2.4 Hydrologic Engineering

2.4.1 Hydrologic Description

2.4.1.1 Introduction

Attachment 2 of the RS-002 discusses the site characteristics that could affect the safe design and siting of the proposed plant or plants. Section 2.4 of the applicant's SSAR describes the hydrological setting and the data used in the applicant's safety conclusions regarding hydrology. The NRC staff's review of the SSAR covers the (1) interface of the plant with the hydrosphere, (2) hydrological causal mechanisms, (3) surface and ground water use, (4) data that forms the basis of the applicant's analysis and conclusions, (5) alternate conceptual models, (6) consideration of other site-related evaluation criteria, and (7) additional information for applications under 10 CFR Part 52.

The VEGP site is located on the southwest side of the Savannah River (SNC, 2007). The VEGP site currently hosts two nuclear power plants, VEGP Units 1 and 2. The VEGP application proposed the addition of two new nuclear power reactors, each plant fitting within the bounding parameters provided in the proposed permit, at the VEGP site (SNC, 2007).

2.4.1.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

1. 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), addresses the hydrologic characteristics of a proposed site that may affect the consequences of an escape of radioactive material from the facility. Applicants should determine factors important to hydrologic radionuclide transport, described in 10 CFR 100.20(c)(3), by using onsite measurements. 10 CFR 100.20(c) also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

Section 2.4.1 of RS-002 provides the following criteria that was used by the NRC staff to evaluate this SSAR section.

- To satisfy the hydrologic requirements of 10 CFR Part 52 and 10 CFR Part 100, the applicant's SSAR should describe the surface and subsurface hydrologic characteristics of the site and region. This description should be sufficient to assess the acceptability of the site and the potential for those characteristics to influence the design of the SSCs of a nuclear unit(s) that might be constructed on the proposed site.

- Meeting Section 2.4.1 of RS-002 provides reasonable assurance that the hydrologic characteristics of the site and potential hydrologic phenomena will pose no undue risk to the type of facility proposed for the site. Further, it provides reasonable assurance that such a facility will pose no undue risk of radioactive contamination to surface or subsurface water from either normal operations or as the result of a reactor accident.

- To meet the requirements of the hydrologic aspects of 10 CFR Part 52 and 10 CFR Part 100, the applicant's SSAR should form the basis for the hydrologic engineering analysis with respect to subsequent sections of the application for an ESP. Therefore, completeness and clarity are of paramount importance. Maps should be legible and adequate in their coverage to substantiate applicable data. Site topographic maps should be of good quality and of sufficient scale to allow independent analysis of preconstruction drainage patterns. Data on surface water users, location with respect to the site, type of use, and quantity of surface water used are necessary. Inventories of surface water users should be consistent with regional hydrologic inventories reported by applicable Federal and State agencies. The description of the hydrologic characteristics of streams, lakes, and shore regions should correspond to those of the USGS, NOAA, Soil Conservation Service (SCS), USACE, or appropriate State and river basin agencies. Applicants should describe all existing or proposed reservoirs and dams (both upstream and downstream) that could influence conditions at the site. Descriptions may be obtained from reports of USGS, U.S. Bureau of Reclamation (USBR), USACE, and others. Generally, reservoir descriptions of a quality similar to those contained in pertinent datasheets of a standard USACE hydrology design memorandum are adequate. Tabulations of drainage areas, types of structures, appurtenances, ownership, seismic and spillway design criteria, elevation-storage relationships, and short- and long-term storage allocations should be provided.

2.4.1.3 Technical Evaluation

The technical evaluation consists of (1) a review of the applicant's technical information presented in the SSAR, and (2) NRC staff's technical evaluation of the hydrology near the site, including appropriateness of the data used by the applicant in its SSAR.

2.4.1.3.1 Technical Information Presented by the Applicant

In Section 2.4 of the SSAR, the applicant described the site area and the facilities that currently exist on the proposed site, including the hydrological and geological setting. In addition, the description included the hydrologic characteristics of the Savannah River Basin along with the major dams and multipurpose projects that manage water supply and provide flood control within the basin. The applicant described that the VEGP site is located on the southeast side of the Savannah River, approximately 15 miles east-northeast of Waynesboro, Georgia, 26 miles southeast of Augusta, Georgia, and 100 miles north-northwest of Savannah, Georgia (SNC, 2006). The VEGP site is located approximately 150 river miles upstream of the mouth of the Savannah River. Elevations in the Savannah River basin range from sea level at the mouth to 5030 ft MSL at Little Bald Peak in North Carolina. The Savannah River system drains a total of 10,577 square miles. The contributing watershed area of the Savannah River near the VEGP site is approximately 8304 square miles. There are 14 dams in the Savannah River Basin upstream of the VEGP site (SNC, 2006) owned and operated by the U.S. Army Corps of

Engineers (USACE) or one of several power generation companies in Georgia and South Carolina. The entire 312-mile reach of the Savannah River is regulated by three major USACE multipurpose projects. The three reservoirs created by these projects are Hartwell Lake and Dam, Richard B. Russell Lake and Dam, and J. Strom Thurmond Lake and Dam (also known as Clarks Hill Lake and Dam).

The applicant mentioned that the average daily discharge at the USGS gauge 02197320, Savannah River near Jackson, SC, which is located approximately six river miles upstream of the VEGP site, based on 31 years of data is 8913 cubic feet per second (SNC, 2006). Based on the same record, the average discharge at this location varies from 7216 cubic feet per second in September to 11,347 cubic feet per second in March.

The applicant described that the VEGP site is located on a high bluff on the west bank of the Savannah River and has an area of approximately 3169 acres (SNC, 2006). The grade elevations of proposed Units 3 and 4 will be 220 feet MSL or higher. Approximately 4 miles from the VEGP site, Georgia State Highway 23 runs along a topographic ridgeline. The ridgeline separates drainages that generally flow northeast towards the Savannah River from drainages that generally flow to the southwest.

The applicant also detailed the local site drainage at the VEGP site, the current water uses within the Savannah River Basin, and the proposed water consumption for the two new units. A storm water drainage system exists on the VEGP site. This system was developed during construction of existing Units 1 and 2 and provides drainage away from the site. Surface runoff from the high ground where Units 1 and 2 are located is collected in four major drainage channels that are aligned with access roads and railroad facilities (SNC, 2006). The outfall of the drainage channels is to the north, the south, the east, and the west of the site.

The applicant described that annual peak discharges in the Savannah River at Augusta, Georgia, reported by the USGS based on observed streamflow at gauge 02197000, located approximately 48.7 miles upstream of the VEGP site, are presented in the SSAR (SNC, 2006). The annual peak discharges were estimated by USGS for water years (October 1 of the previous calendar year through September 30 of current year) 1796, 1840, 1852, 1864, 1865, and 1876. The maximum annual peak discharge in the period of record is 350,000 cubic feet per second, observed on October 2, 1929. The oldest annual peak discharge, on January 17, 1796, was estimated from reported river stages using slope-conveyance methods. The estimated values of the peak discharge on this date vary from 280,000 cubic feet per second for a reported stage of 38 feet to 360,000 cubic feet per second for a reported maximum flood stage of 40 feet. Based on the elevation of the USGS gauge 02197000 being 96.58 feet MSL, the maximum historic flood elevation of the Savannah River at Augusta, Georgia is estimated between 134.6 and 136.6 feet MSL (SNC, 2006).

Average daily and annual peak discharge data for nine streamflow gauges maintained by the USGS on the Savannah River were used in preparation of SSAR Sections 2.4.11 and 2.4.2, respectively.

Unregulated annual peak discharge values for the period after 1952 were estimated by modeling using the 1990 reservoir operation rules and the stage-storage-discharge characteristics of the three major USACE projects. Estimates of regulated peak discharge values for the period prior to 1952 were also generated using the same approach. Four USGS

topographic quadrangles were used to create a map of the topography at the VEGP site. Cross-section profiles of the Savanna River at several locations were used in the SSAR. Air temperature records from eight NWS meteorological stations were used to analyze historical air temperature variations in the SSAR.

2.4.1.3.2 NRC Staff's Technical Evaluation

The NRC staff reviewed the description of the site region, general location and hydrologic interfaces of the VEGP site, and the description of the local site drainage provided by the applicant. The NRC staff independently obtained descriptions and maps of the general region surrounding the VEGP site. The NRC staff created Figure 2.4.1-1 that shows a map of the region where the VEGP site is located. The estimated distances from the VEGP site to the Georgia cities of Augusta, Waynesboro, and Savannah, are 25.7, 14.8, and 83.2 miles, respectively.

The Savannah River Basin straddles the State boundary between Georgia and South Carolina (Figure 2.4.1-2). The NRC staff created the map shown in Figure 2.4.1-2 by using USGS hydrologic unit codes GIS coverages from the Natural Resources Conservation Service Geospatial Data Gateway. The Savannah River Basin consists of 9 level 4 and 312 level 6 hydrologic unit codes (Seaber et al., 1987), with a total area of 10,218 square miles. The area of the Savannah River Basin estimated from the GIS coverages is 3.4-percent less (10,218 square miles versus 10,577 square miles) than that reported by SNC (2006). The NRC staff's research indicated that the Nature Conservancy (2007) reports the area of the Savannah River Basin as 10,577 square miles. The contributing drainage area at the streamflow gauge at Hardeeville, South Carolina, about 10 miles above the mouth of the Savannah River, is approximately 10,250 square miles (Cooney et al., 2005). The differences in the reported drainage areas for the Savannah River Basin are minor and are not expected to result in any significant differences in estimation of the PMP or the probable maximum flood (PMF) for the Savannah River Basin. The estimation of the drainage area is an intermediate step in the determination of the probable maximum flood in streams and rivers.

Based on its independent assessment, the NRC staff concluded that the applicant presented sufficient information related to hydrologic description in SSAR Section 2.4.1. Later sections of this SER describe the NRC staff's review of hydrological causal mechanisms, water uses, data, and conceptual models.

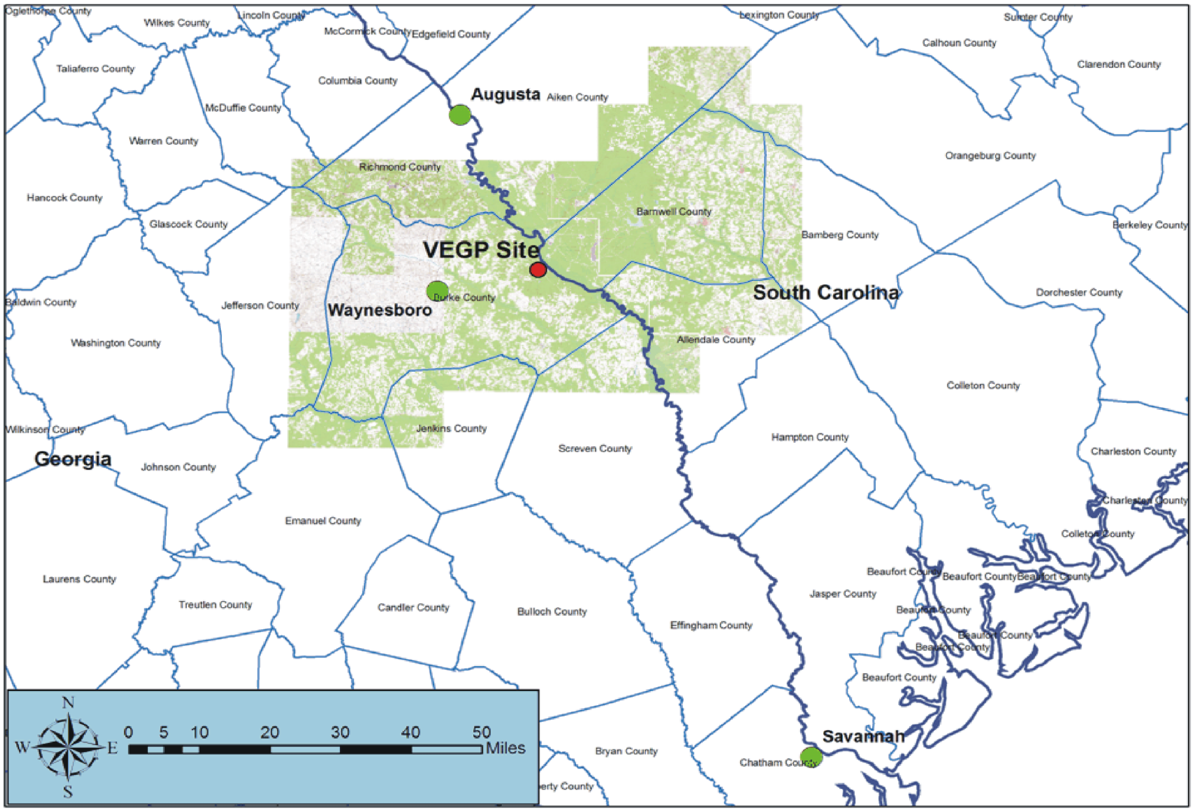

Figure 2.4.1-1 - Location map of the VEGP site

The cities of Augusta, Waynesboro, and Savannah are 25.7, 14.8, and 83.2 miles from the site, respectively. The Savannah River marks the state boundary between South Carolina and Georgia near the VEGP site.

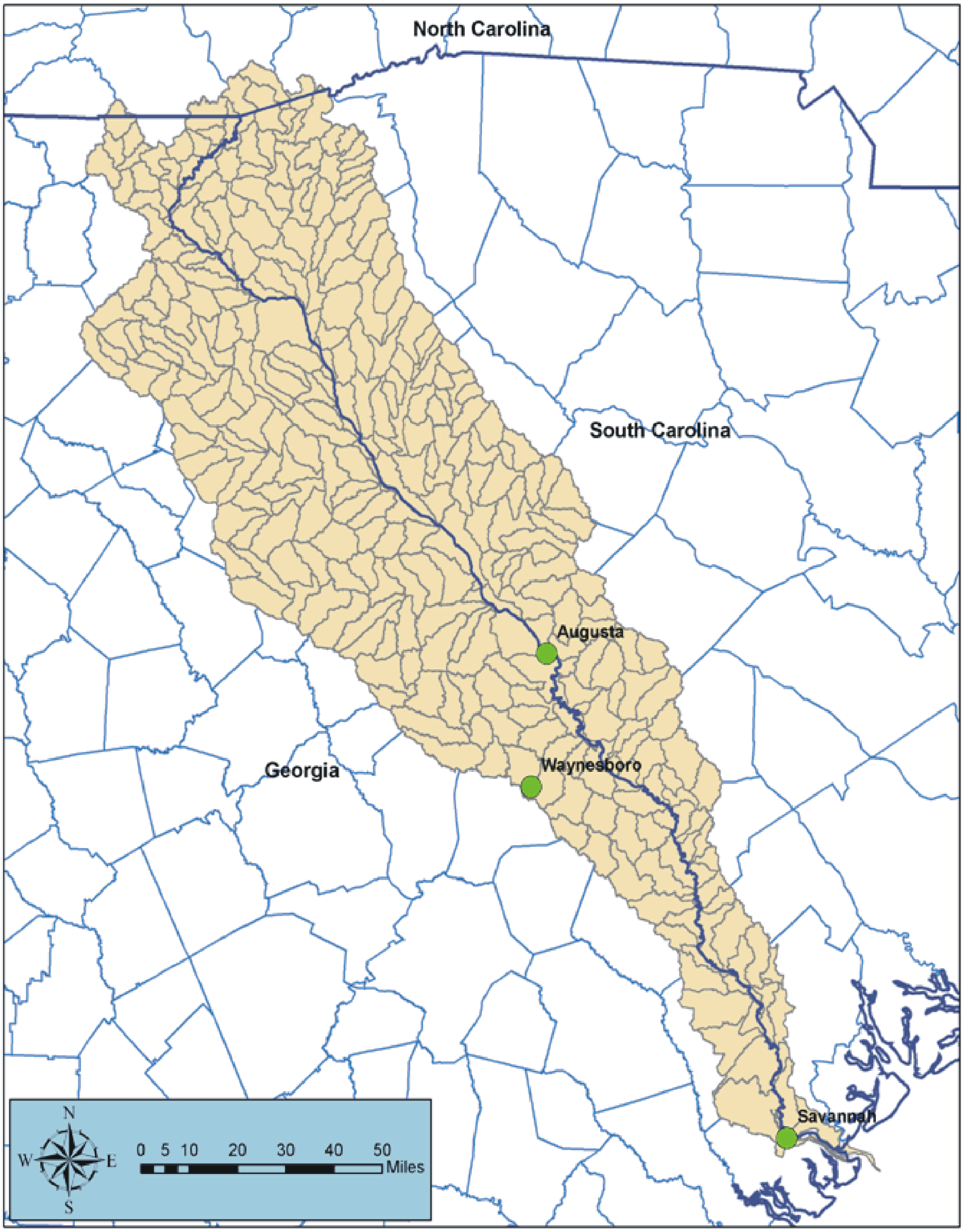

Figure 2.4.1-2 - The Savannah River Basin that straddles the state boundary between Georgia and South Carolina. Portions of the headwaters lie in North Carolina.

2.4.1.4 Conclusion

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the hydrologic description at the proposed site. Section 2.4.1 of RS-002 provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating the hydrology in the vicinity of the site and site regions, including interface of the plant with the hydrosphere, hydrological causing mechanisms, surface and ground water uses, spatial and temporal data sets, and alternate conceptual models of site hydrology.

Therefore, the NRC staff concludes that the identification and consideration of the hydrological setting of the site set forth above are acceptable and meets the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d). In view of the above, the NRC staff finds the applicant's proposed site characterization related to the hydrological setting for the ESP application to be acceptable.

2.4.2 Floods

Section 2.4.2 of the SSAR identified historical flooding (defined as occurrences of abnormally high water stage or overflow from a stream, floodway, lake, or coastal area) at the proposed site or in the region of the site. The applicant, in Section 2.4.2 of the SSAR, summarized and identified the individual types of flood-producing phenomena, and combinations of flood-producing phenomena, considered in establishing the flood design bases for safety-related plant features. In addition, the SSAR covered the potential effects of local intense precipitation. Although topical information may appear in SSAR Sections 2.4.3 through 2.4.7 and Section 2.4.9, the types of events considered and the controlling event are reviewed in this section of the SER.

The NRC staff reviews the flood history and the potential for flooding for the sources and events listed below. Factors affecting potential runoff (such as urbanization, forest fire, or change in agricultural use), erosion, and sediment deposition are considered in the NRC staff's review. In addition to describing flood history, the applicant also determined the local intense precipitation on the site in order to estimate local flooding. Local intense precipitation is reported as a site characteristic used in site grading design. The NRC staff's review of the SSAR covered (1) local flooding on the site and drainage design, (2) stream flooding, (3) surges, (4) seiches, (5) tsunami, (6) seismically induced dam failures (or breaches), (7) flooding caused by landslides, (8) effects of ice formation in water bodies, (9) combined events criteria, (10) consideration of other site-related evaluation criteria, and (11) additional information for 10 CFR Part 52 applications.

2.4.2.1 Introduction

The VEGP site is located on the southeast side of the Savannah River, approximately 15 miles east-northeast of Waynesboro, Georgia, 26 miles southeast of Augusta, Georgia, and 100 miles north-northwest of Savannah, Georgia (SNC, 2006). The VEGP site is located approximately 150 river miles upstream of the mouth of the Savannah River. Elevations in the Savannah River basin range from sea level at the mouth to 5030 feet mean sea level (MSL) at Little Bald Peak in North Carolina. The Savannah River system drains a total of 10,577 square

miles. The contributing watershed area of the Savannah River near the VEGP site is approximately 8304 square miles.

There are 14 dams in the Savannah River Basin upstream of the VEGP site (SNC, 2006), which are owned and operated by the U.S. Army Corps of Engineers (USACE) or one of several power generation companies in Georgia and South Carolina. The three major USACE multipurpose projects regulate the entire 312-mile reach of the Savannah River. The three reservoirs created by these projects are Hartwell Lake and Dam, Richard B. Russell Lake and Dam, and J. Strom Thurmond Lake and Dam (also known as Clarks Hill Lake and Dam).

The VEGP site is located on a high bluff on the west bank of the Savannah River and has an area of approximately 3169 acres (SNC, 2006). The grade elevations of the proposed Units 3 and 4 will be 220 feet MSL or higher. Approximately 4 miles from the VEGP site, Georgia State Highway 23 runs along a topographic ridgeline. The ridgeline separates drainages that generally flow northeast toward the Savannah River from drainages that generally flow to the southwest.

Potential causes of floods at the VEGP site are local runoff from intense point-rainfall near the site and flooding in the Savannah River caused by precipitation in the river basin or floods from cascading failure of upstream dams on the river. The VEGP site is located approximately 150 river miles inland from the ocean; therefore, flooding caused by surges, seiches, and oceanic tsunamis is unlikely to occur. Section 2.4.7 of the SERs addresses Ice-related events that may result in flooding.

2.4.2.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

Section 2.4.2 of RS-002 provides the review guidance that the NRC staff used to evaluate this SSAR section.

- To satisfy the hydrologic requirements of 10 CFR Part 52 and 10 CFR Part 100, the SSAR should contain a description of the surface and subsurface hydrologic characteristics of the site and region and an analysis of the PMF. This description should be sufficient to assess the acceptability of the site and the potential for those characteristics to influence the design of plant SSCs important to safety. Meeting this

guidance provides reasonable assurance that the hydrologic characteristics of the site and potential hydrologic phenomena will pose no undue risk to the type of facility proposed for the site.

As stated in Section 2.4.2 of RS-002, to judge whether the applicant has met the hydrologic requirements of 10 CFR Part 52 and 10 CFR Part 100, the NRC uses the following criteria:

- For SSAR Section 2.4.2.1 (Flood History), the NRC staff compares the potential flood sources and flood response characteristics of the region and site identified in its review (as described in the review procedures) to those identified by the applicant. If similar, the NRC staff accepts the applicant's conclusions. If, in the NRC staff's opinion, significant discrepancies exist, the applicant must provide additional data, reestimate the effects on a nuclear unit(s) of a specified type that might be constructed on the proposed site, or revise the applicable flood design bases, as appropriate.

- For SSAR Section 2.4.2.2 (Flood design Considerations), the applicant's estimate of controlling flood levels is acceptable if it is no more than 5 percent less conservative than the NRC staff's independently determined (or verified) estimate. If the applicant's SSAR estimate is more than 5 percent less conservative, the applicant should fully document and justify its estimate of the controlling level. Alternatively, the applicant may accept the NRC staff's estimate.

- For SSAR Section 2.4.2.3 (Effects of Local Intense Precipitation), the applicant's estimates of the local PMP and the capacity of site drainage facilities (including drainage from the roofs of buildings and site ponding) are acceptable if the estimates are no more than 5 percent less conservative than the corresponding NRC staff assessment. Similarly, conclusions relating to the potential for any adverse effects of blockage of site drainage facilities by debris, ice, or snow should be based upon conservative assumptions of the storm and vegetation conditions likely to exist during storm periods. If a potential hazard does exist (e.g., the elevation of ponding exceeds the elevation of plant access openings), the applicant should document and justify the local PMP basis.

- The NRC staff used the appropriate sections of several documents to determine the acceptability of the applicant's data and analyses in meeting the requirements of 10 CFR Part 52 and 10 CFR Part 100. RG 1.59, Revision 2, "Design Basis Floods for Nuclear Power Plants," issued August 1977, provides guidance for estimating the design-basis flooding considering the worst single phenomenon, as well as combinations of less severe phenomena. The NRC staff used the publications of USGS, NOAA, SCS, USACE, applicable State and river basin authorities, and other similar agencies to verify the applicant's data relating to the hydrologic characteristics and extreme events in the region.

2.4.2.3 Technical Evaluation

The technical evaluation consists of (1) a review of the applicant's technical information presented in the SSAR, and (2) the NRC staff's technical evaluation to determine the potential for site flooding due to various flooding mechanisms.

2.4.2.3.1 Technical Information Presented by the Applicant

Flood History

In Section 2.4.2 of the SSAR, the applicant characterized the historical flooding in streams near the VEGP site was characterized using the discharge record at the USGS gauge 02197000, located on the Savannah River at Augusta, Georgia, approximately 48.7 river miles upstream of the site (SNC, 2006). The maximum annual peak flood discharge of 350,000 cubic feet per second was reported on October 2, 1929. The discharge on January 17, 1796 was estimated to be between 280,000 cubic feet per second for a reported stage of 38 feet (USGS, 2006; gauge datum at 96.58 feet MSL) and 360,000 cubic feet per second for a reported stage of 40 feet (USGS, 1990). Based on an elevation of 96.58 feet MSL for the Augusta, Georgia stream gage datum, the applicant concluded that the historical maximum stage of the Savannah River near the VEGP site is, therefore, between 134.6 and 136.6 feet MSL.

The applicant noted that the average annual peak discharges have declined since the three dams were constructed on the Savannah River (SNC, 2006).

Design-Basis Flood

The applicant selected the design-basis flood from several flooding scenarios including an approximate estimate of the PMF, flooding caused by local intense precipitation on local drainages, and potential dam-failure-generated floods with coincident wind setup and wave runup (SNC, 2006). Flooding from storm surges, seiches, and tsunamis was not considered since the VEGP site is located approximately 150 river miles inland from the Atlantic Coast (SNC, 2006).

