VEGP Groundwater Calculation Package Addendum

Cretaceous Aquifer

Three wells at VEGP are installed within the Cretaceous aquifer: TW-1, MU-1, and MU-2A (SNC 2005). The general site hydrogeologic description in ER Section 2.3.1 indicates that the bottom of the semi-confining unit (Tertiary in age) between the Cretaceous aquifer and the Tertiary aquifer is approximately -254 feet mean sea level (msl). The FSAR indicates that the thickness of the Cretaceous aquifer beneath Units 1 and 2 is approximately 700 feet. The thickness of the semi-confining unit is approximately 146 feet (ER Section 2.3.1). The bottom of the Cretaceous aquifer is approximately -954 feet msl. Table 1 includes well installation data for wells TW-1, MU-1, and MU-2A. Based on the data in Table 1, it appears the sand/gravel packs for the wells were installed into the Tertiary/Cretaceous semi-confining unit but not into the Tertiary aquifer, which has a bottom elevation of approximately -108 feet msl (ER Section 2.3.1). The screens, however, appear to have been installed in the Cretaceous aquifer.

The static/pumping water level elevations in these wells have remained fairly constant from 2000 through 2004 (See Tables 2, 3, and 4) with the greatest fluctuations occurring in Well MU-2A. The static groundwater elevations in these wells range from approximately 150 to 160 feet msl. The potentiometric maps provided in Section 2.3.1 of the ER indicate the Tertiary head across the proposed site varies from approximately 100 to 125 feet msl. The difference in potentiometric head values between the Tertiary and Cretaceous aquifers suggest that the well materials may not extend into the Tertiary aquifer and that there is a degree of separation between the Cretaceous and the Tertiary aquifers. Current flow potential is upward from the Cretaceous aquifer to the Tertiary aquifer.

Table 1
VEGP Production Wells

Well No.	Ground Surface Elevation (Ft msl)	Drilled Depth (feet)	Well Sand/Gravel Depth Interval (feet)	Sand/Gravel Elevation (Ft msl)
TW-1	218.5	860	450 - 860	-231.5 to -641.5
MU-1	196.9	851	435 – 830	-238.4 to -633.1
MU-2A	225	884	435 - 865	-210 to -640

FT msl = Feet mean sea level.
SNC 2005

Table 2 Well TW-1 Static/Pumping Groundwater Elevation (Feet) Cretaceous Aquifer					
	2000	**2001**	**2002**	**2003**	**2004**
January	--	--	--	--	--
February	--	162.1/149.8	--	--	--
March	--	--	--	--	--
April	--	--	--	--	--
May	--	--	--	--	--
June	--	--	--	--	--
July	--	--	--	--	--
August	162.5/148.6	--	--	--	--
September	--	--	--	--	--
October	--	--	--	--	--
November	--	--	--	--	--
December	--	--	--	--	--

Table 3 Well MU-1 Static/Pumping Groundwater Elevation (Feet) Cretaceous Aquifer					
	2000	**2001**	**2002**	**2003**	**2004**
January	--	--	--	--	--
February	155.4/147.9	--	154.6/149.3	--	--
March	--	--	--	--	--
April	--	--	--	--	--
May	--	--	--	--	--
June	--	--	154.6/150.3	154.6/150.3	155.6/149.1
July	--	--	--	--	--
August	155.8/149.3	154.0/147.9	150.8/145.8	--	--
September	--	--	--	--	--
October	--	--	--	--	--
November	--	--	--	--	--
December	--	--	149.7/144.8	155.4/150.7	154.5/150.3

Table 4 Well MU-2A Static/Pumping Groundwater Elevation (Feet) Cretaceous Aquifer					
	2000	**2001**	**2002**	**2003**	**2004**
January	162.2/132.2	--	--	--	--
February	--	155.0/120.4	150.9/133.3	--	--
March	--	--	--	--	--
April	--	--	--	--	--
May	--	--	--	--	--
June	--	--	--	--	--
July	--	--	--	--	--
August	--	157.1/153.0	--	--	--
September	--	--	--	--	--
October	--	--	--	--	--
November	--	--	--	--	--
December	--	--	--	--	--

References: Data for the three wells are included in the following documents already submitted in ER. The reference number was maintained to prevent confusion.
SNC 2000a,b; SNC 2001a,b; SNC 2002a,b,c; SNC 2003a,b; SNC 2004a,b;

Confined Non-leaky Aquifer Scenario

The FSAR stated that the aquifer tests in the Cretaceous aquifer had varied results (SNC 2005.

