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2.4 Hydrologic Engineering

To ensure that a nuclear power plant or plants can be designed, constructed, and safely operated on the combined license (COL) applicant's site and in accordance with the U.S. Nuclear Regulatory Commission (NRC) regulations, the staff evaluated the hydrologic characteristics of the site and surrounding vicinity that may affect the safety of the proposed nuclear power plant. These site characteristics included the maximum flood elevation of surface water from precipitation, riverine processes (runoff, dam breach discharge, channel blockage or diversion), and combined events (e.g., from coincident wind waves). In addition, the staff reviewed the maximum elevation of groundwater and the characteristic ability of the site to attenuate a postulated accidental release of radiological material into surface water and groundwater. The surface-water hydrologic site characteristics determine the design basis flood for the proposed nuclear power plant (William States Lee III Nuclear Station (WLS) Units 1 and 2) and provide the basis for determining whether flood protection will be required. The groundwater hydrologic site characteristics determine the design basis groundwater loadings and provide the basis for radiological dose analysis for a potential receptor from the postulated accidental release of radioactive liquid effluents in surface and ground waters.

The staff prepared Sections 2.4.1 through 2.4.14 of this safety evaluation report (SER) in accordance with the review procedures described in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Sections 2.4.1 through 2.4.14, using information presented in Section 2.4, "Hydrologic Engineering," of the WLS Units 1 and 2 Final Safety Analysis Report (FSAR) Revision 0, Revision 1, Revision 2, Revision 3, Revision 4, Revision 5, Revision 6, Revision 7, AP1000 Design Control Document (DCD) Revision 19, the applicant's responses to the staff's requests for additional information (RAIs), and generally available reference materials (e.g., those cited in applicable sections of NUREG-0800).

In Part 7 of the application, the applicant described an administrative standard departure (STD DEP) (Standard Departure 1.1-1) that remaps WLS COL FSAR section numbers to the associated AP1000 DCD section numbers. This standard departure affected Sections 2.4.1 and 2.4.15 in WLS COL FSAR Section 2.4. The staff determined that this departure has no safety significance.

The nominal proposed site grade for the WLS Units 1 and 2 nuclear power block is 180.4 meters (m) (592 feet (ft)) above mean sea level (MSL) with the nuclear island finished floor elevation[1] at 180.7 m (593 ft) above MSL. The ultimate heat sink (UHS) of the advanced passive pressurized water reactor (AP1000) design is the atmosphere. Therefore, hydrologic characteristics associated with conditions that would result in a loss of external water supply (e.g., low water, channel diversions) are not relevant for this particular design. Also, seismic design considerations of water-supply structures are not relevant for this particular design. Therefore, Regulatory Guide (RG) 1.27, "Ultimate Heat Sink for Nuclear Power Plants," and

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[1] The nuclear island finished floor elevation, 180.7 m (593 ft) above MSL, corresponds to the AP1000 DCD reference floor elevation.

RG 1.29, "Seismic Design Classification," were not part of the regulatory basis for this Section 2.4 review.

As stated above, the site grade near the WLS Units 1 and 2 nuclear power block is 180.4 m (592 ft) above MSL. The following flooding hazard mechanisms, including associated effects, were computed and reported in the WLS COL FSAR Revision 7.

Table 2.4.1-1 Flooding Hazard Mechanisms

Calculated Flooding Hazards and Associated Effects as Evaluated in WLS COL **FSAR Revision 7**	**Water-Surface Elevation**	
	ft[(a)]	**m[(a)]**
Local Intense Precipitation and Associated Drainage	592.6	180.6
Flooding from Streams and Rivers	592.3[(b)]	180.5[(b)]
Failure of Dams and Onsite Water-Control/Storage Structures	592.3[(b)]	180.5[(b)]
Flooding from Storm Surge with Wave Runup	583.9	178
Flooding from Seiche[(c)]	--	--
Flooding from Tsunami[(d)]	--	--
Ice-Induced Flooding[(d)]	--	--
Flooding from Channel Migrations or Diversions[(d)]	--	--

(a) above MSL
(b) stillwater-surface elevation
(c) bounded by other flooding mechanisms
(d) not plausible at the site

2.4.1 Hydrologic Description

2.4.1.1 *Introduction*

WLS COL FSAR Section 2.4.1 describes the site and all safety-related elevations, structures, and systems from the standpoint of hydrologic considerations and provided a topographic map showing the proposed changes to grading and to natural drainage features.