The applicant determined that the design-basis flood for the VEGP site is a flood generated by an upstream breach of dams with coincident wind setup and wave runup. SSAR Section 2.4.4 provides a detailed estimation of this flooding event, which was reviewed by the NRC staff in Section 2.4.4 below.

Local Intense Precipitation

The local intense precipitation was estimated from the recommendations of Hydrometeorological Report Nos. 51 and 52 (SNC, 2006). The 6-hour, 10-square miles PMP depth was estimated from Hydrometeorological Report No. 51 for the location of the VEGP site. A multiplier for the VEGP site was estimated from Hydrometeorological Report No. 52 that, when applied to the 6-hour, 10-square miles PMP depth, yielded the 1-hour, 1-square mile PMP depth. Another set of multipliers for the VEGP site were also obtained from Hydrometeorological Report No. 52. This set of multipliers was applied to the 1-hour, 1-square mile PMP depth to obtain PMP depths at 30, 15, and 5 minutes. The applicant's local intense precipitation is presented in Table 2.4.2-1.

Table 2.4.2-1 - Local Intense Precipitation Depths for Various Durations at the VEGP Site

Duration	Area (square miles)	Multiplier	Applied to	Local Intense Precipitation (inches)
6 hours	10	NA	NA	31.0
1 hour	1	0.620	6-hour, 10-square miles value	19.2
30 minutes	1	0.736	1-hour, 1-square mile value	14.1
15 minutes	1	0.509	1-hour, 1-square mile value	9.8
5 minutes	1	0.323	1-hour, 1-square mile value	6.2

2.4.2.3.2 NRC Staff's Technical Evaluation

The NRC staff's technical evaluation consisted of a review of the data and methods presented in the applicant's SSAR. Sections 2.4.2 through 2.4.7, and 2.4.9 of the SER describe the NRC staff's review of various flooding mechanisms. Based on these reviews, the NRC staff verified that the design-basis flooding scenario at the VEGP site consisted of a domino-type dam-failure scenario-generated flood, and coincident wind setup and wave runup scenario.

The NRC staff independently estimated the local intense precipitation for the VEGP site in order to verify applicant's submission in SSAR Section 2.4.2. Hydrometeorological Report No. 52 recommends that local intense precipitation or point precipitation be estimated as a 1-hour, 1-square mile PMP event. Hydrometeorological Report No. 52 presents a set of maps of estimated PMP depths for several durations ranging from 6 to 72 hours and several areas ranging from 10 to 20,000 square miles. The PMP approach only addressed areas 10 square miles and larger and durations of 6 hours and greater. In order to estimate PMP depths at a point (essentially a 1 square mile area) and for durations of 1 hour and less, Hydrometeorological Report No. 52 recommends the use of a set of multipliers to first estimate the 1-hour, 1-square mile PMP depth from the 6-hour, 10-square miles PMP depth followed by the application of the apply multipliers to the 1-hour, 1-square mile PMP depth to obtain shorter-duration PMP depths for a 1-square mile area.

The 6-hour, 10-square miles PMP for the VEGP site location was estimated from the PMP depth map corresponding to 6-hour duration and 10-square miles drainage area. Hydrometeorological Report No. 52 maps of multipliers were used to obtain the set of multipliers for the VEGP site. Table 2.4.2-2 shows the NRC staff's estimate of the local intense precipitation.

Table 2.4.2-2 - The NRC Staff-estimated Local Intense Precipitation Depths for Various Durations at the VEGP Site

Duration	Area (square miles)	Multiplier	Applied to	Local Intense Precipitation (inches)
6 hours	10	NA	NA	31.0
1 hour	1	0.621	6-hour, 10-square miles value	19.3
30 minutes	1	0.738	1-hour, 1-square mile value	14.2
15 minutes	1	0.509	1-hour, 1-square mile value	9.8
5 minutes	1	0.323	1-hour, 1-square mile value	6.2

The NRC staff concluded that the local intense precipitation values reported by the applicant in the SSAR are essentially identical (less than 5% different) to those independently estimated by the NRC staff and, thus, are acceptable. The local intense precipitation values reported by the applicant in Table 2.4.2-3 of the SSAR will be used as a site characteristic for the VEGP site.

2.4.2.4 Conclusion

The NRC staff independently confirmed the local intense precipitation values estimated and presented by the applicant in SSAR Section 2.4.2. The local intense precipitation values reported by the applicant in Table 2.4.2-3 of the SSAR will be used as a site characteristic for the VEGP site. As discussed in Section 2.4.4 of this SER, the NRC staff also verified that the controlling flood for the VEGP site consists of a domino-type dam failure scenario-generated flood and coincident wind setup and wave runup scenario.

The applicant has presented and substantiated sufficient information pertaining to the local intense precipitation, flooding causal mechanisms, and the controlling flooding mechanism at the proposed site. RS-002, Section 2.4.2 provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating the local intense precipitation, flooding causal mechanisms, and the controlling flooding mechanism in the vicinity of the site and site regions. The applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area, and reasonable combinations of these phenomena in establishing the design-basis information pertaining to the local intense precipitation, flooding causal mechanisms, and the controlling flooding mechanism. The applicant's analysis contained sufficient margin for the limited accuracy, quantity, and period of time in which the historical data has been accumulated. As documented in SERs for previous licensing actions, the NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, the NRC staff concludes that the identification and consideration of the local intense precipitation, flooding causal mechanisms, and the controlling flooding mechanism set forth

above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d).

In view of the above, the NRC staff finds the applicant's proposed site characteristics related to the local intense precipitation, flooding causal mechanisms, and the controlling flooding mechanism for inclusion for the ESP application to be acceptable.

2.4.3 Probable Maximum Flood (PMF) On Streams And Rivers

In this section of the SSAR, the applicant developed the hydrometeorological design basis to determine the extent of any flood protection required for those SSC necessary to ensure the capability to shut down the reactor and maintain it in a safe shutdown condition. The NRC staff's review of the SSAR covers (1) design bases for flooding in streams and rivers, (2) design bases for site drainage, (3) consideration of other site-related evaluation criteria, and (4) additional information for 10 CFR Part 52 applications.

2.4.3.1 Introduction

The VEGP site is located on the southeast side of the Savannah River, approximately 15 miles east-northeast of Waynesboro, Georgia; 26 miles southeast of Augusta, Georgia; and 100 miles north-northwest of Savannah, Georgia (SNC, 2006). The VEGP site is located approximately 150 river miles upstream of the mouth of the Savannah River. The Elevations in the Savannah River basin range from sea level at the mouth to 5030 feet MSL at Little Bald Peak in North Carolina. The Savannah River system drains a total of 10,577 square miles. The contributing watershed area of the Savannah River near the VEGP site is approximately 8304 square miles.

A PMP in the watershed of the Savannah River can cause a flood near the site. The NRC staff's evaluation in this section consisted of verifying the applicant's approach for estimating the PMF in the Savannah River near the VEGP site and independently estimating the PMF.

2.4.3.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

To evaluate the information provided in SSAR 2.4 per the above acceptance criteria, applicant applied the NRC-endorsed analytical methodologies found in RG 1.59, Revision 2, issued August 1977.

Section 2.4.3 of RS-002 provides the review guidance used by the NRC staff to evaluate this SSAR section.

- To satisfy the hydrologic requirements of 10 CFR Part 52 and 10 CFR Part 100, the SSAR should contain a description of the hydrologic characteristics of the site and region and an analysis of the PMF. This description should be sufficient to assess the acceptability of the site and the potential for those characteristics to influence the design of SSCs important to safety for a nuclear unit(s) of a specified type that might be constructed on the proposed site. Meeting this guidance provides reasonable assurance that any hydrologic phenomena of severity up to and including the PMF will pose no undue risk to the type of facility proposed for the site.

- To judge whether the applicant has met the requirements of the hydrologic aspects of 10 CFR Part 52 and 10 CFR Part 100, the NRC uses specific criteria.

- The PMF, as defined in RG 1.59, has been adopted as one of the conditions to be evaluated in establishing the applicable stream and river flooding design basis referenced in GDC 2. PMF estimates are needed for all adjacent streams or rivers and site drainage (including the consideration of PMP on the roofs of safety-related structures). The criteria for accepting the applicant's PMF-related design basis depend on one of the following three conditions:

    1. The elevation attained by the PMF (with coincident wind waves) establishes a necessary protection level to be used in the design of the facility.

    2. The elevation attained by the PMF (with coincident wind waves) is not controlling; the design-basis flood protection level is established by another flood phenomenon (e.g., the probable maximum hurricane (PMH)).

    3. The site is "dry"; that is, the site is well above the elevation attained by a PMF (with coincident wind waves).

- When condition (1) is applicable, the NRC staff will assess the flood level. The NRC staff may perform this assessment independently from basic data, by detailed review and checking of the applicant's analyses, or by comparison with estimates made by others that have been reviewed in detail. The applicant's estimates of the PMF level and the coincident wave action are acceptable if the estimates are no more than 5 percent less conservative than the NRC staff estimates. If the applicant's estimates of discharge are more than 5 percent less conservative than the NRC staff's, the applicant should fully document and justify its estimates or accept the NRC staff estimates.

- When condition (2) or (3) applies, the NRC staff analyses may be less rigorous. For condition (2), acceptance is based on the protection level estimated for another flood-producing phenomenon exceeding the NRC staff estimate of PMF water levels. For condition (3), the site grade should be well above the NRC staff assessment of PMF

water levels. The evaluation of the adequacy of the margin (difference in flood and site elevations) is generally a matter of engineering judgment. Such judgment is based on the confidence in the flood-level estimate and the degree of conservatism in each parameter used in the estimate.

- The NRC staff used the appropriate sections of several documents to determine the acceptability of the applicant's data and analyses. RG 1.59 provides guidance for estimating the PMF design basis. Publications by NOAA and USACE may be used to estimate PMF discharge and water level conditions at the site, as well as coincident wind-generated wave activity.

2.4.3.3 Technical Evaluation

The technical evaluation consists of (1) a review of the applicant's technical information presented in the SSAR, and (2) NRC staff's technical evaluation to determine the potential for site flooding due to PMF.

2.4.3.3.1 Technical Information Presented by the Applicant

The proposed site grade for the new units is 220 feet MSL. The applicant reviewed studies and analysis that were performed for the existing VEGP units to verify that their conclusions are valid for proposed units. The applicant also performed an approximate PMF estimation as described in RG 1.59 to alternatively estimate the maximum flood stage in the Savannah River near the VEGP site.

Previous Studies

For the original VEGP Units 1 and 2, the applicant used two approaches in determinating the PMF in the Savannah River near the VEGP site.

- The first approach used PMP values estimated from Hydrometeorological Report Nos. 51 and 52 and routed the PMP using the U.S. Army Corps of Engineers (USACE) HEC-1 Flood Hydrograph Computer Program. The watershed that was upstream of the Thurmond Dam was characterized by NWS-estimated unit hydrographs of 10 subbasins. The applicant used the USACE DAMBRK computer program to model separately the valley storage below this Thurmond dam. The peak PMF discharge at the VEGP site was reported as 895,000 cubic feet per second when ignoring valley storage and as 540,000 cubic feet per second when accounting for valley storage. The associated flood water surface elevations were 136 feet MSL and 126 feet MSL, respectively. The flood water surface elevation with coincident wind wave action was reported as 163 feet MSL and 153 feet MSL.

- In the second approach, the USACE DAMBRK computer program was used to route the USACE-derived PMF outflow hydrograph from the Thurmond Dam to the VEGP site and combining the PMF outflow hydrograph with the PMF discharge of the drainage area downstream of this dam. The PMF discharge in the Savannah River near the VEGP site was estimated as 710,000 cubic feet per second with a corresponding water surface

elevation of 138 feet MSL. The PMF water surface elevation with coincident wind wave action was estimated as 165 feet MSL.

Approximate PMF Estimation

The applicant used the alternative method for estimation of the PMF described in RG 1.59. The PMF values corresponding to 100, 500, 1000, 5000, 10,000, and 20,000 square miles of contributing areas were obtained from PMF isoline maps given in RG 1.59. The applicant estimated a best-fit power curve to this data and used the estimated power curve to predict the PMF in the Savannah River near the VEGP site. The applicant estimated that the PMF at the VEGP site corresponding to a contributing area of 8,304 square miles is 920,000 cubic feet per second.

In SSAR Section 2.4.4, the applicant simulated floods caused by dam failure to determine the flood water surface elevation that corresponded to the PMF discharge from a stage-discharge relationship obtained from a steady-state backwater analysis for the Savannah River. The flood water surface elevation corresponding to the peak PMF discharge was 138.8 feet MSL.

As described in SSAR Section 2.4.4, the applicant used a 50 miles per hour windspeed over a fetch of 11 miles to estimate the wind setup and wave runup. The estimated wind setup and wave runup was 11.3 feet. The PMF water surface elevation with coincident wind wave action was estimated as 150.1 feet MSL, 69.9 feet below the proposed site grade. As such, the applicant concluded that the VEGP site is a dry site.

2.4.3.3.2 NRC staff’s Technical Evaluation

NRC staff’s technical evaluation consisted of reviewing the data and methods presented in the applicant’s SSAR. The NRC staff independently estimated the PMF and performed an assessment of impacts for flooding on the VEGP site.

In order to verify the applicant’s submittal related to PMF in the Savannah River near the VEGP site, the NRC staff carried out an independent and conservative estimate of the PMF. The NRC staff first estimated the PMP in the Savannah River Basin, as described in Hydrometeorological Report Nos. 51 and 52. The cumulative PMP depths for 6, 12, 24, 48, and 72 hours were obtained from the PMP maps in Hydrometeorological Report No. 51 for drainage areas of 10, 200, 1000, 5000, 10,000, and 20,000 square miles (Table 2.4.3-1). The NRC staff plotted a set of depth-area-duration curves for the PMP values (Figure 2.4.3-1).

Table 2.4.3-1 - PMP Depths for Various Drainage Areas and Durations near the VEGP Site

Area (square miles)	Duration (hours)				
	6	12	24	48	72
10	31.0	37.0	43.8	48.2	51.0
200	23.0	27.9	35.0	38.0	42.0
1000	16.9	22.5	28.5	33.5	35.2
5000	9.7	14.0	19.3	23.8	27.5
10000	7.4	11.1	15.8	20.0	23.3
20000	5.4	8.8	12.5	16.2	19.2

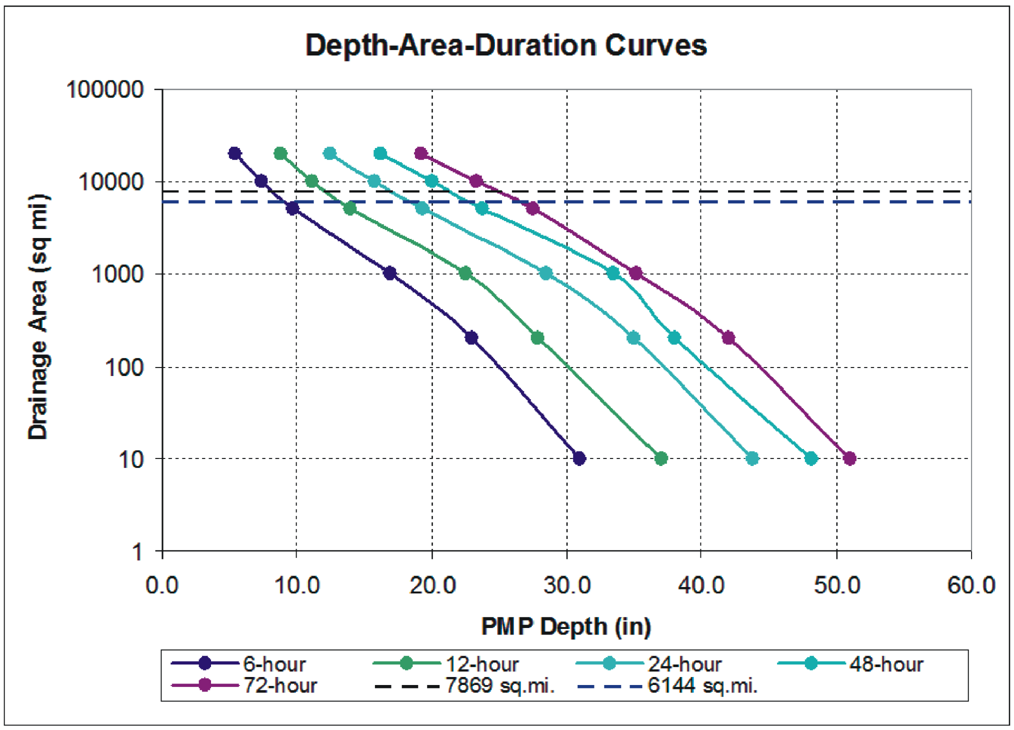

Figure 2.4.3-1 - PMP Depth-Area-Duration Curves Near the VEGP site

The drainage area at the VEGP site was estimated from the hydrologic unit codes that drain areas upstream of the site. The NRC staff estimated the drainage area at the VEGP site to be 7869 square miles. The cumulative PMP values for durations of 6, 12, 24, 48, and 72 hours were then estimated for the corresponding drainage area of the Savannah River near the VEGP site from the depth-area-duration plot (Table 2.4.3-2).

Table 2.4.3-2 - Cumulative PMP for the Savannah River Drainage Area Upstream of the VEGP Site

Area (square miles)	Duration (hours)				
	6	12	24	48	72
7869	8.2	12.1	17.1	21.3	24.9

The incremental PMP depths were calculated from the estimated cumulative PMP depths and the recommended procedure of the American National Standards Institute/American Nuclear Society (ANSI/ANS) Standard 2.8-1992 to estimate the time distribution of the 72-hour PMP storm at 6-hour increments (Table 2.4.3-3).

Table 2.4.3-3 - Incremental 6-hourly PMP Values of the 72-hour PMP Storm for the Savannah River Drainage Near the VEGP Site

6-hr period	Depth (inches)	Group	ANSI/ANS-2.8-1992 Rearrange	PMP Depth (inches)	Time (hour)
1	8.20	1	2.50	1.05	6
2	3.90		3.90	1.05	12
3	2.50		8.20	1.05	18
4	2.50		2.50	1.05	24
5	1.05	2	1.05	2.50	30
6	1.05		1.05	3.90	36
7	1.05		1.05	8.20	42
8	1.05		1.05	2.50	48
9	0.90	3	0.90	0.90	54
10	0.90		0.90	0.90	60
11	0.90		0.90	0.90	66
12	0.90		0.90	0.90	72

In order to estimate the flooding hazard at the VEGP site from a PMF in the Savannah River, the NRC staff adopted a bounding approach. The NRC staff started with a very conservative scenario under which the PMF is obtained by assuming that no losses occur during the PMP event and all of the runoff generated within the drainage area of the Savannah River upstream of the VEGP site is instantaneously delivered to the river near the VEGP site. Under this extremely conservative scenario of PMF generation, the NRC staff estimated the peak PMF discharge in the Savannah River near the VEGP site as 6.94 million cubic feet per second by multiplying the drainage area with the precipitation depth during the 6–hour period with maximum estimated PMP precipitation. Then the volume of water thus obtained was converted to an average discharge during that 6-hour period. The stage-discharge relationship estimated during the review of dam failure-generated floods, described in Section 2.4.4 of this report, indicated that the water surface elevation corresponding to a discharge of 6.94 million cubic feet per second would exceed the site grade. Therefore, the NRC staff determined that the first PMF estimation approach was unnecessarily too conservative. The NRC staff refined their approach for estimating the PMF in the Savannah River near the VEGP site.

In this new approach, the NRC staff estimated the PMF inflow into the Thurmond Lake and then the routed outflow from the Thurmond Dam to the VEGP site. The NRC staff estimated the PMP storm over the 6144 square miles of contributing area for Thurmond Lake, following the same procedure described above for estimation of the PMP storm for the 7689 square miles contributing area at the VEGP site. The NRC staff estimated the maximum depth of PMP for any 6-hour duration in the PMP storm for the contributing area of the Thurmond Lake to be 8.9 inches. In addition, the NRC staff estimated the corresponding maximum PMF inflow into Thurmond Lake assuming no losses and instantaneous translation as 5.9 million cubic feet per second. The NRC staff postulated that this inflow will then be released from the Thurmond Dam and flow downstream to the VEGP site. In Section 2.4.4, the NRC staff computed the flood from the cascading failure of the Russell Dam located upstream of the Thurmond Dam followed by the failure of the Thurmond Dam itself. The inflow into the Thurmond Lake due to the upstream failure of the Russell Dam was 6.5 million cubic feet per second. The NRC staff estimated the corresponding peak discharge as 2.5 million cubic feet per second and the corresponding water surface elevation as 170.1 feet MSL in the Savannah River near the VEGP site after being attenuated along the 70-mile river reach between the Thurmond Dam and the site. The PMF generated by a PMP in the drainage area of the Thurmond Lake would produce an inflow (5.9 million cubic feet per second) less severe than that generated by the postulated failure of the Russell Dam upstream of the Thurmond Lake (6.5 million cubic feet per second). Therefore, the NRC staff concluded that the PMF inflow into the Thurmond Lake is bounded by inflow into the Thurmond Lake caused by the postulated breach of the Russell Dam.

The NRC staff postulated that the outflow from the Thurmond dam would combine with the flood response from the contributing area downstream of the dam and upstream of the VEGP site during the PMP event. This contributing area is 1545 square miles in size (7689 square miles contributing area at the VEGP site – 6144 square miles contributing area for the Thurmond Lake). The NRC staff estimated the peak PMF runoff from this contributing area by conservatively assuming that no losses occur during the PMP event, that the runoff generated anywhere in this area is instantaneously translated to the VEGP site, and that the timing of the peak flow from this area coincides with that of the peak flow of the discharge from the Thurmond Lake routed to the VEGP site. The NRC staff estimated the peak discharge from the 1545 square miles contributing area downstream of the Thurmond dam as approximately 1.4 million cubic feet per second (8.2 inches of excess rainfall over 1545 square miles of drainage area converted to average discharge over a duration of six hours).

The NRC staff conservatively estimated the combined peak discharge in the Savannah River near the VEGP site by adding the bounding peak discharge of 2.5 million cubic feet per second near the VEGP site to the peak PMF discharge of 1.4 million cubic feet per second from the 1545 square miles of contributing area downstream of the Thurmond Dam and upstream of the VEGP site. The bounding peak PMF discharge in the Savannah River near the VEGP site is thus estimated as 3.9 million cubic feet per second. This peak discharge is less than the 5.9 million cubic feet per second needed to raise the stillwater elevation in the Savannah River to inundate the proposed site grade of 220 feet MSL.

The NRC staff estimated the maximum wind wave runup at the VEGP site corresponding to an ANSI/ANS-2.8-1992-recommended windspeed of 50 miles per hour and a maximum fetch of 11 miles, as approximately 19 feet (see Section 2.4.4 of this SER). The NRC staff also estimated the stillwater elevation corresponding to a discharge of 3.9 million cubic feet per second in the Savannah River near the VEGP site using the stage-discharge function estimated

in Section 2.4.4 of this SER. The NRC staff-estimated stillwater elevation corresponding to a discharge of 3.9 million cubic feet per second was 194.8 feet MSL. The bounding maximum water surface elevation accounting for wind wave action was therefore, 213.8 feet MSL (194.8 feet MSL + 19 feet). The NRC staff concluded, therefore, that the VEGP site will remain dry during a bounding PMF event in the Savannah River watershed. This conclusion meets the criterion (3) described above in Section 2.4.3.2.

2.4.3.4 Conclusion

The VEGP site is a dry site with respect to floods in rivers and streams. All safety-related SSC will be placed above the highest flood water surface elevation.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the PMF on streams and rivers at the proposed site. RS-002, Section 2.4.3 provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating the probable maximum flood on streams and rivers. Furthermore, the applicant considered local flooding of the site drainage under local intense precipitation in establishing design-basis information pertaining to flooding, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, the NRC staff concludes that the identification and consideration of the probable maximum floods on streams and rivers set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d).

In view of the above, the NRC staff finds the applicant's proposed site characteristics related to the PMF on streams and rivers for the ESP application to be acceptable.

2.4.4 Potential Dam Failures

In this section of the site SSAR (SSAR), the hydrological design basis is developed to ensure that any potential hazard to the safety-related facilities resulting from the failure of onsite, upstream, and downstream water control structures are considered in plant design. The NRC staff's review of the SSAR covers (3) flood waves from severe breaching of an upstream dam, (2) domino-type or cascading dam failures, (4) dynamic effects of dam-failure induced flood waves on structures, (5) loss of water supply at the plant due to failure of a downstream dam, (6) effects of sediment deposition and erosion, (7) failure of onsite water control or storage structures, (8) potential effects of seismic and non-seismic information on the postulated design

bases and how they relate to dam failures in the vicinity of the site and the site region, and (9) additional information for 10 CFR Part 52 applications.