To determine potential offsite impacts of groundwater drawdown, cumulative well yield was used to calculate drawdown as though it had been pumped from a single onsite well. The well MU-2A location was used, because it is the closest production well to an offsite well (5,700 feet) and because the well has been one of the site's primary production wells.

Data used as input (Table 5) to Theis (1937) Non-equilibrium Well Equations (as presented in Calculation Package Summary for groundwater) was taken from VEGP's Units 1 and 2 FSAR. A mean Transmissivity value of 158,000 gpd/ft (21,123 ft^2/day) was used (SNC 2005). The Storativity value ($3.1x10^{-4}$) is an average of the values calculated for the deeper production wells (FSAR Table 2.4.12-8). Total groundwater use reported to the Georgia Department of Natural Resources by VEGP from 2001 through 2004 averaged 730 gpm. (SNC 2000a,b, 2001a,b, 2002a,b,c, 2003a,b, 2004a,b in Chapter 3 of the Environmental Report) This value is considered the total groundwater use for the existing units. A maximum construction pumping rate of 420 gpm was used (FSAR 2005). The total groundwater use rate for the proposed units is 752 gpm (ER Table 3.3-1).

Table 5
Confined Non-leaky Aquifer Equation
Two Unit Operations (Units 1 and 2)

Case	1	2	3	4	5	6
Distance (FT)	5,700	5,700	5,700	5,700	5,700	5,700
Storage Coefficient	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031
Transmissivity (FT^2/day)	21,123	21,123	21,123	21,123	21,123	21,123
Time (Days)	3,650	7,300	10,950	14,600	18,250	21,900
Flow, Q (gpm)	730	730	730	730	730	730
Drawdown at property boundary (feet)	--	5.6	5.8	5.9	6.0	6.1

Therefore, the pumping rate used in the analysis for most of the construction phase is 1,150 gpm (730 + 420 = 1,150 gpm; pumping scenario 1) (See Table 6). There will be a period, after completion of the Unit 3 and before completion of Unit 4, when the pumping rate will include the 730 gpm for the existing units, a construction rate for Unit 4, and an operational rate for Unit 3. For this construction/operational overlap period, the groundwater pumping rate is calculated as the existing rate of 730 gpm, one-half the construction rate or 210 gpm, and one-half the proposed operational rate or 376 gpm (pumping scenario 2_. The total for this period is 1,316 gpm. The estimated pumping rate during the normal operation of all four units is 1,482 gpm (730 gpm + 752 gpm; pumping scenario 3).

Table 6
Confined Non-leaky Aquifer Equation
Proposed Two Unit Operations (Units 1 and 2) With Construction Activities and Operations of Units 1 and 2 and Proposed Units 3 and 4

Case	1	2	3	4	5
Distance (FT)	5,700	5,700	5,700	5,700	5,700
Storage Coefficient	0.00031	0.00031	0.00031	0.00031	0.00031
Transmissivity (FT^2/day)	21,123	21,123	21,123	21,123	21,123
Time (Days)	8,760	10,950	14,600	18,250	21,900
Flow, Q (gpm)	1,150	1,316	1,482	1,482	1,482
Drawdown at property boundary (feet)	8.9	10.4	12.0	12.2	12.6

Modeling results have the two existing units reducing the potentiometric surface in the Cretaceous aquifer, measured at the VEGP property line, by approximately 5.9 feet by 2025 (Table 5). Two additional units (assuming they become operational in 2015/2016) will increase this drawdown to 12 feet by 2025, using the conservative assumptions in the model (Table 6). By 2045, the potentiometric surface reduction will increase to 12.6 feet (Table 6). For comparison, the two existing units would reduce the potentiometric surface to 6.1 feet by 2045 (Table 5).

The non-leaky aquifer equation (Theis) does not account for the possible semi-confining nature of the Tertiary/Cretaceous confining unit suggested by the results of past pump tests. The equation assumes that the aquifer is homogeneous, isotopic, with negligible recharge and gradient, and that boundary impacts do not occur. The equation was run for each pumping rate scenario described above. The drawdown values calculated are conservative because pumping for each of the simulations was initiated at the start of Unit 1 operations and not adjusted to accommodate changes in pumping rates as described above. Therefore the modeled drawdown at the property boundary is the result of a much longer pumping period for each scenario than will actually occur.