Section 2.4.1 of this report provides a review of the following specific areas: (1) interface of the plant with the hydrosphere including descriptions of site location, major hydrologic features in the site vicinity, surface-water and groundwater characteristics, and the proposed water supply to the plant; (2) hydrologic causal mechanisms that may require special plant design bases or operating limitations with regard to floods and water-supply requirements; (3) current and likely future surface and groundwater uses by the plant and water users in the vicinity of the site that may affect the safety of the plant; (4) available spatial and temporal data relevant for the site

review; (5) alternate conceptual models of the hydrology of the site that reasonably bound hydrologic conditions at the site; (6) potential effects of seismic and non-seismic data on the postulated design bases and how they relate to the hydrology in the vicinity of the site and the site region; and (7) any additional information requirements prescribed within the "Contents of Application," sections of the applicable Subparts to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

As stated above in Section 2.4, hydrologic characteristics associated with conditions that would result in a loss of external water supply and seismic design considerations of water-supply structures are not relevant for the AP1000 design. Therefore, specific area (6), above, was not part of the staff's review.

2.4.1.2 *Summary of Application*

This section of the WLS COL FSAR describes the site and all safety-related elevations, structures and systems from the standpoint of hydrologic considerations and provides a topographic map showing the proposed changes to grading and to natural drainage features. The applicant addressed the COL information item identified in AP1000 DCD Tier 2, Section 2.4.1.1, Revision 19 related to hydrologic description as follows:

AP1000 COL Information Item

- COL Information Item 2.4-1

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Section 2.4.1.1, Revision 19.

- Combined License applicants referencing the AP1000 certified design will describe major hydrologic features on or in the vicinity of the site including critical elevations of the nuclear island and access routes to the plant.

2.4.1.3 *Regulatory Basis*

NRC regulations for the hydrologic description, and the associated acceptance criteria, are specified in NUREG-0800, Section 2.4.1.

The applicable regulatory requirements for identifying site location and describing the site hydrosphere are set forth in the following:

- 10 CFR 52.79(a)(1)(iii), "Contents of Applications; Technical Information in Final Safety Analysis Report," as it relates to the hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, "Reactor Site Criteria," as it relates to identifying and evaluating hydrologic features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100,20(c).

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.1:

- RG 1.59, "Design Basis Floods for Nuclear Power Plants," supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized

- RG 1.102, "Flood Protection for Nuclear Power Plants," as it relates to providing assurance that structures, systems, and components (SSCs) important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

- RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," as it relates to the contents of a COL application

2.4.1.4 *Technical Evaluation*

2.4.1.4.1 Site and Facilities

Information Submitted by the Applicant

The applicant stated in WLS COL FSAR Section 2.4.1.1 that the WLS site is located in eastern Cherokee County, SC, southwest of the Ninety-Nine Islands Reservoir, a portion of the Broad River, approximately 1.6 km (1 mi) northwest of the Ninety-Nine Islands Dam. The applicant noted that in addition to the Broad River and several tributaries, the Ninety-Nine Islands Reservoir, Make-Up Pond A, Make-Up Pond B, Make-Up Pond C, and Hold-Up Pond A make up the majority of the surface-water features in the vicinity of the WLS site. An embankment within Make-Up Pond B creates the Upper Arm Pond, which is connected to Make-Up Pond B by a culvert. The applicant stated that Make-Up Pond C is an offsite facility, located on a tributary of the Broad River, west of the WLS site.

The applicant selected the AP1000 certified plant design for the WLS application with the designed finished floor elevation at 180.7 m (593 ft) above MSL with the nuclear island basemat at 168.7 m (553.5 ft) above MSL. The WLS site grade would be at 180.4 m (592 ft) above MSL. The applicant also described the plant water systems including the water-consumption and water-treatment system, the intake system, which provides all raw water requirements for the plant, and the discharge system, which disperses cooling-tower blowdown into the Broad River.

Construction activities related to the abandoned Cherokee Nuclear Station resulted in extensive alteration of the site, including clearing of vegetation, construction of roads, a railroad spur, warehouses, power unit buildings, and other support buildings, and extensive excavation, and grading. Currently, the site is a partially developed industrial land.

The partially built reactor containment building of the abandoned Cherokee Nuclear Station would be removed during construction activities for the proposed units. The basemat slab and some warehouses would be retained. A new intake structure for the normal cooling-water supply is planned to be installed on the Broad River and the blowdown discharge would be placed on the upstream side of the Ninety-Nine Islands Dam near the turbine intakes.