2.4.4.1 Introduction

The VEGP Site is located at Savannah River mile 150.9, and three large dams lie upstream of the site. Hartwell Dam, located 138 miles upstream of the VEGP site; Richard B. Russell Dam, located 108 miles upstream of the site; and J. Strom Thurmond Dam, located 71 miles upstream of the VEGP site, respectively (USACE 1996). Floods initiated by a domino-type failure of these upstream dams were found to produce a peak discharge and peak stage at the site that was larger than flood waves discussed in Section 2.4.3 of this SER (i.e., waves induced by rainfall events alone).

2.4.4.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.23, “Geologic and Seismic Siting Criteria,” as it relates to establishing the design-basis flood resulting from seismic dam failure

To evaluate the information provided in SSAR 2.4 per the above acceptance criteria, applicant applied the NRC-endorsed analytical methodologies found in the following:

- RG 1.70, Revision 3, issued November 1978

- RG 1.29, “Seismic Design Classification”

- RG 1.59, Revision 2, issued August 1977

- RG 1.102, Revision 1, “Flood Protection for Nuclear Power Plants,” issued September 1976.

Section 2.4.4 of RS-002 provides the review guidance that the NRC staff used to evaluate this SSAR section.

- The regulations at 10 CFR Part 52 and 10 CFR Part 100 apply to SSAR Section 2.4.4 because it addresses the site's physical characteristics, including hydrology, considered by the Commission when determining its acceptability to host a nuclear unit(s). To satisfy the hydrologic requirements of 10 CFR Part 52 and 10 CFR Part 100, the SSAR should contain a description of the hydrologic characteristics of the region and an analysis of potential dam failures. The description should be sufficient to assess the acceptability of the site and the potential for those characteristics to influence the design of SSCs important to safety. Meeting this criterion provides reasonable assurance that the effects of high water levels resulting from the failure of upstream dams, as well as those of low water levels resulting from the failure of a downstream dam, will pose no undue risk to the type of facility proposed for the site.

- The regulation at 10 CFR 100.23 requires consideration of geologic and seismic factors in determining site suitability. Specifically, 10 CFR 100.23(c) requires an investigation of the geologic and seismic site characteristics to permit evaluation of seismic effects on the site. Such an evaluation must consider seismically induced floods, including failure of an upstream dam during an earthquake.

- The regulation at 10 CFR 100.23 applies to SSAR Section 2.4.4 because it requires investigation of seismic effects on the site. Such effects include seismically induced floods or low water levels, which constitute one element in the Commission's consideration of the suitability of proposed sites for nuclear power plants. RG 1.70 provides more detailed guidance on the investigation of seismically induced floods, including results for seismically induced dam failures and antecedent flood flows coincident with the flood peak. Meeting this guidance provides reasonable assurance that, given the geologic and seismic characteristics of the proposed site, a nuclear unit(s) of a specified type could be constructed and operated on the proposed site without undue risk to the health and safety of the public, with respect to those characteristics.

- To judge whether the applicant has met the requirements of 10 CFR Part 52, 10 CFR Part 100, and 10 CFR 100.23 as they relate to dam failures, the NRC uses the following criteria:

    - The NRC staff will review the applicant's analyses and independently assess the coincident river flows at the site and at the dams being analyzed. ANSI/ANS-2.8-1992 provides guidance on acceptable river flow conditions to be assumed coincident with the dam failure event. To be acceptable, the applicant's estimates of the flood discharge resulting from the coincident events (which may include landslide-induced failures) should be no more than 5 percent less conservative than the NRC staff estimates. If the applicant's estimates differ by more than 5 percent, the applicant should fully document and justify its estimates or accept the NRC staff estimates.

    - The applicant should identify the location of dams and potentially likely or severe modes of failure, as well as dams or embankments built to impound water for a nuclear unit(s) that might be constructed on the proposed site. The applicant should discuss the potential for multiple, seismically induced dam failures and the domino failure of a series of dams. Approved USACE and Tennessee Valley

Authority models should be used to predict the downstream water levels resulting from a dam breach. First-time use of other models will necessitate complete model description and documentation. The NRC staff will review the model theory, available verification, and application to determine the acceptability of the model and subsequent analyses. For cases that assume something other than instantaneous failure, the conservatism of the rate of failure and shape of the breach should be well documented. The applicant should present a determination of the peak flow rate and water level at the site for the worst possible combination of dam failures, a summary analysis that substantiates the condition as the critical permutation, and a description of and the bases for all coefficients and methods used. In addition, the effects of other concurrent events on plant safety, such as blockage of the river and waterborne missiles, should be considered.

- The effects of coincident and antecedent flood flows (or low flows for downstream structures) on initial pool levels should be considered. Depending upon estimated failure modes and the elevation difference between plant grade and normal river levels, it may be acceptable to use conservative, simplified procedures to estimate flood levels at the site. For cases in which calculated flood levels employing simplified methods are at or above plant grade and use assumptions which cannot be demonstrated as conservative, it will be necessary to use unsteady flow methods to develop flood levels at the site. The methods described in RS-002 (ADAMS Accession No. ML040700094), are acceptable to the NRC staff; however, other criteria could be acceptable with proper documentation and justification. Applications should summarize the computations, coefficients, and methods used to establish the water level at the site for the most critical dam failures. Coincident wind-generated wave activity should be considered in a manner similar to that discussed in Section 2.4.3 of RS-002.

2.4.4.3 Technical Evaluation

The technical evaluation consists of (1) a review of the information provided by the applicant, and (2) the NRC staff's technical evaluation to determine the potential for site flooding resulting from dam failure.

2.4.4.3.1 Technical Information Presented by the Applicant

In the SSAR, the applicant presented the potential for a domino-type failure of Russell and Thurmond dams to induce flooding at the VEGP site. The applicant performed the calculation using the USACE developed Hydrologic Engineering Center River Analysis System (HEC-RAS) numerical model (2005a). The NRC staff obtained the related input files though a RAI 2.4.1-1 (Enclosure Attachment 2). The applicant's simulation conservatively estimated the volume of the dams upstream of Russell Reservoir, and placed the entire flood volume of these dams in Russell Reservoir at the start of the simulation.

The applicant stated in the SSAR that Russell Dam was breached by overtopping in the HEC-RAS model. After investigating the applicant's model input files, the NRC staff determined that the dam was actually breached by a piping-type failure placed midway up the dam (elevation 420 feet MSL). The dam was assumed to breach 2 hours after the start of the simulation.

The SSAR describes how the applicant chose its breach parameters, and how the selection process applied references from the relevant technical literature. The applicant selected methods that were described in the US Bureau of Reclamation (USB), Department of Interior (1998) Predication of Embankment Dam Breach Parameters: A literature Review and Needs Assessment, Dam Safety Office, Water Resources Research Laboratory. These USB methods are accepted current engineering practices. Breaches of both dams extend the full height of the each dam, and the HEC-RAS model defined them using three parameters: bottom width of the breach, left and right side slope, and breach formation time. For the Russell Dam, the bottom width was 750 feet, the side slopes were 2, and the breach time was 1.0 hour. For the Thurmond Dam, the bottom width was 755 feet, the side slopes were 2, and the breach time was 1.0 hour.

The SSAR states that the applicant assigned the initial water surface elevation in Thurmond Reservoir to be 344.7 feet MSL. After reviewing the applicant's HEC-RAS input files, the NRC staff determined that the actual initial elevation assumed in the model analysis was 342.1 feet MSL. The applicant correctly described elevation 342.1 feet MSL to be the Standard Project Flood (SPF) elevation for Thurmond Reservoir (USACE 1996).

The applicant's computed results for the unsteady dam beach and routing analysis was a peak water surface elevation of 166.8 feet MSL at the VEGP site. The computed peak flow at the VEGP site was approximately 2.3 million cubic feet per second. The applicant also computed the wave runup due to the maximum wave height. Based on ANS/ANSI 2.8 (1992), a 50 miles per hour wind was applied to the longest fetch (11.1 miles) during passage of the flood wave. The resulting maximum wave height was 7.5 feet, with a corresponding maximum runup height of 11.3 feet. After combining the runup height and the peak flood stage, the applicant computed the maximum flood level at the VEGP site as 178.1 feet MSL. This elevation is 41.9 feet below site grade.

2.4.4.3.2 NRC staff's Technical Evaluation

NRC staff independently reviewed the applicant's estimate of the flood water height at the VEGP site resulting from a domino-type failure of upstream dams. This evaluation consisted of a steady flow analysis, used to compute the Savannah River discharge necessary for the water surface elevation at the site to reach the site grade, and (b) an unsteady flow analysis, used to compute the maximum stage and discharge in the Savannah River should an upstream domino-type dam failure occur.

Steady Flow Analysis

The NRC staff performed a steady flow analysis to compute the stage versus discharge rating curve at the VEGP site. The analysis used the current public release of HEC-RAS, version 4.0, which is a numerical model developed by the USACE HEC (HEC-RAS, 2006).

In response to RAI 2.4.1-1, the applicant provided electronically the initial geometric description of Russell and Thurmond dams and the Savannah River cross-sections between river miles 259.2 and 99.4. The applicant stated in SSAR Section 2.4.4.2 that these data were supplied in HEC-RAS format directly from the USACE, Savannah River District. The NRC staff's analysis utilized the latest public release of HEC-RAS, a numerical model developed by the HEC, USACE (HEC-RAS 2006). The NRC staff independently confirmed the geometric description of the dams and cross-sections using USACE (1996) and a 30-meter digital elevation model (DEM) data from the USGS.

The applicant developed HEC-RAS model, was modified by the NRC staff to remove cross-sections and reservoirs upstream of Thurmond Dam tailrace for the steady-state flow analysis. The NRC staff then applied a series of constant flow upstream boundary conditions ranging between 3,800 and 6,400,000 cubic feet per second to compute the rating curve for the Savannah River adjacent to the site. Based on this rating curve, the river discharge at the site necessary for the static water surface elevation to reach elevation 220 feet MSL is approximately 5.9 million cubic feet per second. This discharge is greater than 2.5 times the peak unsteady-flow discharge computed by the applicant as passing at the VEGP site during the dam break analysis. However, as discussed below, the discharge conservatively estimated by the NRC staff using the unsteady flow analysis did not exceed 5.9 million cubic feet per second.

Unsteady Flow Analysis

The NRC staff performed an unsteady flow analysis to examine the sensitivity of the applicant's model parameters. Using the model input files provided by the applicant, this analysis used a bounding assumption to simplify the distribution of impounded water in the Savannah River basin upstream of Thurmond Dam. This assumption assigned as an initial condition of the model, the volume of water impounded in Russell Reservoir to be equal to the maximum volume of water impounded by all dam upstream, including Russell Dam. In other words, the initial Russell Reservoir volume assigned by the applicant, and used by the NRC staff in the unsteady-flow analysis, was 8,022,500 acre-ft. As shown in Table 2.4.4.1, this initial impounded volume was greater than the cumulative impounded volume of all reservoirs in the Savannah River watershed upstream of Russell Dam.

The NRC staff's analysis was similar to the applicant's in that Russell Dam was assumed to breach early in the simulation, followed by an overtopping breach of Thurmond Dam downstream. Both the applicant's and the NRC staff's analyses excluded all bridges and dams downstream of Thurmond Dam, which could constrict the flow of the flood wave and hence attenuate the flood at the VEGP site. The NRC staff assumed that the initial water surface elevation in Thurmond Reservoir was at the Standard Project Flood (SPF) level (elevation of 342.1 feet). The initial Savannah River discharge passing through Thurmond Dam before the breach and downstream, including at the VEGP Site, was 560,000 cubic feet per second. This discharge represents the SPF maximum estimated outflow at Thurmond Dam (USACE 1996).

Table 2.4.4.1 - Storage Volumes of Reservoirs Upstream of Russell Dam

Dam	River System	River Mile above Savannah River Mouth [1]	Maximum Storage (acre-feet) [2]
Bad Creek	Keowee	368.6	33,892
Jocassee	Keowee	366.5	1,287,788
Keowee	Keowee	351.5	955,586
Burton	Tallulah	381.4	108,000
Nacoochee	Tallulah	377.1	8,100
Mathis-Terrora	Tallulah	362.8	31,000
Tallulah Falls	Tallulah	359.9	2,400
Tugaloo	Tugaloo	358.1	42,200
Yonah	Tugaloo	354.9	11,700
Hartwell	Savannah	288.9	3,438,700
Russell	Savannah	259.1	1,488,166
Total			7,407,532

[1] From USACE (1996)
[2] From NID (2007)

The Russell Dam breach simulated by the applicant extended from the thalweg (elevation 345 feet) and to the top of the dam. The final bottom width of the breach was 750 feet, and the breach side slope was 2, resulting in a top width of 1350 feet. These breach parameters are reasonable, and fall within the range suggested by USBR (1998). However, to test the sensitivity of the model to these selected values, the NRC staff increased the total breach area by 50 percent (a more conservative assumption). Specifically, the breach bottom width was increased to 975 feet, the side slope was increased to 4, and the top width was increased to 2175 feet. The impact of this 50 percent increase in total breach area was to increase the peak discharge from Russell Dam, from 4.5 million cubic feet per second to 6.5 million cubic feet per second (approximately 45 percent increase in peak discharge).

The Thurmond Dam breach occurred approximately 2.5 hours after the Russell Dam breach, when the water surface elevation exceeded the top of the dam by 0.1 feet (i.e., elevation 351.1 feet). The applicant's Russell Dam breach parameters were that the final dam breach extended from the top to the bottom (elevation 200 feet) of the dam, with a bottom width of 755 feet, top width of 1359 feet, and side slopes of 2. These breach parameters are reasonable, and fall within the range suggested by USBR (1998). However, to test the sensitivity of the model to these selected values, the NRC staff increased the breach area by 50 percent (a more conservative assumption). NRC staff assigned the breach bottom width to be 981.5 feet, top width of 2189.5 feet, and side slopes of 4. The impact of this 50 percent increase in breach area was to increased the peak discharge issuing from Thurmond Dam. Under this scenario, with both Russell and Thurmond dam breach areas increased by 50 percent, the increase in peak Thurmond Dam discharge was from 5.5 million cubic feet per second to 7.8 million cubic feet per second (approximately 41 percent increase). The peak water surface elevation at Thurmond Dam also increased from 352.4 feet to 353.0 feet.

After the peak flood wave passed Thurmond Dam, the peak was attenuated because of the large overbank areas between Thurmond Dam and the VEGP site. Much of the overbank

lengths in this region are very broad, with some overbank areas extending laterally from the river for than 5 miles.

The NRC staff's evaluation mentioned above assume that the time for the full breach to develop was 1.0 hour. As described in USBR (1998), the breach formation time could take anywhere from 0.1 to 1.0 hour for engineered, compacted earth dams, using the 1987 Engineering Guidelines for the Evaluation of Hydropower Projects, FERC 0119-1, Office of Hydropower Licensing, Federal Energy Regulatory Commission (FERC) method. The sensitivity of the HEC-RAS model to this parameter was tested by decreasing the parameter to 0.1 hour. The simulation results show that the Russell Dam discharge increased to 6.7 million cubic feet per second. However, the overtopping breach at Thurmond Dam did not increase with the decrease in breach formation time. Maximum breach discharge is a function of maximum water surface elevation at the dam, and due to the rapidity of the breach the maximum stage at the dam was lowered by 2.4 feet (350.6 feet versus 353.0 feet). As expected, the maximum stage adjacent to the VEGP site was also lower with the 0.1 hour (169.9 feet) versus the 1.0 hour breach formation time. Therefore, the 1.0 hour breach formation time parameter was used for NRC staff's final analysis.

The NRC staff computed the peak discharge at the VEGP Site, after it was attenuated along the 70 miles between Thurmond Dam and the site, with approximately 2.5 million cubic feet per second. The hydrograph of water surface elevation in the Savannah River near the VEGP Site is shown in Figure 2.4.4-1 of the SER. The applicant computed the peak static water surface elevation at the VEGP site to as 166.8 feet (Southern 2007). The NRC staff's analysis, with a 50 percent increase in breach area, produced a peak water surface elevation of 170.1 feet at the site, an increase in peak flood stage of 3.3 feet.

In order to satisfy the combined effects guidance in ANS/ANSI 2.8 (1992), the maximum wave height and associated maximum wave runup were computed and added to the peak flood wave elevation. The windspeed for the site was assumed to be 50 miles per hour following the guidelines in ANS/ANSI 2.8 (1992). Based on an estimated fetch of 11.2 miles, the maximum wave height was computed to be 9.8 feet using procedures discussed in USACE (2006). In Section 2.4.4 of the SSAR, the applicant stated that the embankment slope near the site will be 2H:1V. Given this slope value and the maximum wave height, the maximum wave runup at the VEGP site was determined to be 19 feet. Combining this value with the peak static water surface elevation determined with the NRC staff's more conservative breach parameters, results in a maximum flood elevation at the VEGP site of 189.1 feet MSL. Even with a more conservative estimate of breaching parameters, the peak flood wave is 30.9 feet below the plant grade (elevation 220 feet MSL). Therefore, the NRC staff concludes that the VEGP site will not be affected by the potential failure of dams upstream of the site. The NRC staff did not apply the "no more than 5% less conservative" criterion to determine the agreement between the NRC staff's estimate of the maximum flood discharge and the corresponding water surface elevation and that of the applicant's from dam-break flooding in the Savannah River. The NRC staff only applies this criterion to compare agreement between the results obtained by the applicant and the results from the NRC staff's independent analysis when the complexity and the conservativeness of the two analyses are the same. Since the NRC staff's independent analysis of the dam-break flooding in the Savannah River is a bounding analysis that is more conservative than the analysis performed by the applicant, the NRC staff did not apply the above-mentioned rule. The NRC staff, based on their independent analysis of dam-break flooding in the Savannah River, determined that the VEGP site would not flood during the

postulated dam-break scenario. The NRC staff agree with the applicant that the VEGP site is "dry."

2.4.4.4 Conclusion

It is possible that dams upstream of the VEGP site could fail and potentially cause a domino-type cascading failure of multiple dams. However, this failure of upstream dams would not affect the VEGP site. The analysis performed by the applicant follows methods accepted in current engineering practice. The NRC staff reviewed these results by first computing the rating curve at the site, and determining that the peak flood wave discharge that was necessary to reach plant grade was more than 2.5 times the peak flood computed by the applicant. The NRC staff then adjusted the breach parameters in the applicant's HEC-RAS model to examine the sensitivity of model results. Although the peak wave could be increased using more conservative values than standard engineering practice, the resulting peak flood wave passing the VEGP site was still below the site grade by more than 30 feet. Therefore, NRC staff concludes the site is dry, and that safe operation and/or shutdown of the plant will not be affected by failure of dams upstream of the site.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the effects of dam failures at the proposed site. RS-002, Section 2.4.4 provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating the effects of dam failures. Furthermore, the applicant considered dam failures in establishing design-basis information pertaining to flooding and safety-related water supply, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs from previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, the NRC staff concludes that the identification and consideration of the dam failures set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d). The NRC staff finds the applicant's proposed site characteristics related to the dam failures for the ESP application to be acceptable.

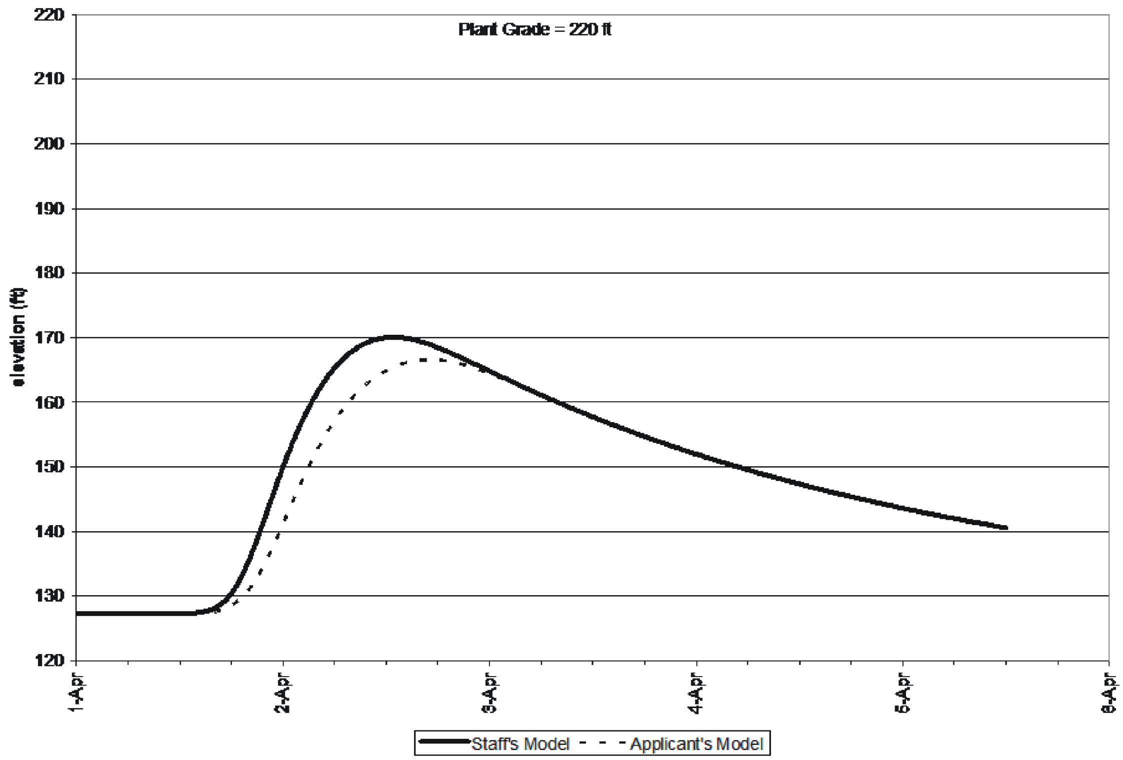

Figure 2.4.4-1 - Stage hydrograph at the VEGP Site

2.4.5 Probable Maximum Surge And Seiche Flooding

In this section of the SSAR, the hydrometeorological design basis is developed to ensure that any potential hazard to the safety-related facilities due to the effects of probable maximum surge and seiche are considered in plant design. The NRC staff's review of the SSAR covers (1) probable maximum hurricane, (2) probable maximum wind storm, (3) seiche and resonance, (4) wave runup, (5) effects of sediment erosion and deposition, (6) consideration of other site-related evaluation criteria, and (7) additional information for 10 CFR Part 52 applications.

2.4.5.1 Introduction

The VEGP site is located on the southeast side of the Savannah River, approximately 15 miles east-northeast of Waynesboro, Georgia, 26 miles southeast of Augusta, Georgia, and 100 miles north-northwest of Savannah, Georgia (SNC, 2006). The VEGP site is located approximately 150 river miles upstream of the mouth of the Savannah River. The grade elevation of the existing VEGP units and the new proposed units is 220 feet MSL.

The Savannah River is the only large body of water that could potentially flood the VEGP site due to surge and seiche effects. Section 2.4.4 discuss the increase in water surface elevation along one bank from the wind blowing across the river's surface.

2.4.5.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

To evaluate the information provided in SSAR 2.4 per the above acceptance criteria, applicant applied the NRC-endorsed analytical methodologies found in the following:

- RG 1.70, Revision 3, issued November 1978

- RG 1.29

- RG 1.59, Revision 2, issued August 1977

- RG 1.102, Revision 1, issued September 1976

- RG 1.125, Revision 1, “Physical Models for Design and Operation of Hydraulic Structures and Systems for Nuclear Power Plants,” issued October 1978

Section 2.4.5 of RS-002 provides the review guidance used by the NRC staff to evaluate this SSAR section.

- To satisfy the hydrologic requirements of 10 CFR Part 52 and 10 CFR Part 100, the applicant’s safety assessment should contain a description of the surface and subsurface hydrologic characteristics of the region and an analysis of the potential for flooding caused by surges or seiches. This description should be sufficient to assess the acceptability of the site and the potential for a surge or seiche to influence the design of SSCs important to safety for a nuclear unit(s) of a specified type that might be constructed on the proposed site. Meeting this requirement provides reasonable assurance that the most severe flooding likely to occur as a result of storm surges or seiches will not pose an undue risk to the type of facility proposed for the site.

- If it has been determined that surge and seiche flooding estimates are necessary to identify flood design bases, the NRC will consider the applicant’s analysis to be complete and acceptable if it addresses the following areas and if the NRC staff can independently and comparably evaluate them based on the applicant’s submission.

- All reasonable combinations of PMH, moving squall line, or other cyclonic windstorm parameters are investigated, and the most critical combination is selected for use in estimating a water level.

- Models used in the evaluation are verified or have been previously approved by the NRC staff.

- Detailed descriptions of bottom profiles are provided (or are readily obtainable) to enable an independent NRC staff estimate of surge levels.

- Detailed descriptions of shoreline protection and safety-related facilities are provided to enable an independent NRC staff estimate of wind-generated waves, runup, and potential erosion and sedimentation.

- Ambient water levels, including tides and sea level anomalies, are estimated using NOAA and USACE publications, as described below.

- Combinations of surge levels and waves that may be critical to the design of a nuclear unit(s) of a specified type that might be constructed on the proposed site are considered, and adequate information is supplied to allow a determination that no adverse combinations have been omitted.

