conditions, and an interpretation of potential post-construction groundwater conditions, will be made available for inspection by the NRC staff when it is complete.

Following construction, near field and far field groundwater monitoring wells will be installed. Well installation will take approximately six months. Completion of the groundwater model is expected to take an additional six months.

FSAR Subsection 2.4.12.3.1 is revised by this RAI response to clarify the discussion on groundwater pathways. The identified changes will be incorporated in a future revision of the Final Safety Analysis Report.

Associated Revisions to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.4.12.3.1

FSAR Subsections 2.4.12.2.3 and 2.4.12.5 as shown in FSAR RAI 02.04.12-006, Attachment 1 (this letter)

FSAR Subsections 2.4.12.2.3 as shown in FSAR RAI 02.04.12-008, Attachment 1 (this letter)

Attachment:

1) Revision to FSAR Subsection 2.4.12.3.1

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.04.12-014

Revision to FSAR Subsection 2.4.12.3.1

COLA Part 2, FSAR. Chapter 2, Subsection 2.4.12.3.1, first paragraph, will be revised as follows:

Within the preferential flow pathway that extends northward from the proposed reactor buildings toward Hold-Up Pond A and the Broad River (Figure 2.4.12-204, Sheet 8), groundwater appears to flow through each of the aquifer materials referenced above. The depth of groundwater circulation in the Piedmont is difficult to define and may be erratic, dependent upon the presence of interconnected rock fractures and gradient. However, based on analysis of groundwater levels at the cluster well locations, vertical gradients are generally in the downward direction, consistent with the topographic slope to the Broad River, indicating that groundwater recharge is occurring and groundwater movement generally parallels topography. ~~Groundwater in storage moves from areas of recharge (impoundments, ridges, mounds, and cooling tower pads) to areas of discharge (impoundments, creeks, and ultimately the Broad River).~~