Two new AP1000 units are proposed to be built near the abandoned Cherokee Units 1 and 3, at the west and east sides of the existing excavation, respectively (Figure 2.4.1-1 of this report). Each of the two proposed AP1000 units would use two mechanical draft cooling towers for its circulating-water system (CWS) cooling with makeup water supplied from the Broad River via Make-Up Pond A during normal river discharge conditions. Water stored in Make-Up Ponds B and C would be used, in that order, to provide water to Make-Up Pond A for CWS cooling water during low-flow conditions in the Broad River. The UHS for the AP1000 units is the atmosphere.

The AP1000 design consists of five principal structures: the nuclear island, the turbine building, the annex building, the diesel generator building, and the radioactive waste building. Only the nuclear island is designed as a Seismic Category I structure and contains all safety-related equipment.

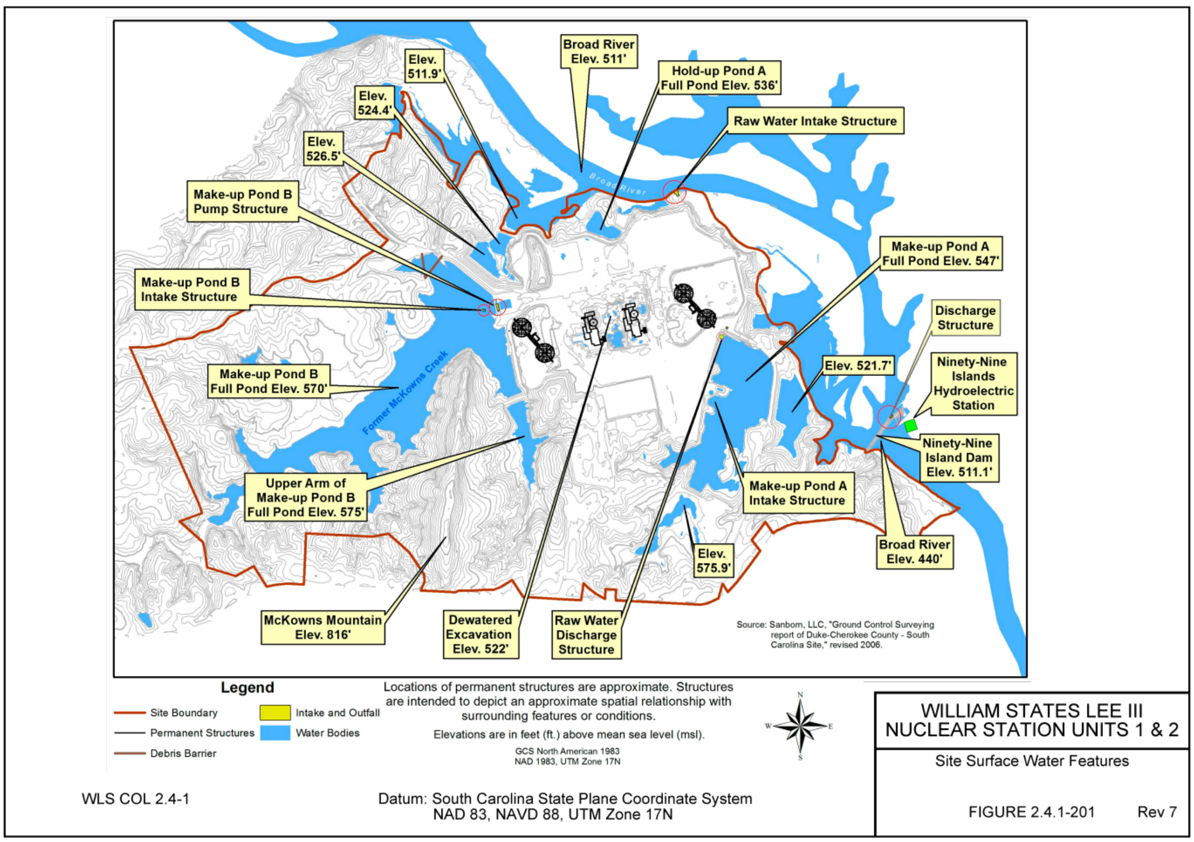

Figure 2.4.1-1 Map of the WLS site (adapted from WLS COL FSAR Revision 7, Figure 2.4.1-201)

The finished floor elevation of the nuclear island, or the AP1000 DCD reference floor elevation of 30.48 m (100 ft), would be placed at 180.7 m (593 ft) above MSL with the nuclear island basemat placed at 168.7 m (553.5 ft) above MSL. The plant grade elevation would be at 180.4 m (592 ft) above MSL.