- At the COL stage, if the applicant elects RG 1.59, Position 2, the adequacy of the design basis for flood protection of all safety-related facilities identified in RG 1.29 should be shown in terms of the time necessary for the implementation of any emergency procedures. The applicant should also demonstrate that the less severe

design basis selected provides for all potential flood situations that could negate the time and capability to initiate flood emergency procedures.

- This section of the SSAR may also state with justification that surge and seiche flooding estimates are not necessary to identify the flood design basis (e.g., the site is not near a large body of water).

- Hydrometeorological estimates and criteria for the development of PMHs for East and Gulf Coast sites, squall lines for the Great Lakes, and severe cyclonic windstorms for all lake sites by USACE, NOAA, and the NRC staff are used for evaluating the conservatism of the applicant's estimates of severe windstorm conditions, as discussed in RG 1.59. USACE and NOAA criteria call for variation of the basic meteorological parameters within given limits to determine the most severe combination that could result. The applicant's hydrometeorological analysis should be based on the most critical combination of these parameters.

- Data from publications by NOAA, USACE, and other sources (such as tide tables, tide records, and historical lake level records) are used to substantiate antecedent water levels. These antecedent water levels should be as high as the 10-percent exceedance monthly spring high tide, plus a sea-level anomaly based on (1) the maximum difference between recorded and predicted average water levels for durations of 2 weeks or longer for coastal locations or (2) the 100-year recurrence interval high water for the Great Lakes. In a similar manner, the NRC staff independently analyzes the storm track, wind fields, effective fetch lengths, direction of approach, timing, and frictional surface and bottom effects to ensure that the applicant selected the most critical values. Models used to estimate surge hydrographs that the NRC staff has not previously reviewed and approved are verified by reproducing historical events, with any discrepancies in the model being on the conservative (i.e., high) side.

- The NRC staff uses USACE criteria and methods, as generally summarized in RS-002, as a standard to evaluate the applicant's estimate of coincident wind-generated wave action and runup.

- The NRC staff uses USACE criteria and methods, as generally summarized in RS-002, and other standard techniques to evaluate the potential for oscillation of waves at natural periodicity.

- At the COL stage, the NRC staff uses USACE criteria and methods to evaluate the adequacy of protection from flooding, including the static and dynamic effects of broken, breaking, and nonbreaking waves.

2.4.5 Technical Evaluation

The technical evaluation consists of (1) a review of the technical information provided by the applicant, and (2) NRC staff's technical evaluation to determine the potential for site flooding due to surge and seiche.

2.4.5.3.1 Technical Information Presented by the Applicant

The proposed site grade for the new units is 220 feet MSL. The applicant reported three major hurricanes, defined as those of Category 3 or larger (Saffir/Simpson Hurricane Scale) that have affected the Atlantic coast of Georgia between 1841 and 2004 (SNC, 2006). The most severe observed hurricane with a landfall location within 100 miles of the Savannah River estuary was Hurricane Hugo that made landfall near Charleston, South Carolina (SNC, 2006). The applicant reported that Hurricane Hugo produced a 20-ft storm surge in the Cape Romain-Bulls Bay area in South Carolina.

The applicant estimated the probable maximum surge height at the mouth of the Savannah River using the RG 1.59 values of 28.2 feet mean low water (MLW) at Folly Island, South Carolina and 33.9 feet MLW at Jekyll Island, Georgia, which are located northeast and southwest of the Savannah River estuary, respectively (SNC, 2006). The applicant obtained from ANSI/ANS-2.8 (1992) the 10 percent exceedance high tide at the Savannah River estuary as 9.0 feet MLW with MLW at the entrance to Savannah River being at 1.2 feet below MSL. The applicant estimated the probable maximum surge water surface elevation with a coincident 10 percent exceedance high tide at the mouth of the Savannah River as 32.3 feet MLW or 31.1 feet MSL (SNC, 2006).

The applicant noted that probable maximum surge data from RG 1.59 do not include hurricanes after 1975. Inclusion of the more recent hurricane data in RG 1.59 could have slightly altered the probable maximum surge estimate (SNC, 2006).

The applicant postulated that a probable maximum surge at the mouth of the Savannah River would only have an insignificant effect near the VEGP site because the surge height would dissipate before reaching the VEGP site, which is located approximately 151 river miles inland from the mouth and the proposed site grade is 220 feet MSL (SNC, 2006).

2.4.5.3.2 NRC Staff's Technical Evaluation

The NRC staff's technical evaluation consisted of a review of the data, the references, and the methods presented in the applicant's SSAR.

The NRC staff reviewed the references provided by the applicant in the SSAR and agreed that three hurricanes exceeding Category 3 have been reported by Blake et al. (2007) on the Georgia coastline within 100 miles of Savannah, Georgia. The NRC staff downloaded historical hurricane track data for the Atlantic basin from the NOAA Coastal Services Center (2007) and created a map of these hurricane tracks in the vicinity of the VEGP site (Figure 2.4.5-1). The NRC staff determined from this map that three Category 4 hurricanes and five Category 3 hurricanes have come within 150 miles and 100 miles of the VEGP site, respectively. One Category 1 and one Category 2 hurricanes came within 50 miles of the VEGP site. Within a 25 mile-radius of the Savannah River Estuary (Figure 2.4.5-2) four Category 3 hurricanes have been observed. Within a 50 mile-radius of the Savannah River Estuary six Category 3 and one Category 4 hurricanes have occurred (Figure 2.4.5-2). Based on these historical data, the NRC staff concluded that storm surges caused by severe hurricanes that exceed Category 4 can occur in the vicinity of the Savannah River Estuary.

The NRC staff reviewed the probable maximum surge estimation performed by the applicant. The NRC staff concluded that the applicant appropriately applied the method described in Appendix C of RG 1.59 to the Savannah River estuary location. In addition, the NRC staff finds that the applicant's estimate of total probable maximum surge height of 32.3 feet MLW or 31.1 feet MSL is acceptable.

The NRC staff reviewed the location of the VEGP site in relation to the Savannah River Estuary, and concluded that effects of storm surge and seiche at the site would likely be small. To quantitatively bound these effects, the NRC staff used the HEC-RAS model described in Section 2.4.4 of this SER. The downstream boundary condition, applied at river mile 99.4, of the NRC staff's unsteady flow analysis was modified to a constant stage height. The selected height for this analysis was elevation 119.7 feet MSL. This elevation is the sum of the peak flood stage at the model's boundary during the dam break simulation (elevation 88.6 feet MSL) and the computed maximum storm surge occurring at the mouth of the Savannah River using RG 1.59 (31.1 feet). This estimate of storm surge at river mile 99.4 does not take into account attenuation of the surge that would occur between the mouth and the model boundary. The peak stage at the site computed during the domino-type failure of the upstream dams using this revised downstream boundary condition was elevation 172.1 feet MSL, which is 47.9 feet below the site grade. Wind blowing along the water surface could increase the water surface elevation along one bank. These effects were computed in Section 2.4.4 to be approximately 19 feet. Combining these effects results in a water surface elevation of 191.1 feet MSL, which is 28.9 feet below the site grade. Therefore, the NRC staff concluded that the probable maximum surge and seiche will not affect the VEGP site.

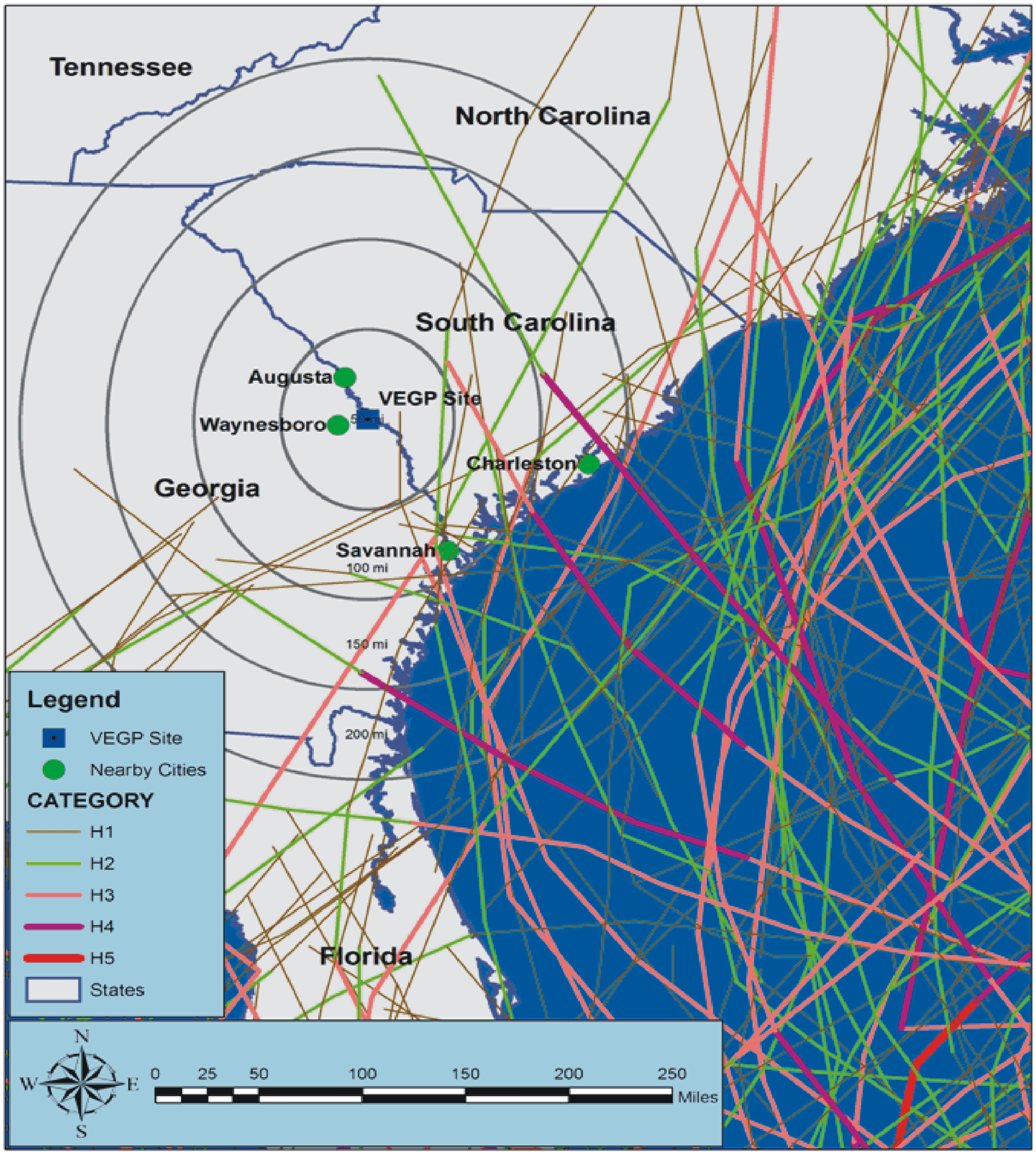

Figure 2.4.5-1 - Hurricane tracks near the VEGP site. The hurricane track data was downloaded from the NOAA Coastal Services Center and all hurricanes (Category H1 through H5) from the dataset were selected to show on the map.

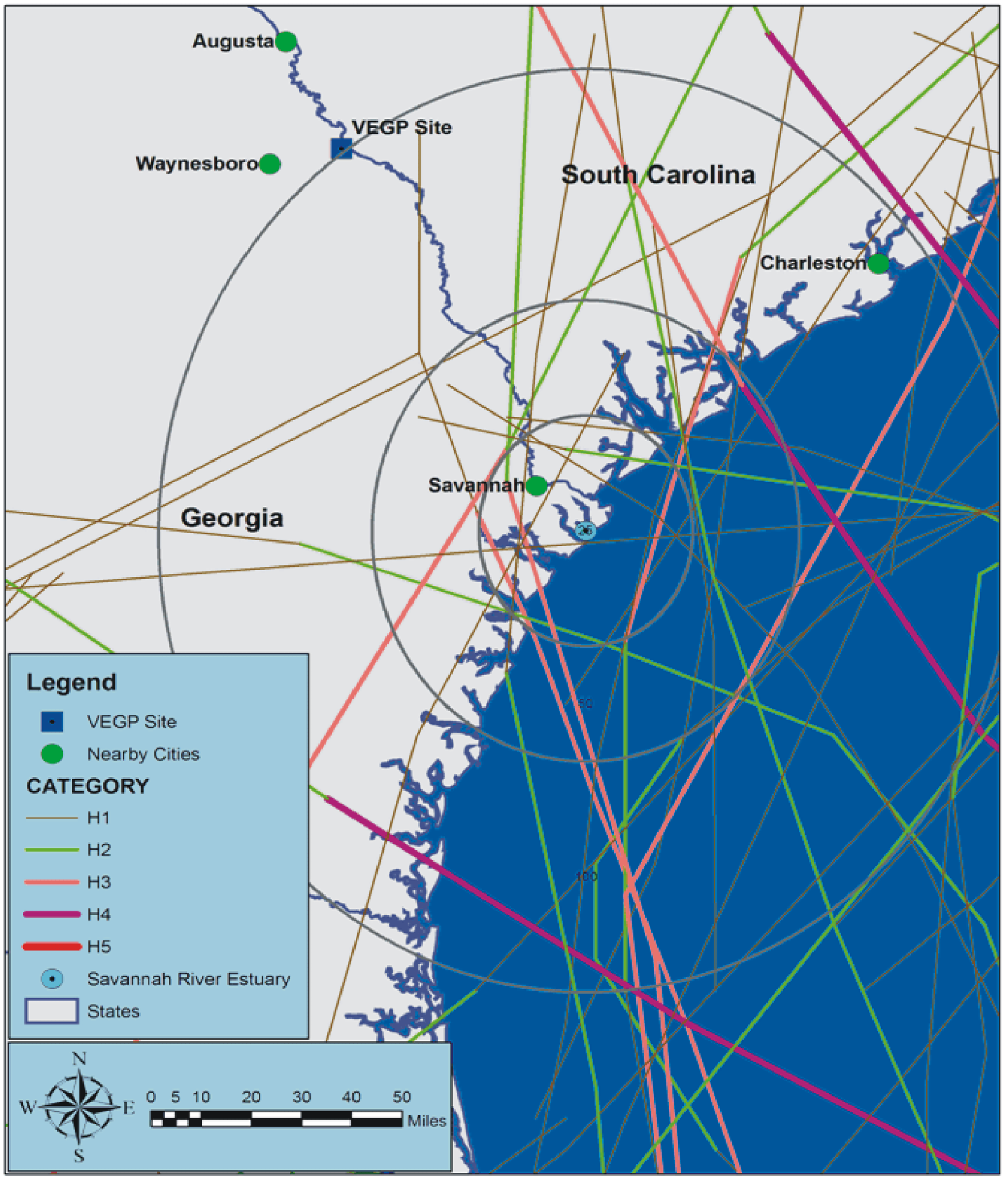

Figure 2.4.5-2 - Hurricane tracks near the Savannah River Estuary. The hurricane track data was downloaded from the NOAA Coastal Services Center and all hurricanes (Category H1 through H5) from the data set were selected to show on the map.

2.4.5.4 Conclusion

A probable maximum surge in the Savannah River Estuary can occur. However, this probable maximum surge does not affect the VEGP site. The VEGP site is also not affected by seiche because the site is located approximately 150 river miles inland from the ocean and there are no large bodies of water in the vicinity. All safety-related SSC will be placed above the highest flood water surface elevation that is controlled by flooding in the Savannah River resulting from cascading upstream dam failures.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the effects of storm surge and seiche at the proposed site. Section 2.4.5 of RS-002 provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating the effects of storm surge and seiche. Furthermore, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the effects of surge and seiche near the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, the NRC staff concludes that the identification and consideration of surge and seiche site characteristics set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d). The NRC staff finds the applicant's proposed site characteristics related to surge and seiche for the ESP application to be acceptable.

2.4.6 Probable Maximum Tsunami Hazards

In this section of the SSAR, the geohydrological design basis is developed to ensure that any plant design considers potential hazards to the safety-related facilities due to the effects of probable maximum tsunami are in the plant design. The NRC staff's review of the SSAR covers (1) historical tsunami data, (2) probable maximum tsunami, (3) tsunami propagation models, (4) wave runup, inundation, and drawdown, (5) hydrostatic and hydrodynamic forces, (6) debris and water-borne projectiles, (7) effects of sediment erosion and deposition, (8) consideration of other site-related evaluation criteria, and (9) additional information for 10 CFR Part 52 applications.

2.4.6.1 Introduction

The VEGP site is located on the southeast side of the Savannah River, approximately 15 miles east-northeast of Waynesboro, Georgia; 26 miles southeast of Augusta, Georgia; and 100 miles north-northwest of Savannah, Georgia (SNC, 2006). The VEGP site is

located approximately 150 river miles upstream of the mouth of the Savannah River. The grade elevation of the existing VEGP units and the proposed new units is 220 feet MSL.

A probable maximum tsunami can be caused near the mouth of the Savannah River by a tsunamigenic source in the Atlantic Ocean. There are no large inland bodies of water near the VEGP site in which a tsunami may be generated.

2.4.6.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.23, as it relates to investigating the tsunami potential at the site

To evaluate the information provided in SSAR 2.4 per the above acceptance criteria, applicant applied the NRC-endorsed analytical methodologies found in the following:

- RG 1.70, Revision 3, issued November 1978
- RG 1.29
- RG 1.59, Revision 2, issued August 1977
- RG 1.102, Revision 1, issued September 1976
- RG 1.125, Revision 1, issued October 1978

Section 2.4.6 of RS-002 provides the following review guidance used by the NRC staff to evaluate this SSAR section. The acceptance criteria for this section are based on meeting the requirements of the following regulations:

- The regulations at 10 CFR 52.17(a) and 10 CFR 100.20(c) require that the NRC take into account the site's physical characteristics (including seismology, meteorology, geology, and hydrology) when determining its acceptability to host a nuclear unit(s). The regulations at 10 CFR Part 52 and 10 CFR Part 100 apply to RS-002, Section 2.4.6, because they address the physical characteristics, including hydrology, considered by the Commission when determining the acceptability of the proposed site. To satisfy the hydrologic requirements of 10 CFR Part 52 and 10 CFR Part 100, the SSAR should contain a description of the hydrologic characteristics of the coastal region in which the proposed site is located and an analysis of severe seismically induced waves. The applicant's description should be sufficient to assess the site's acceptability and the

potential for a tsunami to influence the design of SSCs important to safety for a nuclear unit(s) of specified type that might be constructed on the proposed site. Meeting this requirement provides reasonable assurance that the most severe flooding likely to occur as a result of a tsunami will pose no undue risk to the type of facility proposed for the site.

- The regulation at 10 CFR 100.23(c) requires that the NRC consider the geologic and seismic factors when determining suitability of the site. Pursuant to 10 CFR 100.23(c), an investigation must be completed to obtain geologic and seismic data necessary for evaluating seismically induced floods and water waves. This regulation also applies to RS-002, Section 2.4.6, because it requires the investigation of distantly and locally generated waves or tsunamis that have affected or could affect a proposed site, including available evidence regarding the runup or drawdown associated with an historic tsunami in the same coastal region and local features of coastal topography that might modify runup or drawdown. RG 1.70 provides more detailed guidance on the investigation of seismically induced flooding.

- Though not required at the ESP stage, the applicant for a COL must demonstrate compliance with GDC 2 as it relates to designing SSCs important to safety to withstand the effects of a tsunami.

- To judge whether the applicant has met the requirements of 10 CFR Part 52, 10 CFR Part 100, and 10 CFR 100.23 with respect to tsunamis and the analysis thereof, the NRC uses the following criteria:

- If it has been determined that tsunami estimates are necessary to identify flood or low-water design bases, the NRC will consider the applicant's analysis to be complete if it addresses the following areas and if the NRC staff can independently and comparably evaluate them based on the applicant's submission:

    - All potential distant and local tsunami generators, including volcanoes and areas of potential landslides, are investigated, and the most critical ones are selected.

    - Conservative values of seismic characteristics (source dimensions, fault orientation, and vertical displacement) for the tsunami generators selected are used in the analysis.

    - The NRC staff previously approved or verified all models used in the analysis. RG 1.125 provides guidance in the use of physical models of wave protection structures.

    - Bathymetric data are provided (or are readily obtainable).

    - Detailed descriptions of shoreline protection and safety-related facilities are provided for wave runup and drawdown estimates. RG 1.102 provides guidance on flood protection for nuclear power plants.

- Ambient water levels, including tides, sea level anomalies, and wind waves, are estimated using NOAA and USACE publications, as described below.

- If the applicant adopts RG 1.59, Position 2, the design basis for tsunami protection of all safety-related facilities identified in RG 1.29 should be shown at the COL stage to be adequate in terms of the time necessary for implementation of any emergency procedures.

- The applicant’s estimates of tsunami runup and drawdown levels are acceptable if the estimates are no more than 5 percent less conservative than the NRC staff’s estimates. If the applicant’s estimates are more than 5 percent less conservative (based on the difference between normal water levels and the maximum runup or drawdown levels) than the NRC staff’s, the applicant should fully document and justify its estimates or accept the NRC staff’s estimates.

- This section of the SSAR will also be acceptable if it states that the criteria used to determine that tsunami flooding estimates are not necessary to identify the flood design basis (e.g., the site is not near a large body of water).

2.4.6.3 Technical Evaluation

The technical evaluation consists of (1) a review of the applicant’s technical information presented in the SSAR, and (2) NRC staff’s technical evaluation to determine the potential for tsunami hazards at the site.

2.4.6.3.1 Technical Information Presented by the Applicant

The applicant stated in SSAR Section 2.4.6 that since the VEGP site is not located on an open ocean coast of a large body of water, a tsunami would not produce maximum water level at the site (SNC, 2006).

The Atlantic Ocean is subject to infrequent seismic and volcanic activities that have resulted in few recorded tsunamis. The most notable Atlantic tsunami was generated by the Great Lisbon Earthquake of 1755. The earthquake generated a tsunami that traveled across the Atlantic and produced waves 10 to 15 feet in height on the Caribbean coasts and computer models suggested a wave height of 10 feet along the east coast of the U.S.

The applicant estimated that effects of any tsunami with similar height approaching the Savannah River estuary would be dissipated before reaching the VEGP site, which is located approximately 151 river miles inland and has a grade elevation of 220 feet MSL (SNC, 2006).

2.4.6.3.2 NRC Staff’s Technical Evaluation

The NRC staff’s technical evaluation consisted of a review of the data and the references presented in the applicant’s SSAR. The NRC staff also carried out a hierarchical review of tsunamis near the VEGP site.

The NRC staff carried out a search of the National Geophysical Data Center (NGDC) Tsunami Runup Database to locate all reported tsunami runups on the U.S. east coast. This search returned reported tsunami runup events in the general region of the Savannah River estuary that are shown on the map below (Figure 2.4.6-1).

The NGDC database did not contain the actual runup heights for several of the runup locations shown on the map (Figure 2.4.6-1). The NGDC database reported an observed runup height less than 1 foot at Charleston, South Carolina, near the Savannah River Estuary resulting from the 1929 Grand Banks submarine landslide-generated tsunami. The NGDC database lists the 1886 earthquake in Charleston, South Carolina as having generated three runup events in Copper River, South Carolina and Jacksonville and Mayport in Florida. Runup heights at the three locations are not available. The event description in the NGDC database lists extensive damage to Charleston, South Carolina by a "mighty tidal" presumably the tsunami wave (NGDC, 2007a).

The NGDC tsunami runup database lists the tsunami caused by the 1755 Great Lisbon Earthquake as resulting in runups on the east coast of the U.S. However, the NGDC database does not include runup heights on the east coast of the U.S. (NGDC, 2007b). A computer modeling of the tsunami wave generated by the 1755 Great Lisbon Earthquake suggested runups of approximately 10 feet on the U.S. east coast (Mader, 2001).

Based on the historical tsunami data near the Savannah River estuary, the NRC staff concluded that the region is subject to tsunamis but there is not enough historical data to ascertain the severity of runups near the Savannah River estuary. In order to determine whether tsunamis pose a hazard to the VEGP site, the NRC staff adopted a bounding approach.

Figure 2.4.6-1 - Locations of Tsunami Runups Reported in the NGDC Tsunami Runup Database near the Savannah River Estuary

The NRC staff evaluated three metrics related to the geographical and topographical location of the site in relation to tsunami wave inundation: (1) distance of the site from the shoreline, (2) upriver distance of the site from the shoreline, and (3) elevation of the site relative to the shoreline. These three metrics specifically address (1) if the site is located within the horizontal extent of the tsunami wave inundation zone, (2) if the tsunami wave can produce a bore in the Savannah River that may travel upstream to the site, and (3) if the tsunami wave can run up to site grade.

The NRC staff's search of the NGDC tsunami database revealed that the maximum observed horizontal distance of inundation during a tsunami is approximately 3.4 miles. The accounts from the 2004 Sumatra tsunami indicated the maximum extent of horizontal distance could be 5.0 miles from the shoreline on the island of Sumatra, Indonesia. The VEGP site is located more than 100 miles inland from the east coast of the U.S. Since the distance of the site from the shoreline is an order of magnitude more than the maximum observed horizontal inundation distance from a tsunami, the NRC staff concluded that a tsunami arriving at the Savannah River Estuary from the Atlantic Ocean will not inundate the VEGP site.