Confined Leaky Aquifer Scenario

The issue of connectivity of the Cretaceous and the Tertiary aquifers beneath the site (**SNC 2005**) was not fully supported in the FSAR. However, because the confining unit between the Tertiary and Cretaceous aquifers has been described as semi-confining and from the general description of the unit soils in ER Section 2.3.1, a confined-leaky aquifer is most likely at VEGP. SNC (2005) notes that downstream of the site, the Savannah River cuts through the semi-confining unit separating the Cretaceous and Tertiary aquifers. SNC (2005) does not present hydrologic data for the connectivity of the Cretaceous and Tertiary aquifers beneath the site and no other data on the hydraulic connectivity of the semi-confining unit at VEGP was located. However, data for the Savannah River Site (SRS) just across the Savannah River in South Carolina is available. Aadland et al. (1995) published a study on the SRS groundwater hydrologic units. A vertical hydrologic conductivity value for the corresponding SRS confining unit separating the Cretaceous and the Tertiary aquifers was used for the VEGP analysis.

Prior to construction, pump tests performed in 1977 (**SNC 2005, p. 2.4.12-21 & 22**) indicated the depth from top of casing to water for wells MU-1 and MU-2A was approximately 28 feet and 42 feet, respectively. These depth-to-water values for 1977 and corresponding water elevation data presented in the Groundwater Use Reports submitted to the Georgia Department of Natural Resources (**SNC 2000a,b; SNC 2001a,b; SNC 2002a,b,c; SNC 2003a,b; SNC 2004a,b; SNC 2005**) indicate the preconstruction elevations as approximately 172 feet (MU-1) and 184 feet (MU-2A) for the Cretaceous aquifer at the site and a reduction in the potentiometric surface of the Cretaceous aquifer of approximately 23 feet over the 27-year period from 1977 to 2004.

A leaky scenario (using Hantush-Jacob Non-equilibrium Well Equations; see below) was evaluated to address the characteristics of the likely semi-confined Cretaceous aquifer, The leaky analysis used applicable inputs from the confined non-leaky scenario (Tables 7 and 8). SNC assumed that all of the water pumped from the Cretaceous aquifer was pumped from a fully penetrating single well (MU-2A). The vertical hydraulic conductivity of the Tertiary/Cretaceous confining unit at SRS was used as a surrogate for that at VEGP. The Tertiary/Cretaceous confining unit, known as the Crouch Branch confining unit at SRS, has a vertical hydraulic conductivity for clays to sandy clays of 1.67×10^{-4} ft/day and for clayey sands of 8.90×10^{-3} feet/day (**Aadland et. al. 1995, p. 73**). An average vertical hydraulic conductivity of 4.5×10^{-3} feet/day for the semi-confining unit and unit thickness of 146 feet (from Section 2.3.1 of the

Environmental Report) were used. Section 2.3.1 describes the semi-confining unit as consisting of sand, clay, and silt. The results of the leaky scenario model for the drawdown of the Cretaceous potentiometric surface at the property boundary from pumping groundwater for the existing Units 1 and 2 was 1.9 feet (Table 7) after a period of 40 years (original license period). During the period of current water use by Units 1 and 2 and construction (Table 8) of two new units, the drawdown of the potentiometric surface of the Cretaceous aquifer was estimated to be 2.9 feet (existing and construction of both units) to 3.3 feet (existing and construction of second new unit and operation of first new unit). During the period of operation of all four units the drawdown of the potentiometric surface of the Cretaceous aquifer is estimated to be 3.8 feet.

Table 7
Confined Leaky Aquifer Equation
Current Operations

Case	1	2	3	4	5	6
Distance (FT)	5,700	5,700	5,700	5,700	5,700	5,700
Storage Coefficient	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031
Transmissivity (FT^2/day)	21,123	21,123	21,123	21,123	21,123	21,123
Time (Days)	3,650	7,300	10,950	14,600	18,250	21,900
Flow, Q (gpm)	730	730	730	730	730	730
Confining Unit b' (FT)	146	146	146	146	146	146
K' Ft/Day	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
Drawdown at property boundary (feet)	1.9	1.9	1.9	1.9	1.9	1.9

Table 8
Confined Leaky Aquifer Equation
Proposed Two Unit Operations (Units 1 and 2) With Construction Activities and Operations of Units 1 and 2 and Proposed Units 3 and 4