The applicant stated that the intake system would provide all raw water required by the plant. Raw water would be pumped to Make-Up Pond A from the Broad River under the river's normal flow conditions. During low-flow conditions in the Broad River, water from Make-Up Pond B would be pumped to Make-Up Pond A to provide cooling water to the plant. When the storage in Make-Up Pond B is depleted and low-flow conditions in the Broad River persist, water from Make-Up Pond C would be pumped into Make-Up Pond B and subsequently into Make-Up Pond A to provide cooling water for the plant. Water from the Broad River can also be pumped directly into Make-Up Pond B from the river intake structure. After the Broad River flow returns to normal, Make-Up Pond B would be replenished from water withdrawn from the river. Normally, Make-Up Pond C would be refilled directly from the river intake structure, but an alternate path for refilling Make-Up Pond C would use water from the river intake structure pumped via Make-Up Ponds A and B, in that order.

The applicant stated that the discharge system would use a submerged pipe, perforated along its last portion that would be located near the hydroelectric generating station's intakes upstream of the Ninety-Nine Islands Dam. The discharge from WLS Units 1 and 2 would include non-radioactive and low-level radioactive wastes.

The Staff's Technical Evaluation

The staff reviewed the information related to COL Information Item 2.4-1 related to the provision of a description of all major hydrologic features on or in the vicinity of the site, including critical elevations of the nuclear island and access routes to the plant included under WLS COL FSAR Section 2.4.

In RAI 818, Question 02.04.01-1, the staff requested that the applicant clarify the process for determining the conceptual models of the interface of the plant with the hydrosphere and those of the hydrologic causal mechanisms and to ensure that the most conservative of plausible conceptual models has been identified. In a November 18, 2008, response, to RAI 818, Question 02.04.01-1, the applicant stated that the process followed to determine the conceptual models of the interface of the plant with the hydrosphere and those of the hydrologic causal mechanisms would be addressed in the responses to similar staff RAIs issued for the respective subsections of the WLS COL FSAR. The staff reviewed the applicant's responses to these individual RAIs issued for the respective subsections of the WLS COL FSAR and concluded that the applicant had responded to the individual RAIs and included sufficient information to address the staff's concerns. The staff's evaluations of these individual RAIs are presented in the respective sections of this report. Accordingly, the staff considers RAI 818, Question 02.04.01-1, resolved.

The staff conducted a hydrology site audit May 18 to 20, 2008. The site audit included a visit to the WLS site and a tour of the east end of the existing, dewatered excavation pit, the basemat of abandoned Cherokee Nuclear Station Unit 1 on the west end of the excavation pit, Make-Up Pond B, Hold-Up Pond A, the south end of the excavation pit, the dam impounding the south section of the east arm of Make-Up Pond B, the top of McKowns Mountain, the existing intake structure located on Make-Up Pond A, the proposed location of the new intake on the Broad River, and the Ninety-Nine Islands Dam. The applicant and the staff also reconnoitered the Broad River in the vicinity of the site during a boat tour. The staff reviewed the information regarding major hydrologic features in the vicinity of the site from publicly available sources of hydrologic data. The staff's review is described in the subsections below.

In RAI 818, Question 02.04.01-3, the staff requested that the applicant clarify an ambiguity related to the AP1000 DCD reference elevation and the WLS Units 1 and 2 finished floor elevation. In a November 18, 2008, response to RAI 818, Question 02.04.01-3, the applicant stated that the finished floor elevation refers to the AP1000 DCD reference floor elevation of 30.5 m (100 ft), as stated in AP1000 DCD Tier 2, Section 2.4. The applicant modified the WLS COL FSAR text to indicate that the AP1000 DCD reference floor elevation of 30.5 m (100 ft) corresponds to the site-specific nuclear island finished floor elevation. The staff concluded that the applicant provided sufficient information for staff to proceed with its review. Accordingly, the staff considers RAI 818, Question 02.04.01-3, resolved.

In RAI 818, Question 02.04.01-4, the staff requested that the applicant clarify Make-Up Ponds A and B relationship to safety. In a November 18, 2008, response to RAI 818, Question 02.04.01-4, the applicant confirmed that Make-Up Ponds A and B would not be used for any safety-related purpose. After responding to RAI 818, Question 02.04.01-4, the applicant decided to install Make-Up Pond C to address low-water conditions related to normal operations of the proposed units. The exchange of water among the three ponds is described in the "Information Submitted by the Applicant" section above. Since the water pumped from the Broad River to the three makeup ponds would only provide cooling during normal operations, the staff concluded that none of this water would be safety-related. The UHS for the AP1000 units is the atmosphere. The staff concluded that the applicant provided sufficient information related to the function of Make-Up Ponds A and B. Accordingly, the staff considers RAI 818, Question 02.04.01-4, resolved.