The NRC staff's search of the NGDC tsunami database revealed that the maximum observed tsunami runup, defined as the highest ground elevation the waters from a tsunami reached, is 1720 feet caused by the giant Lituya Bay subaerial landslide on July 10, 1958. There have been other tsunamis caused by landslides in Lituya Bay on October 27, 1936, on an unspecified day in 1853, and on September 10, 1899, which had reported runups of 490 feet, 394 feet, and 200 feet, respectively. The NGDC tsunami database also reports runups of 820 feet and 738 feet on May 18, 1980 in Spirit Lake located in the Washington State, which was caused by the catastrophic collapse of the north flank of the Mount St. Helens dome and the subsequent pyroclastic flow into the lake. The NGDC tsunami database also contains a few observed runups exceeding 150 feet (Table 2.4.6-1).

The tsunami events that caused runups exceeding 150 feet have properties that are not similar to those at the Savannah River Estuary. The Lituya Bay tsunami events are characterized by subaerial landslides in a very narrow inlet bay flanked by steep and high slopes. The Spirit Lake events were cause by the catastrophic failure of the north flank of the Mount St. Helens volcano. The 1674 tsunami runups on Ambon Island, Indonesia were caused by a near-field tsunamigenic earthquake in the Banda Sea. The events in Japan and Russia and those in Alaska were generated by tsunamigenic sources in the Pacific Ocean. The NRC staff concluded that none of these runup events can be considered representative of tsunamigenic conditions that may affect the Savannah River Estuary. Therefore, the NRC staff carried out a search for tsunami runups with tsunamigenic sources located in the Atlantic Ocean and in the Caribbean Sea, the most likely locations of tsunamigenic sources relevant to the Savannah River Estuary. Table 2.4.6-2 shows the results of this search.

Table 2.4.6-1 - Tsunami Runups Exceeding 150 Feet in the NGDC Tsunami Database

Date			Cause*	Country	Location	Runup (feet)
Year	Month	Day				
1958	7	10	3	USA	Lituya Bay, Alaska	1720
1980	5	18	6	USA	Spirit Lake West, Washington	820
1980	5	18	6	USA	Spirit Lake East, Washington	738
1936	10	27	8	USA	Lituya Bay, Alaska	490
1853	--	--	8	USA	Lituya Bay, Alaska	394
1674	2	17	1	Indonesia	Ceyt, Ambon Island	328
1674	2	17	1	Indonesia	Hila, Ambon Island	328
1674	2	17	1	Indonesia	Hitu Peninsula, Ambon Island	328
1674	2	17	1	Indonesia	Lima, Ambon Island	328
1741	8	29	5	Japan	Sado Island	295
1788	7	21	1	USA	Unga Island, Alaska	289
1788	8	6	1	USA	Unga Island, Alaska	289
1771	4	24	1	Japan	Ishigaki Island	280
1899	9	10	3	USA	Lituya Bay, Alaska	200
1737	10	17	0	Russia	Bering and Commander Islands	197
1771	4	24	1	Japan	Shiraho	197
1771	4	24	1	Japan	Ara	185
1792	5	21	5	Japan	Shimbara	180
1964	3	28	3	USA	Valdez Inlet, Alaska	170
2004	12	26	1	Indonesia	Labuhan, NW Coast of Sumatra	167
1650	9	29	6	Greece	West Coast Patmos	164
2004	12	26	1	Indonesia	Rhiting, Aceh, Sumatra	160
1771	4	24	1	Japan	Nobaruzaki	153

* Cause Codes:

0: Unknown
1: Earthquake
2: Questionable Earthquake
3: Earthquake and Landslide
4: Volcano and Earthquake
5: Volcano, Earthquake, and Landslide
6: Volcano
7: Volcano and Landslide
8: Landslide
9: Meteorological
10: Explosion
11: Astronomical Tide

Table 2.4.6-2 - Runups Exceeding 30 Feet Caused by Tsunamigenic Sources in the Atlantic Ocean and the Caribbean Sea

Date			Cause*	Country	Location	Runup (feet)
Year	Month	Day				
1755	11	1	1	Portugal	Lagos	98
1954	10	--	0	Greenland	Aputiteq Point	60
1755	11	1	1	Portugal	Lisbon	40
1894	11	21	6	Ireland	West Coast	40
1867	11	18	1	Guadeloupe	Deshaies	33
1867	11	18	1	Guadeloupe	Sainte-Rose	33
1900	10	29	1	Venezuela	Puerto Tuy	33

The 1755 Great Lisbon Earthquake, the only known great teletsunami in the Atlantic basin, produced runups of nearly 100 feet in Lagos, Portugal and approximately 40 feet in Lisbon, Portugal. According to the NGDC tsunami database, reported runups at Saint Martin harbor and Samana Bay in the Dominican Republic, both in the Caribbean Sea, were approximately 15 feet and 12 feet, respectively. Computer modeling of the tsunami waves generated by the 1755 Great Lisbon Earthquake, Mader (2001) estimated the runup heights on the east coast of the U.S. to be approximately 10 feet.

Based on the above data, the NRC staff concluded that all known tsunami runups on the Atlantic coast of the U.S. have been at least an order of magnitude less than the elevation of the site grade of the proposed new units at the VEGP site.

A tidal bore is a solitary, non-linear, shallow-water undular wave (Chen, 2003) that is caused by a large tide and typically propagates upstream in a slowly flowing estuary. The tidal bore is hydraulically similar to a traveling hydraulic jump characterized by supercritical flow upstream of the estuary. The formation of supercritical flow in the estuary is a necessary condition for the formation of a tidal bore (Chen, 2003). Supercritical flow is described by the Froude number, the ratio of inertial to gravity forces in open channel flow (Chow, 1959), exceeding 1.0. The Froude number is expressed by

$$Fr = V\big/(gL)^{1/2} \qquad (1)$$

where V is the velocity of flow, g is the acceleration due to gravity, and L is a characteristic length taken as the hydraulic depth for open channels. The hydraulic depth is defined as the ratio of the cross sectional area of discharge normal to the direction of flow to the top width of the free surface (Chow, 1959). For wide rectangular channels, therefore

$$Fr = V\,/\,(gh)^{1/2} \qquad (2)$$

where h is the depth of flow. Therefore, the criteria for supercritical flow in wide, rectangular channels, F_r >= 1.0, can also be stated as

$$V \geq (gh)^{1/2} \qquad (3)$$

The right hand side of equation (3) is the celerity, or speed, of a shallow-water wave. Therefore, when the Froude number exceeds 1.0, the velocity of flow exceeds shallow-water wave celerity.

Tidal bores are rare occurrences. Bartsch-Winkler and Lynch (1988) presented a catalog of worldwide occurrences and characteristics of tidal bores. This catalog listed 67 known locations where tidal bores occur. The only documented occurrences of tidal bores in the U.S. are those in the Knik and Turnagain Arms of Cook Inlet in Alaska (Bartsch-Winkler and Lynch, 1988). The NRC staff's additional search did not find any reference to the formation of a tidal bore in the Savannah River Estuary. The NRC staff concluded that a tsunami-induced bore traveling upstream from the mouth of the Savannah River would not occur.

A tsunami that causes a runup near the mouth of the Savannah River would have to reach an elevation of 220 feet MSL more than 100 miles inland in order to inundate the VEGP site. Both these metrics are an order of magnitude greater than the maximum estimated tsunami runup on the Atlantic coast near the site and the maximum reported horizontal extent of tsunami inundation anywhere, respectively. Based on the data pertaining to the geographical and topographical location of the VEGP site as it relates to tsunamis, the NRC staff concluded that a tsunami at the mouth of the Savannah River would not affect the VEGP site, which is located more than 100 miles from the mouth and at a grade elevation of 220 feet MSL.

2.4.6.4 Conclusion

The VEGP site is not affected by probable maximum tsunami. All safety-related SSC will be placed above the highest flood water surface elevation that is controlled by flooding in the Savannah River resulting from to cascading upstream dam failures.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the effects of probable maximum tsunami hazards at the proposed site. RS-002, Section 2.4.6 provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating the effects of probable maximum tsunami hazards. Furthermore, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the probable maximum tsunami hazards, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, the NRC staff concludes that the identification and consideration of the probable maximum tsunami hazards site characteristics set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d). The

NRC staff finds the applicant's proposed site characteristics related to probable maximum tsunami hazards for the ESP application to be acceptable.

2.4.7 Ice Effects

This section of the applicant's SSAR develops the hydrometeorological design basis to ensure that ice-induced hazards do not affect safety-related facilities and water supply. The applicant is responsible for providing site characteristics and other hydrometeorological parameters related to ice formation at or near the site to the organization responsible for review of the SSCs to ascertain whether the mechanical or structural design basis for the plant properly considers ice effects on potentially affected SSC. The review covers (1) historical ice accumulation, (2) high and low water levels, (3) ice sheet formation, (4) ice-induced forces and blockages, (5) consideration of other site-related evaluation criteria, and (6) additional information for 10 CFR Part 52 applications.

2.4.7.1 Introduction

The VEGP site is located on the southeast side of the Savannah River, approximately 15 miles east-northeast of Waynesboro, Georgia, 26 miles southeast of Augusta, Georgia, and 100 miles north-northwest of Savannah, Georgia (SNC, 2007). The VEGP site is located approximately 150 river miles upstream of the mouth of the Savannah River. The grade elevation of the existing VEGP units and the new proposed units is 220 feet MSL.

The site may be affected by icing in the Savannah River near the site. There are no large inland bodies of water near the VEGP site and no water reservoirs are proposed for safety-related use.

2.4.7.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.23, as it relates to investigating the tsunami potential at the site

To evaluate the information provided in SSAR 2.4 per the above acceptance criteria, applicant applied the NRC-endorsed analytical methodologies found in the following:

- RG 1.59, Revision 2, issued August 1977

- The regulations at 10 CFR 52.17(a) and 10 CFR 100.20(c) require that the NRC take into account the site's physical characteristics (including seismology, meteorology, geology, and hydrology) when determining its acceptability for hosting a nuclear power reactor(s). To satisfy the hydrologic requirements of 10 CFR Part 52 and 10 CFR Part 100, the SSAR should contain a description of any icing phenomena with the potential to result in adverse effects to the intake structure or other safety-related facilities for a nuclear unit(s) of a specified type that might be constructed on the proposed site. Applicants should describe ice-related characteristics historically associated with the site and region, and they should perform an analysis to determine the potential for flooding, low water, or ice damage to safety-related SSCs. The analysis should be sufficient to evaluate the site's acceptability and to assess the potential for those characteristics to influence the design of SSCs important to safety for a nuclear unit(s) of a specified type that might be constructed on the proposed site. Meeting this guidance provides reasonable assurance that the effects of potentially severe icing conditions will pose no undue risk to the type of facility proposed for the site.

- Publications by NOAA, USGS, USACE, and other sources are used to identify the history and potential for ice formation in the region. The historical maximum depths of icing should be noted, as well as mass and velocity of any large, floating ice bodies. The phrase, "historical low water ice affected," or similar phrases in streamflow records (USGS and State publications) will alert the reviewer to the potential for ice effects. The following items should be considered and evaluated, if necessary:

    - The regional ice and ice jam formation history should be described to enable an independent determination of the need for including ice effects in the design basis.

    - If the potential for icing is severe, based on regional icing history, it should be shown that water supplies capable of meeting safety-related needs are available from under the ice formations postulated and that safety-related equipment could be protected from icing. If this cannot be shown, it should be demonstrated that alternate sources of water are available that could be protected from freezing and that the alternate source would be capable of meeting safety-related requirements in such situations.

    - If floating ice is prevalent, based on regional icing history, potential impact forces on safety-related intakes should be considered. The structural design basis should include dynamic loading caused by floating ice. (This item will be addressed at the COL or CP stage.)

    - If ice blockage of the river or estuary is possible, it should be demonstrated that the resulting water level in the vicinity of the site has been considered. If this water level would adversely affect the intake structure or other safety-related facilities of a nuclear unit(s) of a specified type that might be constructed on the proposed site, it should be demonstrated that it would not also adversely affect an alternate safety-related water supply.

- The applicant's estimates of potential ice flooding or low flows are acceptable if the estimates are no more than 5 percent less conservative than the NRC staff estimates. If the applicant's estimates are more than 5 percent less conservative than the NRC staff's, the applicant should fully document and justify its estimates or accept the NRC staff estimates.

2.4.7.3 Technical Evaluation

The technical evaluation consists of (1) a review of the applicant's technical information presented in the SSAR, and (2) NRC staff's technical evaluation to determine the potential for ice-related hazards at the site.

2.4.7.3.1 Technical Information Presented by the Applicant

The applicant used air temperature records from eight locations, including seven cooperative stations, around the VEGP site to analyze historical extreme air temperature variations (SNC, 2007). The applicant also used air temperature data from onsite measurements.

The climate at the VEGP site consists of short, mild winters and long, humid summers (SNC, 2007). At the Augusta, Georgia station, based on 129 years of records, January is the coldest month with a mean temperature of 46.8 ºF. Among the eight stations, the lowest air temperature was -4.0 ºF at Aiken, South Carolina in January 1985. During the same period, the air temperature at the VEGP site was -0.1 ºF, with air temperatures remaining below freezing (32 ºF) for approximately 50 hours (SNC, 2007). Onsite measurements from 1984 to 2002 showed that mean daily air temperature remained below freezing for a maximum of three consecutive days (SNC, 2007).

Historical water temperature data from five USGS gauging stations located on the Savannah River covering an area that includes the VEGP site showed that the minimum water temperature is observed in the month of February and varies from 39.2 ºF and 42.8 ºF (SNC, 2007).

Based on historical air and water temperature records, the applicant concluded that it is very unlikely that surface or frazil ice formation would occur in the Savannah River in the vicinity of the proposed intake location of the new VEGP units (SNC, 2007).

The applicant reported in SSAR Section 2.4.7 that the USACE Ice Jam Database includes no recorded ice jam events in the lower reaches of the Savannah River. The existence of dams and reservoirs on the Savannah River upstream of the VEGP site reduce the possibility of any surface ice or ice floes moving downstream (SNC, 2007). Since the water temperature in the lower reach of the Savannah River consistently remains above freezing, the applicant concluded that formation of frazil ice or ice jams is very unlikely at the proposed intake location for the new VEGP units.

The proposed VEGP units would use a closed-cycle cooling system with cooling towers for the circulating water system cooling (SNC, 2007). Makeup water for the circulating water system cooling towers will be supplied from the Savannah River using a new intake system comprising

of an intake canal and a pump intake structure located upstream of the existing river intake system for VEGP Units 1 and 2 (SNC, 2007).

The reactors for the proposed VEGP units will use passive UHS systems that do not require any safety-related water supply (SNC, 2007). The proposed reactors would have a non-safety related auxiliary heat sink service water system that will be used for shutdown, normal operations, and anticipated operational events (SNC, 2007). The makeup water to the service water system will be supplied from groundwater wells or an onsite water storage tank (SNC, 2007). No water will be necessary from the Savannah River or any other open surface water source for the proposed reactors' UHS (SNC, 2007). The applicant concluded, therefore that any ice event in the Sacannah River will not have an impact on the safe operation of the proposed units (SNC, 2007).

2.4.7.3.2 NRC Staff's Technical Evaluation

The NRC staff's technical evaluation consisted of a review of the data and the references presented in the applicant's SSAR.

The NRC staff carried out a review of historical air temperature data near the VEGP site. The stations used by the NRC staff and their periods of record are shown in Table 2.4.7-1.

Table 2.4.7-1 - Meteorological stations near the VEGP site used by the NRC staff

Name (State)	COOP ID	Start Date	End Date
Augusta Bush Field Airport (Georgia)	090495	03/01/1949	04/30/2007
Louisville 1E (Georgia)	095314	01/01/1893	03/31/2007
Midville Experiment Station (Georgia)	095863	06/01/1957	03/31/2007
Millen 4N (Georgia)	095882	11/01/1891	12/31/1998
Newington (Georgia)	096323	09/01/1956	02/28/2003
Waynesboro 2S (Georgia)	099194	11/01/1893	02/28/2007
Aiken 5SE (South Carolina)	380074	01/01/1893	03/31/2007
Bamberg (South Carolina)	380448	08/01/1951	01/31/2007
Blackville 3W (South Carolina)	380764	06/01/1894	07/31/2002

In reviewing the daily minimum air temperature record at these stations, the NRC staff determined that the lowest daily minimum air temperature, -4 ºF, was observed at the Aiken 5SE station on January 21, 1985. The range of the lowest daily minimum air temperatures at all stations was 0 ºF to -4 ºF. The NRC staff estimated the mean daily minimum air temperature during the winter months, December through March, for all stations (see Table 2.4.7-2). None of these temperatures was below freezing.

Table 2.4.7-2 - Mean Daily Minimum Air Temperatures During the Months of December Through March for All Stations Used in the NRC Staff's Review

Name (State)	Mean Daily Minimum Air Temperature (ºF)			
	December	January	February	March
Augusta Bush Field Airport (Georgia)	34.7	33.5	35.8	42.3
Louisville 1E (Georgia)	49.2	49.9	55.7	62.4
Midville Experiment Station (Georgia)	37.1	35.5	38.3	45.2
Millen 4N (Georgia)	38.1	37.6	39.8	45.9
Newington (Georgia)	38.8	36.4	39.4	45.5
Waynesboro 2S (Georgia)	42.3	41.5	45.5	52.5
Aiken 5SE (South Carolina)	39.0	37.8	40.7	47.3
Bamberg (South Carolina)	37.4	35.5	37.9	43.8
Blackville 3W (South Carolina)	52.1	54.4	59.4	67.8

The NRC staff also identified the longest consecutive period during which the mean daily air temperature (estimated as the average of the daily minimum and maximum temperatures) was below freezing at each of the stations (see Table 2.4.7-3). The longest duration, that of nine days, of mean daily air temperature below freezing was observed at the Aiken station from January 13 to January 21, 1893.

According to USACE (2002), frazil ice forms in turbulent, supercooled water that is not covered by an ice layer. The NRC staff identified the maximum number of consecutive days that mean daily air temperature falls below 18 ºF for each of the stations (Table 2.4.7-3). Two consecutive days of mean daily air temperatures below 18 ºF were observed twice at Waynesboro 2S and once at Blackville 3W. At all other stations experienced only 1 consecutive day with the mean air temperature below 18 ºF.

In response to NRC staff's RAI (RAI ref.), the applicant provided water temperature data at the Shell Bluff Landing site, which is located approximately 11 river miles upstream of the VEGP site. The NRC staff reviewed water temperature data supplied by the applicant. The period of record for these monthly water temperatures was from January 30, 1973 to August 13, 1996. From these data, the NRC staff computed the following water temperature statistics: the minimum water temperature was 41.0 °F, the average water temperature was 63.4 °F, the median water temperature was 64.4 °F, and the maximum water temperature was 81.0 °F.

Based on its independent review of air temperature data near the VEGP site, the NRC staff concluded that the occurrence of air temperatures below freezing at and near the VEGP site are brief and infrequent. Although air temperature could fall below 18 ºF in the vicinity of the VEGP site, the duration of such a freezing spell would be unlikely to exceed two days. Since the water temperatures in the Savannah River near the site have never approached freezing (minimum water temperature estimated from 13 years of monthly data was 41.0 ºF), the NRC staff concluded that the VEGP site would not support the formation of frazil ice.

Table 2.4.7-3 - Longest Consecutive Period of Mean Daily Air Temperature below Freezing for All Stations Used in the NRC Staff's Review

Name (State)	Longest Consecutive Period of Mean Daily Air Temperature Below Freezing	
	Duration (days)	Dates
Augusta Bush Field Airport (Georgia)	6	01/10/1982 – 01/15/1982, 12/30/2000 – 04/01/2001
Louisville 1E (Georgia)	8	01/14/1893 – 01/21/1893
Midville Experiment Station (Georgia)	4	02/16/1958 – 02/19/1958, 01/08/1970 – 01/11/1970, 12/23/1989 – 12/26/1989
Millen 4N (Georgia)	5	01/13/1912 – 01/17/1912, 01/25/1940 – 01/29/1940
Newington (Georgia)	5	01/16/1977 – 01/20/1977
Waynesboro 2S (Georgia)	6	12/30/1917 – 01/04/1918, 01/11/1982 – 01/16/1982
Aiken 5SE (South Carolina)	9	01/13/1893 – 01/21/1893
Bamberg (South Carolina)	5	02/01/1980 – 02/05/1980, 12/31/2000 – 01/04/2001
Blackville 3W (South Carolina)	5	12/30/1899 – 01/03/1900

Table 2.4.7-3 - Number of Days with Minimum Daily Temperature at or below 18 ºF

Name (State)	Longest Consecutive Period of Mean Daily Air Temperature Below 18 ºF
Augusta Bush Field Airport (Georgia)	1
Louisville 1E (Georgia)	1
Midville Experiment Station (Georgia)	1
Millen 4N (Georgia)	1
Newington (Georgia)	1
Waynesboro 2S (Georgia)	2
Aiken 5SE (South Carolina)	1
Bamberg (South Carolina)	1
Blackville 3W (South Carolina)	2

The proposed units at the VEGP site have no safety-related water requirement and would not use any safety-related intakes. Consequently, formation of ice sheets, forces induced by ice, and blockages caused by ice are not areas of concern for this review.

The NRC staff searched the USACE Ice Jam Database for ice jam events reported in the states of Georgia, North Carolina, and South Carolina (CRREL, 2007a; 2007b; 2007c). The Ice Jam Database contains no ice jams reported in Georgia and South Carolina (CRREL, 2007d; 2007f). There are two ice jams reported in North Carolina (CRREL 2007e), one on the Neuse River and the other on the Missouri River. Based on these search results, the NRC staff concluded that ice jams in the Savannah River near the VEGP site are not likely.

The NRC staff proposed a site characteristic related to frazil ice that states that hydrometeorologic conditions at the VEGP site do not support formation of frazil ice.

2.4.7.4 Conclusion

Based on its review and independent analysis of data available publicly and those provided by the applicant, the NRC staff concluded that icing in the vicinity of the VEGP site is unlikely. Since the proposed units have no safety-related water requirement other than initial filling and occasional makeup purposes, for continuous supply, no safety-related water reservoirs or canals, intakes, and structures will be used. Therefore, the NRC staff concluded that ice effects will not affect safety of the proposed units.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the identification and evaluation of ice effects at the proposed site. Section 2.4.7 of RS-002 provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating ice effects at the site. Furthermore, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the hydrologic interface of the plant with the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, the NRC staff concludes that the identification and consideration of the site characteristics related to ice effects set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d). The NRC staff finds the applicant's proposed site characteristics related to ice effects for the ESP application to be acceptable.

2.4.8 Cooling Water Canals and Reservoirs

In this section of the applicant's SSAR, the hydraulic design basis is developed for canal and reservoirs used to transport and impound water supplied to the safety-related SSC. The NRC staff's review of the SSAR covers (1) hydraulic design bases for protection of structures, (2) hydraulic design base of canals, (3) hydraulic design bases of reservoirs, (4) consideration of other site-related evaluation criteria, and (5) 10 CFR Part 50, Appendix A, GDC 44, for CP and OL applications, as it relates to providing an UHS for normal operating and accident conditions.

2.4.8.1 Introduction

The VEGP site is located on the southwest side of the Savannah River (SNC, 2007). The two proposed units will use a closed-cycle cooling system with cooling towers. Make-up

water for the cooling towers' evaporative and other losses will be supplied from the Savannah River using a new intake system consisting of a canal and an intake structure.

The proposed units at the VEGP site will use no safety-related cooling water. The applicant has not proposed any safety-related cooling water supply canals and reservoirs.

2.4.8.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

To satisfy the hydrologic requirements of 10 CFR Part 52 and 10 CFR Part 100, the applicant's SSAR should describe the cooling water canals and reservoirs for a nuclear power plant(s) of specified type that might be constructed on the proposed site. The analysis related to cooling water canals and reservoirs should be sufficient to evaluate the site's acceptability and to assess the potential for those characteristics to influence the design of SSCs important to safety for a nuclear power plant(s) of specified type that might be constructed on the proposed site. Meeting this requirement provides reasonable assurance that the capacities of cooling water canals and reservoirs are adequate.

2.4.8.3 Technical Evaluation

The technical evaluation consists of (1) a review of the technical information presented in the application, and (2) NRC staff's technical evaluation to determine the acceptability of the design bases for canals and reservoirs.

2.4.8.3.1 Technical Information Presented by the Applicant

The proposed VEGP units will use a closed-cycle cooling system with cooling towers for condenser heat removal during normal operation (SNC, 2007). To replenish the water losses due to evaporation, drift and blowdown, the Savannah River will supply makeup water from at a maximum rate of approximately 57,784 gallons per minute (SNC, 2007). The makeup water intake system for the proposed units will be located upstream of the intake for the existing units (SNC, 2007).