Case	1	2	3	4	5	Maximum Off-normal Operations
Distance (FT)	5,700	5,700	5,700	5,700	5,700	5,700
Storage Coefficient	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031
Transmissivity (FT^2/day)	21,123	21,123	21,123	21,123	21,123	21,123
Time (Days)	8,760	10,950	14,600	18250	21,900	21,900
Flow, Q (gpm)	1,150	1,316	1,482	1,482	1,482	5,540
Confining Unit b' (FT)	146	146	146	146	146	146
K' Ft/Day	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
Drawdown at property boundary (feet)	2.9	3.3	3.8	3.8	3.8	8.8

Off-normal operation, such as a fire affecting all four units would require the maximum use of groundwater. Although very unlikely, for purpose of analysis SNC assumed groundwater pumping for 2 days at a rate of approximately 5,540 gpm. Using the same leaky aquifer scenario (Table 8), this resulted in a drawdown of the potentiometric surface of 8.8 feet 5,700 feet from Well MU-2A in the direction of the closest off-site well .

Hantush-Jacob Non-equilibrium Well Equations

$s=[Q/4(3.14)T](Wu,r/B)$

$u = r^2S/4tt$

Tertiary Aquifer

Based on water use in 2005, VEGP used approximately 4 gpm of groundwater from its wells in the Tertiary aquifer. Because the current usage from the Tertiary aquifer is only 4 gpm (Section 2.3.2, Table 2.3.2-12) and because SNC plans to use groundwater from the Cretaceous aquifer to support construction and operation of proposed Units 3 and 4, no modeling was performed for the Tertiary aquifer. The top of the Tertiary aquifer is approximately 74 feet msl. The top of the Tertiary/Cretaceous semi-confining unit is approximately -108 feet msl (Section 2.3.1 of the ER). Therefore, the Tertiary aquifer thickness is approximately 182 feet. The Tertiary aquifer potentiometric surface elevations are shown in ER Section 2.3.1. The potentiometric surface elevations across the proposed power block area for Units 3 and 4 ranges from approximately 100 to 125 feet msl. The Tertiary Potentiometric Surface maps in Section 2.3.1 when compared to the Potentiometric Surface of the Confined aquifer map (Figure 2.5-13) from the 1974 Georgia Power ER for Units 1 and 2 (**Georgia Power 1974**) indicate very little change in the Tertiary aquifer beneath the site.

Water Table Aquifer

The Units 3 and 4 powerblock would be in an area where multi-directional flow is believed to occur as are Units 1 and 2's powerblock as shown on Figure 2.3.1-16 in Section 2.3.1 of the Environmental Report. The final grade elevation will be approximately 225 feet msl. The top of the marl is at 137 feet msl. Flow through the Water Table aquifer at the Units 3 and 4 location is lateral to drainage features which drain to the Savannah River which in effect eliminates the potential for flow from the Units 3 and 4 locations to off-site. As discussed in Section 2.3.1.2.4 of the Environmental Report, the Blue Bluff Marl, which separates the Water Table aquifer from the Tertiary aquifer, is an effective confining unit. It contained no free groundwater in samples monitored for the construction of Units 1 and 2 (**SNC 2005**). The marl, just north of the powerblock, generally dips downward to the north away from the proposed construction area. The pumping proposed to take place in the Cretaceous aquifer would have no effect on the Water Table aquifer or on Mallard Pond due to the presence of the marl.

The potentiometric surface of the water table is higher than that of the underlying confined Tertiary aquifer (100 to 125 feet msl). This would normally indicate a downward flow of water from the water table to the underlying unit. But because of the confining characteristics of the Blue Bluff marl, this does not occur at the proposed site location. A comparison of the Water Table maps in Section 2.3.1 to the Water Table map (Figure 2.5-14) from the 1974 Georgia Power ER for Units 1 and 2 (**Georgia Power 1974**) indicates no change to the water table elevations within the area of the proposed new units due to pumping within the Cretaceous aquifer over time.

Mallard Pond is situated in a drainage feature north of the proposed new units where the Blue Bluff Marl dips directly beneath the upper portion of the pond and continues to dip to the north. Due to the confining capacity of the Blue Bluff marl, Mallard Pond is isolated from the effects of pumping in the Tertiary or Cretaceous aquifers. Therefore, there would be no impact to the waters of Mallard Pond due to the pumping activities during proposed operations.

References:

(Aadland et. al. 1995) Aadland, Rolf K., Joseph A. Gellici, and Paul A. Thayer, 1995, *Hydrogeologic Framework of West-Central South Carolina*, State of South Carolina Department of Natural Resources, Water Resources Division, Report 5.

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