The proposed plants for the new VEGP units use a passive UHS with in-plant storage of safety-related cooling water (SNC, 2007). The proposed plant design does not require an

external water-cooled UHS (SNC, 2007). The makeup water intake that will supply water to the condenser heat removal system will not be safety-related (SNC, 2007). Since the proposed VEGP units will not rely on the Savannah River for safety-related water supply, low-water conditions in the river will not affect safety-related SSC (SNC, 2007).

2.4.8.3.2 NRC Staff's Technical Evaluation

The NRC staff's technical evaluation consisted of a review of the data and the references presented in the applicant's SSAR.

The NRC staff reviewed the information provided by the applicant in the SSAR. The NRC staff concluded that as proposed in the application, the new VEGP Units 3 and 4 will not rely on any external water source for safety-related cooling water. The applicant did not propose any safety-related canals or reservoirs as a source for cooling water. However, there will be the need for safety-related water for initial filling and occasional makeup purposes. In this regard, the applicant has not provided design parameters for these values. This is **Open Item 2.4-1**.

The NRC staff has identified **Permit Condition 1** stating that VEGP Units 3 and 4 will not rely on any external water source for safety-related cooling water other than initial filling and occasional make-up water. This permit condition precludes the use of on-site surface and ground water for safety-related water supply except for initial filling and occasional make-up water.

2.4.8.4 Conclusion

As proposed, VEGP Units 3 and 4 will not rely on any external water source for safety-related cooling water except for initial filling and make-up water. The units will not use any safety-related canals or reservoirs. Having recognized the need for safety-related water for initial filling and occasional make-up purposes, the applicant should provide design parameters for these values. The staff considers this Open Item 2.4-1. The NRC staff proposed Permit Condition 1 above that VEGP Units 3 and 4 will not rely on any external water sources for safety-related cooling water except for initial filling and occasional make-up.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the design bases of canals and reservoirs at the proposed site. The SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating design bases of canals and reservoirs at the site. Furthermore, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the hydrologic interface of the plant with the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, pending resolution to the open items, the NRC staff concludes that the identification and consideration of the safety-related canals and reservoirs set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d). The NRC staff finds the applicant's site characterization related to canals and reservoirs for inclusion in an ESP for the applicant's site acceptable.

2.4.9 Channel Diversions

In this section of the applicant's SSAR, the geohydrologic design basis is developed to ensure that the plant and essential water supplies will not be adversely affected. This review includes stream channel diversions away from the site (which may lead to loss of safety related water) and stream channel diversions towards the site (which may lead to flooding). Additionally, in such an event, the applicant needs to show that alternate water supplies are available to safety-related equipment. The NRC staff's review of the SSAR covers (1) historical channel diversions, (2) regional topographic evidence, (3) ice causes, (4) flooding of site due to channel diversion, (5) human-induced causes of channel diversion, (6) alternate water sources, (7) consideration of other site-related evaluation criteria, and (8) additional information for 10 CFR Part 52 applications.

2.4.9.1 Introduction

The VEGP site is located on the southwest side of the Savannah River (SNC, 2007). The site is located on a plateau with natural drainages that drain water away from the site in all directions. The proposed site grade for the new units is 220 feet MSL. The two proposed units will use a closed-cycle cooling system with cooling towers. Make-up water for the cooling towers' evaporative and other losses will be supplied from the Savannah River using a new intake system consisting of a canal and an intake structure.

The proposed units at the VEGP site will not rely on safety-related cooling water from the Savannah River. The highest water surface elevation caused by flooding in the Savannah River is 189.1 feet MSL, more than 30 feet below the proposed site grade.

2.4.9.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c) and 10 CFR 100.20(d), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

Section 2.4.9 of RS-002 provides the following criteria that was used by the NRC staff to evaluate this SSAR section.

- Channel diversion or realignment poses the potential for flooding or for an adverse effect on the supply of cooling water for a nuclear unit(s) of a specified type that might be constructed on the proposed site. Therefore, it is one physical characteristic that must be evaluated pursuant to 10 CFR 100.21(d). The consideration of the 10 CFR 100.21(d) criteria in this evaluation provides reasonable assurance that the effects of flooding caused by channel diversion resulting from severe natural phenomena will pose no undue risk to the type of facility proposed for the site.

- To judge whether the applicant has met the requirements of 10 CFR Part 52 and 10 CFR Part 100 as they relate to channel diversion, the NRC uses the following criteria:

  - A description of the applicability (potential adverse effects) of stream channel diversions is necessary.

  - Historical diversions and realignments should be discussed.

  - The topography and geology of the basin and its applicability to natural stream channel diversions should be addressed.

  - If applicable, the safety consequences of diversion and the potential for high or low water levels caused by upstream or downstream diversion to adversely affect safety-related facilities, water supply, or the UHS should be addressed. RG 1.27 provides guidance on acceptable UHS criteria.

2.4.9.3 Technical Evaluation

The technical evaluation consists of (1) a review of the technical information presented in the application, and (2) NRC staff's technical evaluation to determine the effects of potential channel diversions near the site.

2.4.9.3.1 Technical Information Presented by the Applicant

The applicant provided information related to physiographic, topographic, hydrologic, and geologic characteristics of the region within which the VEGP site is located (SNC, 207). Based on these data, the applicant concluded that it could not completely discount diversion of the river channel in this region (SNC, 2007).

The applicant stated that although meandering of the river channel upstream and downstream of the VEGP site can be observed on topographic maps, the Savannah River near the VEGP site has a relatively straight and stable reach from River Mile 143 to River Mile 152 and the river plan-form did not change between 1965 and 1989 as inferred from USGS topographic maps (SNC, 2007). The applicant also stated that the flow in the Savannah River is controlled by upstream multipurpose projects in the Savannah River system (SNC, 2007). The effect of the control on the Savannah River results in lowering of peak flows and augmentation of low flows with an associated reduction in the morphological activity of the river (SNC, 2007). The

applicant concluded that it is unlikely the river will be diverted away from the VEGP site due to natural causes.

2.4.9.3.2 NRC Staff's Technical Evaluation

The NRC staff's technical evaluation consisted of a review of the approach presented in the applicant's SSAR.

As proposed in the application, the new VEGP Units 3 and 4 will not rely on any external water source for safety-related cooling water. The applicant did not propose any safety-related intakes for cooling water from the Savannah River. The NRC staff-proposed Permit Condition 1, stated in Section 2.4.8 of this report, which requires that VEGP Units 3 and 4 will not rely on any external water source for safety-related cooling water other than initial fill and occasional makeup. The NRC staff concluded that diversion of the Savannah River away from the VEGP site for any cause would not adversely affect the safety of the proposed VEGP Units 3 and 4.

The topographic elevations within the floodplain adjacent to the Savannah River northeast of the VEGP site are approximately 90 feet MSL and lower. The proposed grade elevation of the VEGP Units 3 and 4 is 220 feet MSL. In order to cause flooding at the VEGP site, the Savannah River would have to erode through more than 100 feet of terrain. Upstream dams regulate peak flood discharges in the Savannah River near the VEGP site and the river plan-form near the VEGP site is relatively straight. Based on these topographic, morphologic, and hydrologic characteristics, the NRC staff concluded that it is unlikely that flooding at the VEGP site can occur due to the Savannah River diverting towards the VEGP site.

2.4.9.4 Conclusion

As proposed, VEGP Units 3 and 4 will not rely on any external water source for safety-related cooling water. The NRC staff-proposed Permit Condition 1, stated in Section 2.4.8 of this report, requires that VEGP Units 3 and 4 will not rely on any external water sources for safety-related cooling water other than initial fill and occasional makeup. The NRC staff concluded that diversion of the Savannah River away from the VEGP site for any reason would not result in an adverse effect on safety of proposed VEGP Units 3 and 4. Based on topographic, morphologic, and hydrologic characteristics of the Savannah River, the NRC staff concluded that flooding of the VEGP site due to the river diverting towards the site is unlikely.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the identification and evaluation of channel diversions at the proposed site. Section 2.4.9 of RS-002 provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating channel diversions affecting the site. Furthermore, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the hydrologic interface of the plant with the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics

containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, the NRC staff concludes that the identification and consideration of the channel diversion site characteristics set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d).

In view of the above, the NRC staff finds the applicant's site characterization related to channel diversions for inclusion in an ESP for the applicant's site acceptable.

2.4.10 Flooding Protection Requirements

In this section of the applicant's SSAR, the locations and elevations of safety-related facilities and those of structures and components required for protection of safety-related facilities are compared with design-basis flood conditions to determine if flood effects need to be considered in plant design or in emergency procedures. The NRC staff's review of the SSAR covers (1) safety-related facilities exposed to flooding, (2) type of flooding protection, (3) emergency procedures, (4) consideration of other site-related evaluation criteria, and (5) additional information for 10 CFR Part 52 applications.

2.4.10.1 Introduction

The VEGP site is located on the southwest side of the Savannah River (SNC, 2007). The proposed site grade for the new units is 220 feet MSL. The proposed units at the VEGP site will not rely on safety-related cooling water from the Savannah River.

2.4.10.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

The regulation at 10 CFR 100.20(c) requires estimation of the PMF using historical data. Meeting this requirement provides reasonable assurance that the effects of flooding or a loss of flooding protection resulting from severe natural phenomena will pose no undue risk to the type of facility proposed for the site.

To judge whether the applicant has met the requirements of 10 CFR Part 52 and 10 CFR Part 100 as they relate to flooding protection, the NRC uses the following criteria:

- The applicability (potential adverse effects) of a loss of flooding protection should be described.
- Historical incidents of shore erosion and flooding damage should be discussed.
- The topography and geology of the basin and its applicability to damage as a result of flooding should be addressed.

If applicable, the safety consequences of a loss of flooding protection and the potential to adversely affect safety-related facilities, water supply, or the UHS should be addressed. RG 1.27 provides guidance on acceptable UHS criteria.

2.4.10.3 Technical Evaluation

The technical evaluation consists of (1) a review of the technical information presented in the application, and (2) NRC staff's technical evaluation to determine flooding protection requirements.

2.4.10.3.1 Technical Information Presented by the Applicant

The applicant stated that entrances and openings of all safety-related SSCs will be placed at or above the proposed site grade of 220 feet MSL (SNC, 2007). The design-basis flood elevation in the Savannah River is 178.1 feet MSL (SNC, 2007). The applicant concluded that safety-related SSC of the proposed VEGP Units 3 and 4 will not be exposed to flooding from the Savannah River.

The applicant stated that the effects of local intense precipitation will be considered in the design of site drainage system (SNC, 2007). The applicant committed to designing the site drainage system such that all safety-related SSC would be safe from flooding from local intense precipitation (SNC, 2007). All drainage structures such as culverts, storm drains, and bridges would be assumed to be blocked during the local intense precipitation event (SNC, 2007).

2.4.10.3.2 NRC Staff's Technical Evaluation

In the preceding sections of this report, the NRC staff estimated the highest water surface elevation due to flooding in the Savannah River and concluded that it is well below the proposed site grade. The NRC staff concluded that protection from flooding in the Savannah River is not needed for a safety-related SSC if its entrances and openings are located above the proposed site grade of 220 feet MSL.

2.4.10.4 Conclusion

The proposed site grade of 220 feet MSL is safe from flooding in the Savannah River. The entrances and openings of all safety-related SSC that are located above the proposed site grade would be safe from flooding.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the flood protection measures at the proposed site. RS-002, Section 2.4.10 of provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating flood protection measures at the site. Furthermore, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the flooding protection requirements at the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, the NRC staff concludes that the identification and consideration of the flooding protection requirement site characteristics set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d). In view of the above, the NRC staff finds the applicant's proposed site characteristics related to flooding protection requirements for inclusion in an ESP for the applicant's site, acceptable.

2.4.11 Low Water Considerations

In this section of the applicant's SSAR, natural events that may reduce or limit the available safety-related cooling water supply, are identified and the applicant ensures that an adequate water supply will exist to shut down the plant under conditions requiring safety-related cooling. The NRC staff's review of the SSAR covers (1) low water from drought, (2) low water from other phenomena, (3) effect of low water on safety-related water supply, (4) water use limits, (5) consideration of other site-related evaluation criteria, and (6) additional information for 10 CFR Part 52 applications.

2.4.11.1 Introduction

The VEGP site is located on the southwest side of the Savannah River (SNC, 2007). The proposed units at the VEGP site will not rely on safety-related cooling water from any external source including the Savannah River and groundwater.

2.4.11.2 Regulatory Basis

The acceptance criteria for this section relate to the following regulations:

- 10 CFR Part 52 and 10 CFR Part 100 require that hydrologic characteristics be considered in the site evaluation.

- 10 CFR 100.23 requires that siting factors to be evaluated must include the cooling water supply.

Section 2.4.11 of RS-002 provides the following criteria that was used by the NRC staff to evaluate this SSAR section.

- The regulations at 10 CFR Part 52 and 10 CFR Part 100 require that the evaluation of a nuclear power plant site consider the hydrologic characteristics. To satisfy the requirements of 10 CFR Part 52 and 10 CFR Part 100, the applicant's SSAR should describe the surface and subsurface hydrologic characteristics of the site and region. In particular, the UHS for the cooling water system may consist of water sources that could be affected by the site's hydrologic characteristics that may reduce or limit the available supply of cooling water for safety-related SSCs, such as those resulting from river blockage or diversion, tsunami runup and drawdown, and dam failure.

- Meeting the requirements of 10 CFR Part 52 and 10 CFR Part 100 provides reasonable assurance that severe hydrologic phenomena, including low-water conditions, will pose no undue risk to the type of facility proposed for the site.

- As required by 10 CFR 100.23, siting factors, including cooling water supply, must be evaluated for a nuclear unit. The evaluation of the emergency cooling water supply for a nuclear power plant(s) of a specified type that might be constructed on the proposed site should consider river blockages, diversions, or other failures that may inhibit the flow of cooling water, tsunami runup and drawdown, and dam failures.

- The regulation at 10 CFR 100.23 applies to this section because the UHS for the cooling water system consists of water sources that are subject to natural events that may reduce or limit the available supply of cooling water (i.e., the heat sink). Natural events such as river blockages, diversions, or other failures that may inhibit the flow of cooling water, tsunami runup and drawdown, and dam failures should be conservatively estimated to assess the potential for these characteristics to influence the design of those SSCs important to safety for a nuclear unit(s) of a type specified by the applicant that might be constructed on the proposed site. The available water supply should be sufficient to meet the needs of the unit(s) to be located at the site. Specifically, those needs include the maximum design essential cooling water flow, as well as the maximum design flow for normal plant needs at power and at shutdown.

- The specific criteria discussed in the paragraphs below assess the applicant's ability to meet the requirements of the hydrologic aspects of the above regulations. Acceptance is based primarily on the adequacy of the UHS to supply cooling water for normal operation, anticipated operational occurrences, safe shutdown, cooldown (first 30 days), and long-term cooling (periods in excess of 30 days) during adverse natural conditions.

<u>Low Flow in Rivers and Streams</u>

- For essential water supplies, the low-flow/low-level design for the primary water supply source is based on the probable minimum low flow and low level resulting from the most severe drought that can reasonably be considered for the region. The low-flow/low-level site parameters for operation should not allow shutdowns caused by inadequate water supply to trigger the frequent use of emergency systems.

Low Water Resulting from Surges, Seiches, or Tsunami

- For coastal sites, the applicant should postulate the appropriate PMH wind fields at the ESP stage to estimate the maximum winds blowing offshore, thus creating a probable minimum surge level. Low-water levels on inland ponds, lakes, and rivers caused by surges should be estimated based on the probable maximum winds oriented away from the plant site. The same general analysis methods discussed in Sections 2.4.3, 2.4.5, and 2.4.6 of RS-002 apply to low-water estimates resulting from the various phenomena discussed. If the site is susceptible to such phenomena, minimum water levels resulting from setdown (sometimes called runout or rundown) from hurricane surges, seiches, and tsunamis should be verified at the COL or CP stage to be higher than the intake design basis for essential water supplies.

Historical Low Water

- If historical flows and levels are used to estimate design values by inference from frequency distribution plots, the data used should be presented to allow for an independent determination. The data and methods of NOAA, USGS, SCS, USBR, and USACE are acceptable.

Future Controls

- This section is acceptable if water use and discharge limitations (both physical and legal), which are already in effect or under discussion by the responsible Federal, State, regional, or local authorities and which may affect the water supply for a nuclear unit(s) of a type specified by the applicant that might be constructed on the proposed site, have been considered and are substantiated by reference to reports of the appropriate agencies. The design basis should identify and take into account the most adverse possible effects of these controls to ensure that essential water supplies are not likely to be negatively affected in the future.

2.4.11.3 Technical Evaluation

The technical evaluation consists of (1) a review of the technical information presented in the application, and (2) NRC staff's technical evaluation to determine effects of low water conditions.

2.4.11.3.1 Technical Information Presented by the Applicant

The applicant stated that proposed VEGP Units 3 and 4 will not use any external water sources for safety-related cooling water supply (SNC, 2007).

2.4.11.3.2 NRC Staff's Technical Evaluation

The applicant stated that proposed VEGP Units 3 and 4 will not need any external water sources for safety-related cooling water supply for continuous use. The Permit Condition 1, stated in Section 2.4.8 of this SER, requires that VEGP Units 3 and 4 will not rely on any

external water source for safety-related cooling water other than initial filling and occasional makeup. Consequently, low water conditions will not affect any safety-related SSCs.

2.4.11.4 Conclusion

As stated by Permit Condition 1 in Section 2.4.8 of this report, the proposed VEGP Units 3 and 4 will not rely on any external source of water supply for safety-related cooling on a continuous basis, and therefore, low water conditions will not affect any safety-related SSC.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the identification and evaluation of low water conditions at the proposed site. RS-002, Section 2.4.11 of provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating low water conditions affecting the site. Furthermore, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the hydrologic interface of the plant with the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, the NRC staff concludes that the identification and consideration of the climatic site characteristics set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d). In view of the above, the NRC staff finds the applicant’s site characterization related to low water considerations for inclusion in an ESP for the applicant’s site acceptable.

2.4.12 Groundwater

2.4.12.1 Introduction

This section of the applicant’s SSAR evaluates the hydrogeological characteristics of the site for the purpose of describing the effects of groundwater on the plant foundations and reliability of safety-related water supply and dewatering systems. The NRC staff’s review of the SSAR covers (1) Local and Regional Groundwater Characteristics and Use, (2) Effects on Plant Foundations and other Safety-Related SSCs, (3) Reliability of Groundwater Resources and Systems Used for Safety-Related Purposes, (4) Reliability of Dewatering Systems, and (5) Consideration of Other Site-Related Evaluation Criteria.

The proposed VEGP Units 3 and 4 are to be located on a topographic ridge that is perpendicular to the Savannah River and forms a boundary between two watersheds. The watershed to the northwest is dominated by Mallard Pond and an unnamed drainage from it that discharges to the Savannah River. The watershed to the southeast is dominated by Daniels Branch, Telfair Pond and Beaverdam Creek. Beaverdam Creek discharges to the

Savannah River. Construction of the proposed facilities may alter the topography of the site and alter recharge to the unconfined aquifer in the immediate vicinity of the proposed units. Groundwater has no safety-related role in the operation of the proposed VEGP units.

A complete discussion and evaluation of accidental radioactive releases, (i.e., the release, migration, and fate), can be found in the SER Section 2.4.13.

2.4.12.2 Regulatory Basis

The acceptance criteria for this section relate to the following regulations:

- 10 CFR Part 52 and 10 CFR Part 100 require that hydrologic characteristics be considered in the site evaluation.

- 10 CFR 100.23 sets forth the criteria to determine the suitability of design bases for a nuclear unit(s) of specified type that might be constructed on the proposed site with respect to its seismic characteristics. This section also requires applicants to ensure the adequacy of the cooling water supply for emergency and long-term shutdown decay heat removal, taking into account information concerning the physical, including hydrological, properties of the materials underlying the site.

As specified in 10 CFR 100.20(c), the NRC must consider the site's physical characteristics (including seismology, meteorology, geology, and hydrology) when determining its acceptability to host a nuclear unit(s).

The regulation at 10 CFR 100.20(c)(3) requires that the NRC address factors important to hydrologic radionuclide transport using onsite characteristics. To satisfy the hydrologic requirements of 10 CFR Part 100, the NRC review of the applicant's SSAR should verify the description of ground water conditions at the proposed site and of the effect on those conditions of the construction and operation of a nuclear unit(s) of specified type that might be constructed on the site. Meeting this requirement provides reasonable assurance that the release of radioactive effluents from a unit(s) of specified type that might be constructed on the proposed site will not significantly affect the ground water at or near the site.
The regulation at 10 CFR 100.23 requires that the evaluation consider geologic and seismic factors when determining the suitability of the site and the acceptability of the design for each nuclear power plant. In particular, 10 CFR 100.23(d)(4) requires consideration of the physical properties of materials underlying the site when designing a system to supply cooling water for emergency and long-term shutdown decay heat removal.

Though not required at the ESP stage, the applicant for a COL must demonstrate compliance with GDC 2 as it relates to designing SSCs important to safety to withstand the effects of natural phenomena.

To judge whether the applicant has met the requirements of the hydrologic aspects of 10 CFR Part 52 and 10 CFR Part 100, the NRC uses the following criteria:

- Section 2.4.12.1 of the SSAR must provide a full, documented description of regional and local ground water aquifers, sources, and sinks. In addition, the type of ground water use, wells, pump, storage facilities, and the flow needed for a nuclear unit(s) of specified type that might be constructed on the site should be described. If ground water is to be used as an essential source of water for safety-related equipment, the design basis for protection from natural and accident phenomena should compare with RG 1.27 guidelines. Bases and sources of data should be adequately described and referenced.

- Section 2.4.12.2 of the SSAR should provide a description of present and projected local and regional ground water use. Existing uses, including amounts, water levels, location, drawdown, and source aquifers, should be discussed and tabulated. Flow directions, gradients, velocities, water levels, and effects of potential future use on these parameters, including any possibility for reversing the direction of ground water flow, should be indicated. Any potential ground water recharge area within the influence of a nuclear unit(s) of specified type that might be constructed on the site, as well as the effects of construction, including dewatering, should be identified. The influence of existing and potential future wells with respect to ground water beneath the site should also be discussed. Bases and sources of data should be described and referenced. RS-002 discusses certain studies concerning ground water flow problems.

- Section 2.4.12.3 of the SSAR must discuss the need for and extent of procedures and measures, including monitoring programs, to protect present and projected ground water users. These items are site specific and will vary with each application.

To judge whether the applicant has met the requirements of 10 CFR Part 50; 10 CFR 50.55, “Conditions of Construction Permits”; the NRC uses the following criteria:

SSAR Section 2.4.12.4 should describe the design bases (and development thereof) for ground water-induced loadings on subsurface portions of safety-related SSCs at the COL stage. If a permanent dewatering system is employed to lower design-basis ground water levels, the bases for the design of the system and determination of the design basis for ground water levels should be provided. Information should be provided regarding the following:

  - all structures, components, and features of the system

  - the reliability of the system as related to available performance data for similar systems used at other locations

  - the various soil parameters (such as permeability, porosity, and specific yield) used in the design of the system

  - the bases for determination of ground water flow rates and areas of influence to be expected

  - the bases for determination of time available to mitigate the consequences of system failure where system failure could cause design bases to be exceeded

- the effects of malfunctions or failures (such as a single failure of a critical active component or failure of circulating water system piping) on system capacity and subsequent ground water levels

- a description of the proposed ground water level monitoring program and outlet flow monitoring program

In addition, if wells are proposed for safety-related purposes, the hydrodynamic design bases (and development thereof) for protection against seismically induced pressure waves should be described and should be consistent with site characteristics.

2.4.12.3 Technical Evaluation

The Technical Evaluation section consists of (1) a review of the information provided by the applicant and (2) the NRC staff's evaluation on the effects of groundwater.

2.4.12.3.1 Technical Information Presented by the Applicant

The VEGP site is located on a ridge perpendicular to the Savannah River which lies to the northeast. This ridge separates two drainages; to the northwest lies Mallard Pond and an unnamed drainage stream, and to the southeast lies Daniels Branch, Telfair Pond and Beaverdam Creek (Southern 2007a, Section 2.4.1.2.2).

The applicant described the hydrogeology in Section 2.4.12.1.1 of the SSAR (Southern 2007a). The thickness of Coastal Plain sediments varies from less than 200 feet at the Fall Line to 4000 feet at the coastline, and is approximately 1000 feet thick at the site (Southern 2007a, Section 2.4.12.1.1). A surface topography of gently rolling hills ranges in elevation from less than 90 feet MSL to nearly 300 feet MSL in the immediate vicinity of the VEGP site (Southern 2007b, Section 2.6.1). Developed portions of the site have ground surface elevations of approximately 220 feet MSL. The Savannah River has incised the Coastal Plain sediments and formed steep bluffs exhibiting topographic relief of nearly 150 feet from the river to the developed portions of the existing VEGP site. The source of groundwater is precipitation onto outcrops of aquifer sediments. Locally, net infiltration from precipitation recharges the Water Table aquifer (Southern 2007a, Section 2.4.12.1.2). Net infiltration from precipitation recharges the locally confined Tertiary and Cretaceous aquifers at outcrops of these formations nearer the Fall Line (Southern 2007a, Section 2.4.12.1.2).

The applicant stated that the Water Table aquifer drains to wells, and springs, seeps, and local drainages that ultimately drain to the Savannah River (Southern 2007a, Section 2.4.12.1.2). Figure 2.4.12-7 of the SSAR shows the piezometric surface of the Water Table aquifer and implies groundwater flow throughout the power block area moving to the north-northwest and Mallard Pond. Depictions of the piezometric surface from 1971 (see Southern, 2003 drawing # AX6DD329) and 1984 (see Southern, 2003 drawing # AX6DD330) reveal the evolution of the piezometric surface of the Water Table aquifer.

The applicant stated that the Tertiary aquifer drains to the Savannah River (see Figure 2.4.12-14 in Southern 2007a) and also discharges to wells and natural springs, and to subaqueous outcrops presumed to exist offshore (Southern 2007a, Section 2.4.12.1.2). Discharge to the

Savannah River occurs where the river has completely eroded the Blue Bluff Marl confining layer. Depictions of the piezometric surface from 1971 (see Southern, 2003 drawing # AX6DD327) and 1984 (see Southern, 2003 drawing # AX6DD328) reveal the evolution of the piezometric surface of the Tertiary aquifer.

In RAI 2.4.12-1, the NRC staff (Southern 2007c) requested that the applicant revisit the issue of well data in conflict with the conceptual model advanced in the SSAR (Southern 2007a, Sections 2.4.12 and 2.4.13), and the potential for alternate conceptual models of groundwater flow and potential contaminant movement during an accidental release. As a result of their review, the applicant concluded that piezometric head data for observation wells OW-1001 and OW-1001A were invalid and removed the data from the ESP application (Southern 2007a, 2007c). The well screen for OW-1001A ranges in elevation from 146.13 to 136.13 feet MSL and is about 10 feet above the top of the Blue Bluff Marl as reported by the applicant in the RAI Response. Omission of these data and information lead the applicant to interpolate other nearby measurements and assign a piezometric head value to this location of approximately 145 feet (see Southern 2007a, Figure 2.4.12-7).

The applicant reported hydraulic properties of the Barnwell Formation sediments employed in safety analyses and include the maximum hydraulic conductivity measured for the Utley Limestone of 125,400 feet/year (343 feet/day). A value for effective porosity of 0.32 (Southern 2007a, Section 2.4.12.1.4) was derived by the applicant from the median specific gravity and moisture content measurements. To further assure conservatism in their calculations, the applicant used a literature based value of 0.10 for effective porosity in Section 2.4.13 (Southern 2007a). The release pathway in the Water Table aquifer was described in Section 2.4.12.1.4 (Southern 2007a) as being "... a distance of approximately 2450 feet between either auxiliary building and the south side of Mallard Pond..." A hydraulic gradient of 0.014 feet/feet was estimated by the applicant to apply to the Water Table aquifer. The applicant based this on the maximum gradient between observation wells OW-1009 and OW-1005 (Southern 2007a, Section 2.4.12.1.4).

A maximum measured hydraulic conductivity value of 1220 feet/yr (3.3 feet/day) was assigned by the applicant to the engineered backfill (Southern 2007a, Section 2.4.12.1.4). This value was taken from the prior post-construction testing of backfill regions underlying VEGP Units 1 and 2 as reported in Updated Final Safety Analysis Report (UFSAR), Table 2.4.12-14 (Southern 2003).

The applicant reported hydraulic properties of the Tertiary aquifer sediments (Southern 2007a, Section 2.4.12.1.4, Table 2.4.12-3) employed in the safety analyses. They include a range of hydraulic conductivities from 0.35 to 2.1 feet/day with a geometric mean of 0.83 feet/day, an effective porosity of 0.31, and a storage coefficient of 1.0E-4. A maximum hydraulic gradient of 0.005 feet/feet is estimated by the applicant to apply to a distance of 5600 feet between the center of the power block and the Savannah River.

In RAI 2.4.12-2 (Southern 2007c), the NRC staff requested the applicant revisit the issue of Water Table aquifer response to drought and the recovery from drought, and the continuity versus discontinuity of select hydrogeologic units, especially with regard to the applicant's examination of alternate conceptual models explaining field observations. In RAI 2.4.12-3 (Southern 2007c) NRC staff requested all available information on the thickness and continuity of hydrogeologic units of the Water Table aquifer. These requests focused on the applicant's

adoption of a single conceptual model as the basis for releases to the groundwater environment from the operating facility. In their response, the applicant revised substantially their conceptual model used as the basis for estimating the potential impact of an accidental release. However, the applicant continues to rely on a single conceptual model. The applicant describes a north-northwest directed release through the Water Table aquifer to Mallard Pond and its drainage (Southern 2007a, Section 2.4.12.1.4). However, the applicant does note that increased impervious surfaces resulting from construction of power generation and associated facilities and the construction of storm-water management facilities will tend to reduce recharge to the Water Table aquifer in the vicinity of proposed VEGP Units 3 and 4 (Southern 2007a, Section 2.4.12.1.4).

The applicant stated that the future plant or plants fitting within the bounding parameters provided in the proposed permit application has a passive safety-related UHS, and there are no safety-related groundwater supplies except for initial fillup and occasional makeup water (Southern 2007b).

The applicant stated the plant grade for the proposed units is elevation 220 feet MSL (Southern 2007a, Section 2.5.4.5.1), and the foundation embedment depth is 39.5 feet from plant grade (Southern 2007a, Table 1-1). The elevation of containment and auxiliary building foundations are approximately 180 feet MSL. The applicant stated the maximum groundwater elevation of the water table of the unconfined aquifer underlying the proposed VEGP units is 165 feet MSL (Southern 2007a, Table 1-1).

The applicant stated the excavated natural materials will be replaced with compacted structural fill with properties that provide an adequate factor of safety against liquefaction (Southern 2007a, Section 2.5.4.8.4). Confirmatory liquefaction analyses will be performed by the applicant during the COL phase of the project (Southern 2007a, Section 2.5.4.8.3).

2.4.12.3.2 NRC Staff's Technical Evaluation

The technical evaluation by NRC staff is presented below for each of the specific RS acceptance criteria.

<u>**Local and Regional Groundwater Characteristics and Use**</u>

Based on a review of USGS documents Clarke and West (1997, 1998) and Cherry (2006) as well as State of Georgia documents Huddlestun and Summerour (1996) and Summerour et al (1994, 1998) the NRC staff determined that the applicant's description of the regional and local hydrogeologic conditions is accurate with two exceptions; (1) groundwater flow within the Water Table aquifer may not always be from the power block area to the north-northwest and Mallard Pond, and (2) not all data support the applicant's statements to the effect that groundwater in South Carolina does not affect and is not affected by VEGP site operation. NRC staff investigations of the site and review of topographic maps confirm the proposed location is on a ridge perpendicular to the Savannah River and separating drainages to the north-northwest (Mallard Pond) and to the south-southeast (Daniels Branch, Telfair Pond, Beaverdam Creek).

The NRC staff confirmed that the current piezometric surface contour plots including seasonal and climatic fluctuations of the Water Table aquifer indicate drainage today toward the north-

northwest and Mallard Pond from release points within the power block area. However, a number of lines of reasoning lead the NRC staff to question whether this would be the only groundwater flow and contaminant release direction for future release events.

First, the applicant stated that the piezometric head level in the Water Table aquifer is a function of the topography and recharge, and the applicant also stated they are changing both in the vicinity of the proposed VEGP Units 3 and 4. Substantial areas of the proposed site will be leveled and made impervious by construction of buildings and paved surfaces. Other substantial areas of the proposed site will be leveled and may be made more transmissive by converting them to gravel surfaces maintained essentially vegetation free. Storm-water management facilities will be constructed to route run-off (i.e., potential sources of infiltration) away from the site. Each of these actions implies a potentially substantial change in the net infiltration to the Water Table aquifer in the immediate vicinity of proposed VEGP Units 3 and 4.

Second, NRC staff review of the history of piezometric head contours in the Water Table aquifer for the years 1971 (see Southern, 2003 drawing # AX6DD329), 1984 (see Southern, 2003 drawing # AX6DD330), and 2005 (see SSAR Figure 2.4.12-7 in Southern 2007a) revealed evidence of change in the piezometric head that has occurred since 1971 as a result of the construction and operation of VEGP Units 1 and 2. This suggests the assumption that the current piezometric surface will exist after construction and during operation of the proposed Units is not realistic.

Finally, NRC staff used a simple analytic element groundwater model to evaluate how changes in net infiltration or recharge to the Water Table aquifer in the vicinity of a large industrial facility can result in a shift in the position of the highest piezometric head, and in the direction of future groundwater flow. A region of lower recharge resulting from impermeable materials and/or storm-water management in the vicinity, and a region of higher recharge resulting from portions of the landscape being covered with gravel and maintained vegetation free can result in a significant shift in the distribution of piezometric head in the vicinity of the facility. Such a change was shown to appreciably alter the trajectories of effluents that might be released from various locations within the vicinity of the facility.

Thus, the NRC staff found that the SSAR Section 2.4.12 (Southern 2007a) does not adequately describe the local hydrogeologic conditions that could occur following plant construction and subsequent operation of the proposed units.

The NRC staff confirmed the hydraulic conductivity values for the Water Table aquifer presented by the applicant. The NRC staff independently determined that the USGS derived minimum and maximum range of transmissivity values based on field data (i.e., 500 feet^2/day to 9500 feet^2/day or 3700 gallons/day/feet to 71,000 gallons/day/feet) (Clarke and West 1998, Table 3), when combined with the local thickness of the Water Table aquifer (i.e., approximately 30 feet) are indicative of the higher values of the Utley Limestone of the Barnwell Formation cited by the applicant.

NRC staff review of the SSAR (Southern 2007a, Section 2.4.12) and USGS documents (Clarke and West 1997, 1998; Cherry 2006) supports the applicant's interpretation that the Tertiary aquifer drains toward the Savannah River. The sequence of piezometric head maps from 1971 (see Southern, 2003 drawing # AX6DD327), 1984 (see Southern, 2003 drawing # AX6DD328), and the seasonal fluctuations in the 2005-2006 (see SSAR Figure 2.4.12-14 through Figure

2.4.12-18 in Southern 2007a) indicate the direction of groundwater flow has been maintained. However, these piezometric head data reveal a pattern of decline in head values over time.

Regarding applicant's reported values of hydraulic conductivity in the Tertiary aquifer, the NRC staff independently reviewed USGS minimum and maximum ranges of transmissivity estimates based on field data (1346 to 91,200 gal/d/ft) and based on regional simulation (100 to 185,000 gal/d/ft) (Clarke and West 1998, Table 12). When combined with the local thickness of the Tertiary aquifer (approximately 182 feet) the USGS data bracket the central value of hydraulic conductivity provided by the applicant (i.e., 0.83 feet/day), but are generally higher.

One purpose of admitting an alternate conceptual model is to express the uncertainty in the interpretation of field observations and data sets that are, by their nature, incomplete. An example lies in the interpretation of data available from observation wells OW-1001 and OW-1001A. A poorly constructed and slowly responding well (i.e., OW-1001) may still provide valid data, until the validity of the data are disproved by completion of a competent observation well at the location. Observations of hydraulic head below the screened interval elevation of a well (i.e., OW-1001A) are obviously not valid as head observations; however, they suggest that the hydraulic head at that location is below the bottom of the screen (i.e., 136.13 feet). Again, until replaced with a competent observation well and an unambiguous data set, the information provided by OW-1001 and OW-1001A suggest an alternate interpretation of local communication between the Water Table and Tertiary aquifers. The data and information from these two wells are consistent with groundwater movement from the Water Table aquifer into the Tertiary aquifer at this location. This alternate conceptual model is discussed further in this SER Section 2.4.13.

NRC staff reviewed aspects of the groundwater system that lead the applicant to state that groundwater in South Carolina does not affect nor is it affected by VEGP site operation. The NRC staff reviewed the USGS groundwater model of the region that included the VEGP site in Georgia as well as the SRS in South Carolina (Clarke and West 1998, Cherry 2006). This recent USGS work presents a current interpretation of groundwater data and provides insight into where the Savannah River has incised confining zones, and allowed releases to occur from confined aquifers into the Savannah River alluvium and hence to the Savannah River. The deep confined aquifers of the Cretaceous aquifer system (i.e., described as the Dublin and Midville aquifer systems in USGS reports) are not incised by the river opposite the VEGP site, but several miles upstream (Clarke and West 1998, Figure 5). Therefore, the confining zones are intact beneath the Savannah River opposite the VEGP site. This allows complete communication of groundwater in the Cretaceous aquifer between the States of Georgia and South Carolina. Accordingly, the absence of information or data on groundwater use in the State of South Carolina is a data gap in the SSAR Section 2.4.12.2. The NRC staff noted that ER Section 2.3.2 on Water Use includes some limited information on South Carolina wells.

Water use data for a period of 20 years ending in the year 2000 suggest that withdrawal rates for surface water and groundwater remained nearly unchanged (Fanning 2003) in the vicinity of the VEGP site. Projected water demand in Burke County, Georgia, indicates an increase of 50 percent by 2035 (Rutherford 2000). In South Carolina an increase of 50 percent is projected by 2045 (SC DNR 2004). However, despite these projections, a recent report by the USGS assigned lower groundwater pumping rates for the region in the future (i.e., through 2020) than have occurred during the recent drought (Cherry 2006, Figure 34). Thus, there is reason to believe that stress on the groundwater resource was highest during the recent drought and

could now diminish. The future demand described above includes production from the Water Table aquifer; however, wells in the Water Table aquifer are relatively low production wells providing groundwater for domestic use. Such wells exhibit a relatively local drawdown and when located on the VEGP property boundary, they are so distant from the proposed power block area that they would not substantially influence the pathway of accidental releases.

The aquifers of interest in the evaluation of safety-related issues are the unconfined or Water Table aquifer, and the uppermost confined or Tertiary aquifer. An accidental release to groundwater would contaminate the Water Table aquifer. It is possible, but perhaps unlikely that communication exists between the Water Table and Tertiary aquifers; however, such communication, if it exists, could lead to an accidental release reaching the Tertiary aquifer. Based on NRC staff review of available data on the piezometric levels of these aquifers, the NRC staff concluded they are influenced by local changes in aquifer characteristics and water use, and discharge locally to surface drainage systems that ultimately discharge to the Savannah River. Man-made changes with a potential to affect regional groundwater characteristics (i.e., the deep confined or Cretaceous aquifer system) over the long term will not influence the safety-related analysis of the groundwater system which focuses on the unconfined or Water Table aquifer.

Any plant or plants fitting within the bounding parameters provided in the proposed permit application would not need ground water for safety-related use; therefore, the staff did not conduct any further review of potential impact of safety-related use of ground water on present and projected groundwater users.

Effects on Plant Foundations and Other Safety-Related SSCs

The proposed VEGP Units 3 and 4 will have foundations for the containment and auxiliary buildings at approximately elevation 180 feet MSL. The maximum water table elevation or design groundwater level will be taken as 165 feet MSL based on monitoring of the unconfined aquifer over the past decade. The plant grade elevation is 220 feet MSL. Foundations of all safety-related structures will be on structural backfill that will be placed above the Blue Bluff Marl. The excavated natural materials will be replaced with compacted structural fill.

Based on the maximum observed groundwater level of 165 feet MSL, the water table elevation of the unconfined aquifer would not contribute a buoyant force on the nuclear island structure(s), all of which would have foundation elevations at or higher than 180 feet MSL. However, following construction activity and modification of surface condition of the area surrounding the safety-related plant structures, sufficient changes in ground water recharge may significantly change the elevation of the ground water table. In absence of specific analyses presented by the applicant, the NRC staff was unable to evaluate the future change in ground water table surrounding the foundation areas of safety-related structures.

The applicant should provide an improved and complete description of the current and future local hydrological conditions, including alternate conceptual models, to demonstrate that the design bases related to groundwater-induced loadings on subsurface portions of safety-related SSCs would not be exceeded. Alternatively, the applicant can provide design parameters for buoyancy evaluation of the plant structures. This is **Open Item 2.4-2**.

Reliability of Groundwater Resources and Systems Used for Safety-Related Purposes

There are no SSCs that depend on groundwater for the operation of proposed VEGP Units 3 and 4. Therefore, the NRC staff has not evaluated the reliability of groundwater source for safety-related use. The NRC staff proposed Permit Condition 1 in Section 2.4.8 of this document that the proposed VEGP Units 3 and 4 will have no SSCs that rely on any groundwater for a safety-related use other than initial fill and occasional makeup.

Reliability of Dewatering Systems

The applicant has proposed no permanent dewatering systems as part of the operation of proposed VEGP Units 3 and 4. The NRC staff will evaluate the need for a safety-related dewatering system after resolution of Open Item 2.4-2, stated above.

2.4.12.4 Conclusion

The NRC staff specified Open Item 2.4-2 stating that the applicant should provide an improved and complete description of the current and future local hydrological conditions, including alternate conceptual models, to demonstrate that the design bases related to groundwater-induced loadings on subsurface portions of safety-related SSCs would not be exceeded. Alternatively, the applicant can provide design parameters for buoyancy evaluation of the plant structures. The NRC staff's review of SSAR Section 2.4.12 would be completed after resolution of this Open Item.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the identification and evaluation of effects of groundwater in the vicinity of the proposed site. Section 2.4.12 of RS-002, "Groundwater" provides that the SSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating effects of groundwater in the vicinity of the site and site regions. Furthermore, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the hydrologic interface of the plant with the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Therefore, pending resolution to the open item, the NRC staff concludes that the identification and consideration of the groundwater characteristics set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.23(d)(4). In view of the above, the NRC staff finds the applicant's proposed site characteristics related to hydrology for inclusion in an ESP for the applicant's site acceptable.

2.4.13 Accidental Releases of Radioactive Liquid Effluents In Ground And Surface Waters

2.4.13.1 Introduction

This section of the applicant's SSAR evaluates the hydrogeological characteristics of the site for the purpose of describing the effects of the accidental releases of radioactive liquid effluents in ground and surface waters on existing uses and known and likely future uses of ground and surface water resources. The NRC staff's review of the applicant's SSAR addresses only accidental releases of radioactive liquid effluent. The NRC staff's review of releases from normal operations, and from more likely accidents, are discussed in the applicant's environmental report. The NRC staff's review of the SSAR covers (1) Alternate Conceptual Models, (2) Characteristics that Affect Transport, (3) Pathways, and (4) Consideration of Other Site-Related Evaluation Criteria.

The process followed and documented to identify and quantify the accidental radioactive liquid effluent release, its pathway to the accessible environment and man, and the processes that would describe its migration and attenuation in surface and ground waters is reviewed by the NRC staff in this section of the SER.

2.4.13.2 Regulatory Basis

The acceptance criteria for identifying potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR 52.17 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements in reviewing the identification of potential hazards in site vicinity:

- 10 CFR 52.17(a), with respect to the requirement that the application contain information regarding the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.20(c), also requires that the review take into account the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) to determine its acceptability to host a nuclear unit(s).

- 10 CFR 100.21(d), requires that the physical characteristics of the site, including seismology, meteorology, geology, and hydrology must be evaluated and site parameters established such that potential threats from such physical characteristics will pose no undue risk to the type of facility to be located at the site.

Section 2.4.13 of RS-002 provides the following criteria that was used by the NRC staff to evaluate this SSAR section.

- Compliance with 10 CFR Part 52 and 10 CFR Part 100 requires that the NRC consider the local geologic and hydrologic characteristics when determining the acceptability of a site to host a nuclear unit(s). The geologic and hydrologic characteristics of the site may have a bearing on the potential consequences of radioactive materials escaping

from a nuclear unit(s) of specified type that might be constructed on the proposed site. Special precautions should be planned if a reactor(s) will be located at a site where a significant quantity of radioactive effluent could accidentally flow into nearby streams or rivers or find ready access to underground water tables.

- These criteria apply to RS-002, Section 2.4.13, because the reviewer evaluates site hydrologic characteristics with respect to the potential consequences of radioactive materials escaping from a nuclear unit(s) of specified type that might be constructed on the proposed site. The review considers the radionuclide transport characteristics of ground water and surface water environments with respect to accidental releases to ensure that current and future users of ground water and surface water are not adversely affected by an accidental release from a nuclear unit(s) of specified type that might be constructed on the proposed site. RG 1.113, Revision 1, "Estimating Aquatic Dispersions of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," issued April 1977, and RG 4.4, "Reporting Procedure for Mathematical Models Selected to Predict Heated Effluent Dispersion in Natural Water Bodies," issued May 1974, provide guidance in the selection and use of surface water models for analyzing the flow field and dispersion of contaminants in surface waters.

- Meeting the requirements of 10 CFR Part 52 and 10 CFR Part 100 provides reasonable assurance that accidental releases of liquid effluents to ground water and surface water, and their adverse impact on public health and safety, will be minimized.

- To judge whether the applicant has met the requirements of 10 CFR Part 52 and 10 CFR Part 100 with respect to accidental releases of liquid effluents, the NRC uses the following criteria:

    - Radionuclide transport characteristics of the ground water environment with respect to existing and future users should be described. Estimates and bases for coefficients of dispersion, adsorption, ground water velocities, travel times, gradients, permeabilities, porosities, and ground water or piezometric levels between the site and existing or known future surface water and ground water users should be described and be consistent with site characteristics. Potential pathways of contamination to ground water users should also be identified. Sources of data should be described and referenced.

    - Transport characteristics of the surface water environment with respect to existing and known future users should be described for conditions which reflect worst-case release mechanisms and source terms to postulate the most pessimistic contamination from accidentally released liquid effluents. Estimates of physical parameters necessary to calculate the transport of liquid effluent from the points of release to the site of existing or known future users should be described. Potential pathways of contamination to surface water users should be identified. Sources of information and data should be described and referenced. The NRC staff will base its acceptance on its evaluation of the applicant's computational methods and the apparent completeness of the set of parameters necessary to perform the analysis.

- Mathematical models are acceptable to analyze the flow field and dispersion of contaminants in ground water and surface water, providing that the models have been verified by field data and that conservative site-specific hydrologic parameters are used. Furthermore, conservatism should guide the selection of the proper model to represent a specific physical situation. Radioactive decay and sediment adsorption may be considered, if applicable, providing that the adsorption factors are conservative and site specific. RG 1.113 guides in the selection and use of surface water models. RS-002 discusses the transport of fluids through porous media.

2.4.13.3 Technical Evaluation

The Technical Evaluation section consists of (1) a review of the information provided by the applicant and (2) the NRC staff's evaluation on the applicant's submittal.

2.4.13.3.1 Technical Information Presented by the Applicant

In SSAR Section 2.4.13.1.1, the applicant selected the accident scenario from the information provided by the reactor vendor for the future plant or plants fitting within the bounding parameters provided in the SSAR. The accident scenario is an instantaneous release from an effluent holdup tank located at the lowest level of the auxiliary building within the power block area (Southern 2007a). The applicant stated the effluent holdup tank has a volume of 28,000 gallons and the postulated rupture leads to a loss of 80 percent of that volume or 22,400 gallons. In its analysis, the applicant assumed that the release instantaneously enters the backfilled region of the Water Table aquifer that underlies the auxiliary building, and displaces all pore water in a region 21 feet wide, 21 feet long, and 20 feet deep.

The applicant assumed a release pathway in the groundwater environment from the auxiliary building northward to the south side of Mallard Pond, a distance estimated as 2450 feet; 460 feet through backfill, 990 feet through undisturbed aquifer to the vicinity of OW-1005, and an additional 1000 feet to the south side of Mallard Pond. The applicant estimated a maximum hydraulic gradient of 0.014 feet/feet to apply to the Water Table aquifer in the vicinity of proposed Units 3 and 4. This estimate was based on the gradient between observation wells OW-1009 and OW-1005 (Southern 2007a, Section 2.4.12.1.4). A maximum gradient of 0.023 feet/feet was estimated by the applicant for the aquifer between OW-1005 and Mallard Pond. This was the only release pathway analyzed by the applicant.

In SSAR Section 2.4.12 (Southern 2007a), the applicant reported hydraulic properties of the Barnwell Formation sediments employed in safety analyses and include the maximum hydraulic conductivity measured for the Utley Limestone of 125,400 feet per year (343 feet per day). The applicant derived a value for effective porosity of 0.32 (Southern 2007a, Section 2.4.12.1.4) from the median specific gravity and moisture content measurements. To further assure conservatism in their calculations, the applicant used a literature based value of 0.10 for effective porosity in SSAR Section 2.4.13 (Southern 2007a). The applicant estimated a hydraulic gradient of 0.014 feet/feet to apply to the Water Table aquifer. It was based on the maximum gradient between observation wells OW-1009 and OW-1005 (Southern 2007a, Section 2.4.12.1.4).

In SSAR Section 2.4.12.1.4, the applicant assigned a maximum measured hydraulic conductivity value of 1220 feet per year (3.3 feet per day) to the engineered backfill (Southern 2007a). As reported in UFSAR Table 2.4.12-14, this value was taken from the prior post-construction testing of backfill regions underlying VEGP Units 1 and 2 (Southern 2003). The applicant also estimated the effective porosity as 0.34 based on information from the UFSAR (Southern 2003). The hydraulic gradient in the engineered backfill was estimated to be the same as in the surrounding water table aquifer, a maximum estimated value of 0.014 ft/ft.

In SSAR Section 2.4.12.1.4, Table 2.4.12-3, the applicant reported hydraulic properties of the Tertiary aquifer sediments (Southern 2007a) employed in safety analyses and they include a range of hydraulic conductivities from 0.35 to 2.1 feet per day with a geometric mean of 0.83 feet per day, an effective porosity of 0.31, and a storage coefficient of 1.0E-4. A maximum hydraulic gradient of 0.005 ft/ft is estimated by the applicant to apply to a distance of 5600 feet between the center of the power block and the Savannah River (Southern 2007a, Section 2.4.12.1.4).

The applicant described Mallard Pond as being controlled by a combination of standpipe and spillway with discharge to a stream that ultimately discharges to the Savannah River (Southern 2007c). The applicant identified two companies as the nearest downstream industrial surface water users; both located about 106 miles downstream of VEGP (Southern 2007a, Section 2.4.13.1.2).

In RAI 2.4.13-1 (Southern 2007c), the NRC staff requested the applicant revisit the process used to establish the conceptual model adopted for release analyses as well as the conservative or bounding hydraulic properties employed in safety related calculations. As a result the applicant maintained a single conceptual model for release, (e.g., the northward release groundwater pathway to Mallard Pond); however, the applicant revised the conceptual model substantially to present an analysis consistent with the site characterization data presented in SSAR Section 2.4.12 (Southern 2007a).

The applicant’s analysis considered (1) radionuclide decay associated with travel times in sequential portions of the groundwater pathway (i.e., backfill travel time of 9.16 year, aquifer to OW-1005 travel time of 0.06 year, and aquifer to Mallard Pond travel time of 0.03 year), (2) adsorption and decay during a retarded travel time for sorbed radionuclides, and (3) dilution of the groundwater released to Mallard Pond (i.e., 0.10 gallons per minute) in the stream below the pond (i.e., 1125 gallons per minute). The applicant developed distribution coefficients for cobalt, strontium, and cesium. The minimum values of distribution coefficient from sixteen soil samples of potential backfill material were 1.4 milliliters per gram (mL/g) for cobalt, 6.0 mL/g for strontium, and 3.5 mL/g for cesium. Minimum values from three samples of aquifer materials, identified by the applicant as the Utley limestone, were 3.9 mL/g for cobalt, 14.4 mL/g for strontium, and 22.7 mL/g for cesium.

In RAI 2.4.13-2 (Southern 2007c), the NRC staff requested the applicant evaluate the potential for chelation and complexation agents, (e.g., organic acids), to mix with the radiological liquid effluents, and, adversely impact sorption phenomena. The NRC staff requested the applicant make a clear statement whether or not mixing with chelation agents was possible. In the RAI response (Southern 2007c) the applicant stated the site does not prohibit the use of chelants, but rather requires a comprehensive evaluation prior to use. The applicant stated that any future use of chelating agents at Vogtle will be tightly controlled, and that use of chelating

agents is not anticipated if they could come in contact with radioactive materials. The applicant summarized that release of radioactive liquids in contact with chelating agents would be extremely unlikely.

In RAI 2.4.13-3 (Southern 2007c), the NRC staff requested the applicant to more fully describe the basis for the estimated groundwater flow into Mallard Pond, and to fully disclose all data supporting the dilution of the release in surface water flow within the Mallard Pond drainage. In SSAR Section 2.4.13.1.3.3, the applicant provided a full description of groundwater release (Southern 2007a) and a calculation package which details the measurements made for Mallard Pond and its downstream drainage (Southern 2007c). This calculation package, dated September 27, 1985, documents field observations made during June and July of 1985. These measurements represent single moment-in-time measurements. The applicant's calculation package states the discharge downstream of the confluence of Mallard Pond drainage and West Branch drainage ranges from 800 to 1200 gallons per minute (Southern 2007c). The applicant used a discharge of 1125 gallons per minute in calculations of the release dilution.

Of the 56 radionuclides in the effluent holdup tank inventory (Southern 2007a, Table 2.4.13-1), only eight were identified by the applicant as requiring more than decay in the groundwater pathway to be reduced to less than one percent of their maximum permissible concentration (MPC) (Southern 2007a). The eight radionuclides were H-3, Mn-54, Fe-55, Co-60, Sr-90, I-129, Cs-134, and Cs-137.

In SSAR Section 2.4.13.1.3.2, the applicant identified six radionuclides as requiring more than decay and adsorption in the groundwater pathway to be reduced to less than one percent of their MPC (Southern 2007a). Distribution coefficients were only available for cobalt, strontium, and cesium. Following inclusion of adsorption and decay associated with retarded travel time, the remaining six radionuclides requiring further analysis were identified by the applicant as H-3, Mn-54, Fe-55, Sr-90, I-129, and Cs-137.

The applicant applied dilution downstream of Mallard Pond to the decayed radio-isotope concentrations entering Mallard Pond from the Water Table aquifer. The estimated concentration of each radio-isotope downstream of the dilution location is below their respective MPCs; however, Cs-137 is approximately 25 percent of its MPC (Southern 2007a, Section 2.4.13.1.3.3, Table 2.4.13-5). The applicant calculated the cumulative measure, (i.e., the sum of all ratios), and reported 0.32 which is less than one and meets the requirement in Note 4 in Appendix B, 10 CFR Part 20, "Standards for Protection Against Radiation," (Southern 2007a, Section 2.4.13.1.3.4).

The applicant noted that the compliance demonstrated is for a point along the stream within the restricted area and does not represent a potable water source. The applicant stated that the stream is a gaining stream (i.e., not discharging to groundwater) and that it discharges to the Savannah River. A conservative representation of Savannah River flow was provided by the applicant as the 100-year drought flow, 3298 cubic feet persec (1,480,000 gallons per minute). If all the dilution necessary in the drainage stream were not available, that flow, (i.e., 1125 gallons per minute) represents less than one tenth of one percent of the 100-year drought flow (i.e., 0.076 percent) (Southern 2007a, Section 2.4.13.1.4).

In SSAR Section 2.4.13.2, the applicant stated there are no outdoor tanks containing liquid radwaste in the reactor design under consideration, and no accident scenario is projected to result in a liquid effluent release directly to the surface water environment (Southern 2007a).

2.4.13.3.2 NRC Staff's Technical Evaluation

The NRC staff is divided its technical evaluation into four topics; alternate conceptual models, characteristics that affect transport, pathways, and consideration of other site-related evaluation criteria.

<u>**Alternate Conceptual Models**</u>

Transport of an accidental release of radioactive liquid effluent is viewed as a combinatorial problem with multiple possible environmental pathways. It is the pathway that results in the most severe release consequence that is of interest ultimately for the site suitability determination.

The critical pathway is made uncertain as a result of spatially and temporally varying characteristics and because the release will occur in the future, after substantial change has or may have occurred to the local landscape and near-field hydrology of the proposed site.

The existing hydrology of the site does not necessarily represent the future hydrology of the site. The applicant has described a single possible groundwater migration pathway for all accidental releases of radioactive liquid effluent. As described by the NRC staff in Section 2.4.12 of this SER, there are multiple lines of reasoning that lead the NRC staff to question the existence of only one groundwater pathway for all future accidental releases. Construction of a large industrial facility such as a nuclear power plant can lead to substantial change to the post-construction landscape and hydrologic features of this site. These changes lead to alterations in the distribution of recharge in the vicinity of the proposed plant(s) and in the water table of the aquifer underlying the proposed site. The NRC staff conclude that releases from the site may move through the Water Table aquifer to the northwest toward Mallard Pond. The NRC staff also concludes that a feasible alternate conceptual model exists that would result in releases moving to the west and eventually to the southeast through the Daniels Branch drainage. The NRC staff also concludes that, because of potential communication from the Water Table aquifer to the Tertiary aquifer, another feasible alternate conceptual model exists that would result in releases moving into the uppermost Tertiary aquifer and to the east toward the Savannah River.

In its application, the applicant provided bounding parameters for the accidental release, including the tank, its relative location in the facility, its volume, and its contents. The applicant has specified a single possible location for the accidental release of radioactive liquid effluents. The NRC staff postulated that a release could occur anywhere within the PA in order to estimate the most severe accidental release consequences. Alternate release locations could result in feasible alternate pathways in the groundwater and surface water environments resulting in more severe consequences.

The NRC staff found the applicant's analysis in the SSAR to be incomplete; because it did not include consideration for the inevitable change in hydrology, and, hence, the potential change in

flow direction within the Water Table aquifer for some release locations within the PA. The applicant's analysis provided no assurance that an adequate number of combinations of release locations and feasible pathways had been considered. This is **Open Item 2.4-3**.

Characteristics that Affect Transport

The NRC staff independently determined that the USGS derived minimum and maximum range of transmissivity values based on field data (i.e., 500 feet^2/day to 9500 feet^2/day or 3700 gallons/day/feet to 71,000 gallons/day/feet) (Clarke and West 1998, Table 3), when combined with the local thickness of the Water Table aquifer (i.e., approximately 30 feet) are indicative of the higher values of the Utley Limestone of the Barnwell Formation cited by the applicant (i.e., 125,400 feet/year (343 feet/day). The NRC staff reviewed the estimates by the applicant of the magnitude of the hydraulic gradient (i.e., 0.014 and 0.023) and effective porosity (i.e., 0.10). Ultimately, use by the applicant of the highest observed transmissivity value attributed to Utley Limestone for the entire Water Table aquifer pathway assures a conservative estimate of pore-water speed and travel time (i.e., 0.09 years). However, the NRC staff notes the future direction of groundwater flow will be determined after resolution of Open Item 2.4-3.

The NRC staff reviewed the hydraulic properties assigned by the applicant to the engineered backfill. The applicant's analysis of transport characteristics in the engineered backfill relies on the observed hydraulic conductivity of the existing units' engineered backfill (1220 feet per year) and estimated values of effective porosity (0.34) and hydraulic gradient (0.014).

Regarding the applicant's reported values of hydraulic conductivity in the Tertiary aquifer, the NRC staff independently reviewed USGS minimum and maximum ranges of transmissivity estimates based on field data (1346 to 91,200 gallons/day/feet) and based on regional simulation (100 to 185,000 gallons/day/feet) (Clarke and West 1998, Table 12). When combined with the local thickness of the Tertiary aquifer (approximately 182 feet) the USGS data bracket the central value of hydraulic conductivity provided by the applicant (i.e., 0.83 feet/day), while being higher generally. The NRC staff reviewed the estimates by the applicant of the magnitude of the hydraulic gradient (i.e., 0.005) and effective porosity (i.e., 0.31). Ultimately, the NRC staff's use of the highest observed transmissivity value attributed to Tertiary aquifer (i.e., 2.1 feet/day) assures a conservative estimate of pore-water velocity and travel time (i.e., 450 years). The NRC staff notes that the applicant employed the geometric mean of the hydraulic conductivity values (i.e., 0.83 feet/day) and calculated a travel time of 1180 years. Such a value would represent the central tendency of the travel time and should not be viewed as overly conservative. The NRC staff notes the future direction of groundwater flow will be determined after resolution of Open Item 2.4-3.

The applicant has not committed to precluding the use of complexants or chelating agents for proposed VEGP Units 3 and 4. Therefore, NRC staff assumes for its analysis that complexants or chelating agents may be present.

The NRC staff reviewed the applicant's estimate of streamflow that would dilute the radiological effluent released into Mallard Pond after an accident. The NRC staff determined that lower dilution streamflow than estimated by the applicant are feasible based on the data provided. It is of note that the applicant did not employ the minimum estimate of streamflow in the drainage

to support the dilution calculations in SSAR Section 2.4.13 (Southern 2007a). Additionally, since the data were not gathered during the most severe drought of record (USACE 2006), the NRC staff concluded that it is not unreasonable to assume that the discharge from Mallard Pond could cease entirely for a period of time during a drought. It is also of note that the stream downstream of Mallard Pond appears to cross the Plant Vogtle property boundary and then re-enter the VEGP property before discharging to the Savannah River. Thus, the discharge from Mallard Pond would appear to enter the public domain prior to its discharge to Savannah River.

Based on information made available by the USACE Savannah Office (USACE 2006, 2007; NRC 2007a, b), the level 3 drought flowrate of the Savannah River opposite the VEGP site is 3800 cubic feet per second (1.706E+06 gallons per minute). The applicant stated the magnitude of the 100-year drought flow of the Savannah River was 3,298 cubic feet per second (1.48E+06 gallons per minute). The NRC staff calculations will employ the level 3 drought value from the USACE since it represents a more current value.

The applicant identified the closest surface water withdrawal downstream of the release as two industrial surface water users; both located about 106 miles downstream of the VEGP site. However, the NRC staff noted that both the existing and proposed water intakes for the operation of the VEGP site are downstream of the point where the Mallard Pond drainage empties into the Savannah River. Therefore, the proposed VEGP intake structure may be affected by the accidental release of radioactive effluents carried to the Savannah River through the Mallard Pond drainage.

Pathways

In order to bound the most severe radiological consequences of radioactive liquid effluent release, the NRC staff postulated multiple feasible pathways to the accessible environment. The technical evaluation in Section 2.4.12 of this SER comments on pathways that an accidental release may take in the surface environment. The NRC staff concluded that the drainage dominated by Mallard Pond would likely intercept many accidental releases from the proposed VEGP Units 3 and 4. However, the future direction of groundwater flow within the Water Table aquifer is uncertain and it is not unreasonable to expect that some accidental release locations within the PA would result in releases moving to the west. Such releases could flow into the unnamed drainage leading to Daniels Branch, Telfair Pond and Beaverdam Creek, and ultimately to the Savannah River. Another feasible accidental release pathway would involve transport from the Water Table aquifer into the Tertiary aquifer, with subsequent migration toward and discharge into the Savannah River from the Tertiary aquifer. The NRC staff concludes that these three pathways, (i.e., northward in the Water Table aquifer toward Mallard Pond, westward in the Water Table aquifer toward an unnamed drainage leading to Daniels Branch, and eastward in the uppermost confined aquifer toward the Savannah River), represent feasible alternate pathways for the transport of an accidental release of radioactive liquid effluents.

The NRC staff reviewed of the sole accidental release pathway postulated by the applicant and concluded that such a release and pathway analysis would require inclusion of release and dilution in a fraction of the Savannah River discharge to assure levels of radionuclide

concentration meeting site suitability requirements. The hypothetical release posed by the applicant is conservative in that it ignores the integrity of the engineered system.

The NRC staff reviewed the applicant's calculations regarding the inventory, its accidental release, and its decay, adsorption, and dilution during transport through the environment. The NRC staff concluded that use by the applicant of adsorption to allow additional decay of cobalt, strontium and cesium isotopes during retarded travel times was not warranted given the feasibility that chelating agents could be present. The NRC staff also concluded that flow measurements and dilution calculations performed by the applicant for the drainage stream north of the proposed VEGP Units 3 and 4 were not adequately supported by analysis or data, and that it was not unreasonable to assume that flow within the drainage, especially from Mallard Pond, ceased in the past and could cease in the future during times of extreme drought. However, the applicant stated that Mallard Pond and its drainage stream are not accessible to the public. Neglecting adsorption and onsite dilution, the NRC staff determined that release from the drainage to the Savannah River would require mixing with approximately 10 percent of the river flow during a level 3 drought (i.e., 170,600 gallons per minute) to achieve concentrations meeting the site suitability requirements (i.e., levels of less than 1 percent of the maximum permissible radionuclide concentration ratios). However, it would appear the stream downstream of Mallard Pond and it confluence with the West Branch leaves VEGP property and enters the accessible environment prior to re-entering the VEGP property and discharging into the Savannah River.

The NRC staff considered alternate subsurface conceptual models and release locations, with the release moving in another direction, (e.g., towards the west), and determined that a pathway leading to Beaverdam Creek drainage was feasible. The NRC staff finds that, because substantial dilution of the release could not occur prior to reaching the site boundary, such a pathway could pose a greater threat than the event and pathway analysis described and quantified by the applicant in SSAR Section 2.4.13 (Southern 2007a).

The NRC staff concluded that in addition to alternate conceptual models involving the direction of groundwater flow in the Water Table aquifer, there is an alternate conceptual model that admits possible local communication between the unconfined Water Table aquifer and the confined Tertiary aquifer. The NRC staff determined that limited evidence suggests the possibility of a local hydraulic flaw in the aquitard separating these two aquifers. If an accidental release from proposed Units 3 and 4 were intercepted by such a local communication region of the Water Table aquifer, then NRC staff concluded that the release would move into the Tertiary aquifer, and move toward and discharge into the Savannah River. Using the maximum hydraulic conductivity cited by the applicant for the Tertiary aquifer, the shortest travel time to the river would be approximately 450 years. After accounting for decay during this travel time, of all radionuclides listed (Southern 2007a, Table 2.4.13-1), only iodine-129 and cesium-137 would require future concentration reduction by mixing or dilution in the Savannah River. The NRC staff determined that dilution in only 76 gallons per minute of flow would be required in the Savannah River, (i.e., 0.0045 percent of the level 3 drought flow), to achieve the level of less than 1 percent of their MPCs. In this instance, the hierarchical process followed by the NRC staff to evaluate alternate conceptual models yields a release that is of less consequence than either a release through Mallard Pond, or to the drainage to the west. The NRC staff's review of the release location, migration, attenuation, and dilution of the radioactive liquid effluent inventory was incomplete because, as stated in Open Item 2.4-3, the applicant has not considered a sufficient number of alternate conceptual models to identify

potential release points and pathways. Therefore, the applicant needs to specify the nearest point along each potential pathway that may be accessible to the public. This is **Open Item 2.4-4**.

2.4.13.4 Conclusion

The NRC staff concluded that the following issues shall be considered Open Items: (1) Open Item 2.4-3: The NRC staff found the applicant's analysis in the SSAR to be incomplete; because it did not include consideration for the inevitable change in hydrology, and, hence, the potential change in flow direction within the Water Table aquifer for some release locations within the PA. The applicant's analysis provided no assurance that an adequate number of combinations of release locations and feasible pathways have been considered. (2) Open Item 2.4-4: The NRC staff's review of the release location, migration, attenuation, and dilution of the radioactive liquid effluent inventory was incomplete because of the following reasons: (1) as stated in Open Item 2.4-3, the applicant needs to consider a sufficient number of alternate conceptual models to identify potential release points and pathways, and (2) the applicant needs to specify the nearest point along each potential pathway that may be accessible to the public.

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the identification and evaluation of effects of accidental releases of radioactive liquid effluents in ground and surface waters on existing users and known and likely future users of ground and surface water resources in the vicinity of the proposed site. Section 2.4.13 of RS-002 provides that the SSAR should address the requirements of 10 CFR Part 100 as they relate to identifying and evaluating effects of accidental releases of radioactive liquid effluents in ground and surface waters on existing users and known and likely future users in the vicinity of the site. Furthermore, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the hydrologic interface of the plant with the site, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The NRC staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the NRC staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or CP application.

Pending resolution of Open Items 2.4-3 and 2.4-4, the NRC staff concludes that the identification and consideration of the site characteristics set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c) and 10 CFR 100.21(d).

2.4.14 Site Characteristics

This section of the SER lists site characteristics recommended by the NRC staff for inclusion in any ESP that may be granted for the VEGP site as given in table below.

Table 2.4.14-1 - Proposed Site Characteristics Related to Hydrology

SITE CHARACTERISTIC	VALUE	DEFINITION
Proposed Facility Boundaries	Figure 2.4.14-1	The site boundary within which all safety-related SSC will be located.
Site Grade	220 feet MSL	The elevation of the finished ground surface that prevents the flood produced by the local intense precipitation from affecting the safety-related SSCs.
Highest Ground Water Elevation	165 feet MSL at the Water Table Aquifer	The highest elevation of the water table within the site boundaries.
Highest Flood Level (maximum hydrostatic water surface elevation due to a postulated upstream dam breach scenario)	170.1 feet MSL	The stillwater elevation, without accounting for wind-induced waves, that the water surface reaches during a flood event.
Wind run-up (to add to the highest flood elevation)	19 feet	The water surface elevation reached by wind-induced waves running up on the shore.
Combined Effects Maximum Flood Elevation	189.1 feet MSL; the proposed site grade is 220ft MSL, therefore, the VEGP site is “dry”	The water surface elevation obtained by adding wind run-up to the highest flood level.
Local Intense Precipitation	19.2 inches during 1 hour 6.2 inches during 5 minutes	The depth of PMP for a duration of one hour on a one square-mile drainage area. The surface water drainage system should be designed for a flood produced by the local intense precipitation. The local intense precipitation is specified by SSAR Table 2.4.2-3 (see Table 2.4.2-1 of this SER).
Frazil Ice	The ESP site does not have the potential for the formation of frazil and anchor ice	Ice crystals that form in turbulent, open waters in presence of supercooling. Frazil ice is very sticky and may lead to blockages of intake screens and trash racks.

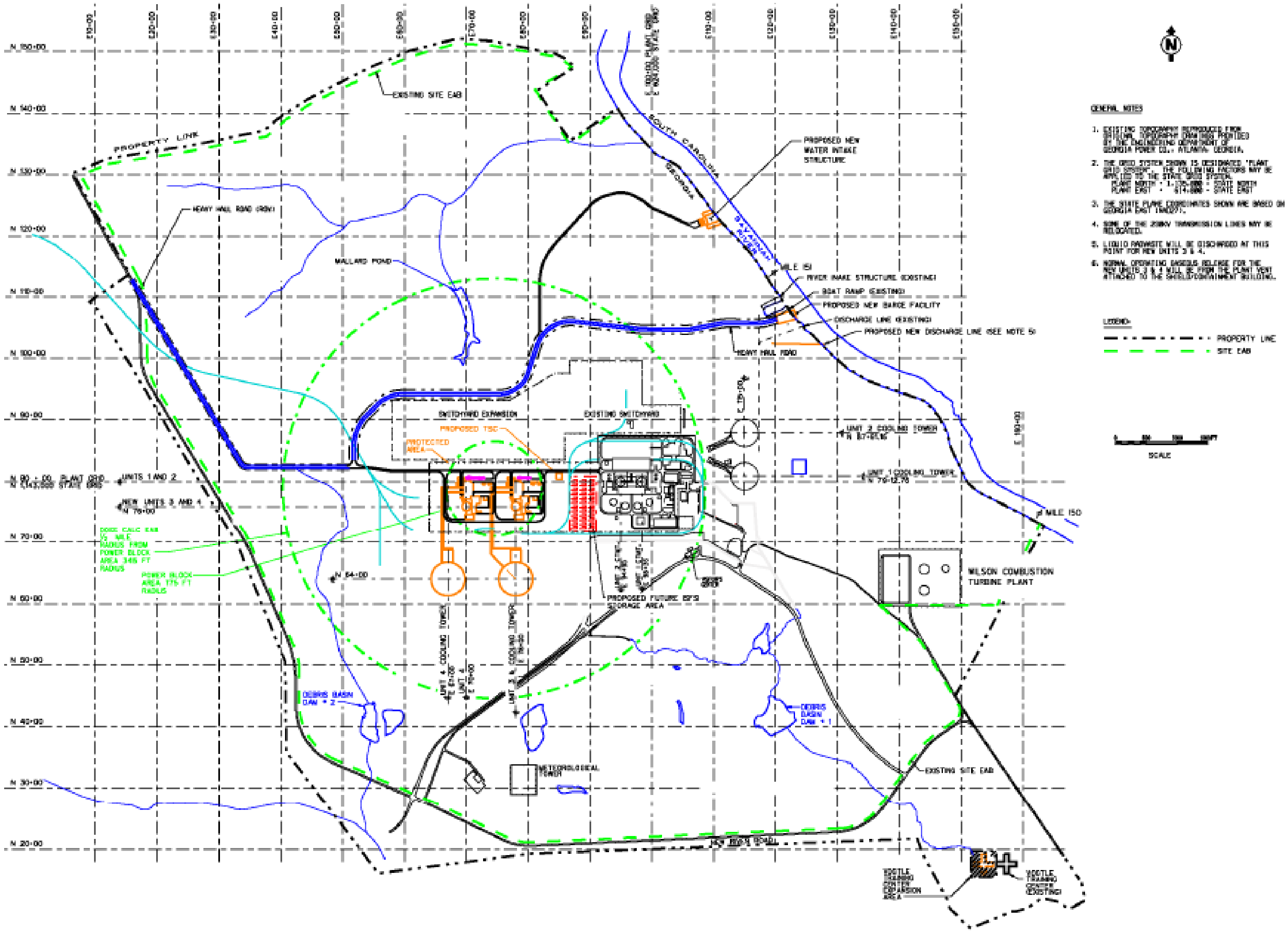

Figure 2.4.14-1 - The Proposed facility boundary for the VEGP site (Taken from SSAR Figure 1-4).