In a November 22, 2011, submittal, the applicant provided revisions to the CWS. The applicant stated that the revisions resulted from the change in the design of two cooling towers from the previous design that used three cooling towers per unit.

Based on a review of the material presented by the applicant in WLS COL FSAR Section 2.4.1 and the staff's observations made during the WLS site audit, and based on the reasons given above, the staff concluded that the applicant adequately considered the hydrologic characteristics of the WLS site as they relate to identifying and evaluating hydrologic features.

2.4.1.4.2 Hydrosphere

Information Submitted by the Applicant

The applicant provided a detailed description of the main hydrologic features in the vicinity of the WLS site including the Broad River and the Ninety-Nine Islands Reservoir. The applicant's description included a specific description of the site and all safety-related elevations, structures, exterior access, equipment, and systems from the standpoint of hydrology considerations. The applicant also described the current surface-water features on and off the site (Make-Up Ponds A, B, and C and Hold-Up Pond A) and the local groundwater conditions.

The WLS site is located within the Piedmont physiographic province, the non-mountainous portion of the older Appalachians. The main drainage in the region is the Broad River with tributaries that drain through deep and steep valleys. The Broad River Basin contains rolling hills and small floodplains.

The Broad River and most of its tributaries originate in the Blue Ridge Mountains of North Carolina. The WLS site is located in the Upper Broad River Basin (U.S. Geological Survey (USGS) Hydrologic Unit Code (HUC) 03050105), parts of which lie in both the states of North Carolina and South Carolina. The drainage basin above the Ninety-Nine Islands Dam, approximately 4,014 km^2 (1,550 mi^2) in size, contains tributaries to the Broad River, including the Green River, the First and Second Broad rivers, and Buffalo Creek. Elevations in the watershed upstream of the Ninety-Nine Islands Reservoir range from approximately 366 m (1,200 ft) above MSL at the headwaters of the First Broad River, to approximately 155.8 m (511 ft) above MSL above the Ninety-Nine Islands Dam, and approximately 134 m (440 ft) above MSL below the Ninety-Nine Islands Dam.

Discharge in the Broad River, recorded at USGS streamflow gauge 02153551, located just downstream of the Ninety-Nine Islands Dam, ranges from 3.9 cubic meters per second (m^3/s) (138 cubic feet per second (cfs) on September 14, 2002, to more than 1,699 m^3/s (60,000 cfs) in September 2004. The Gaffney USGS streamflow gauge 02133500, is located approximately 12.9 km (8 mi) upstream of the WLS site and has a contributing area of 155.4 km^2 (60 mi^2) less than that of the Broad River above the Ninety-Nine Islands Dam. The Gaffney USGS gauge recorded the highest discharge on record at 3,373 m^3/s (119,100 cfs) on August 14, 1940. Based on streamflow data at the USGS Gaffney gauge, the applicant estimated that the 100- and 500-year flood discharges in the Broad River are 2,722 to 3,956 m^3/s (97,900 to 127,000 cfs). The applicant also estimated the corresponding water-surface elevations based on the rating curve of the Ninety-Nine Islands Dam, assuming flashboard failure as being at 158.8 and 159.3 m (521 and 522.6 ft) above MSL, respectively.

The applicant filled in data gaps and extrapolated streamflow records from the Gaffney streamflow gauge to construct an 83-year record of streamflow discharge. The applicant estimated that the average annual flow in the Broad River is 70.8 m^3/s (2,500 cfs). The applicant also quantified the low-flow condition in the Broad River using the lowest consecutive 7-day streamflow likely to occur every 10 years, or 7Q10, as 12.4 m^3/s (439 cfs). The applicant stated that the monthly water temperature data from the USGS streamflow gauge 02156500, located near Carlisle, SC, for the period 1996 to 2006, ranged from 4.9ºC to 29.6ºC (40.8ºF to 85.3ºF).

Several small streams in the vicinity of the WLS site exist, including Cherokee Creek, Doolittle Creek, London Creek, McKowns Creek, and an intermittent stream that flows into Make-Up Pond A. McKowns Creek, which has a drainage area of approximately 661 hectares (ha) (1,633 acres (ac)), is impounded by a dam to create Make-Up Pond B on the WLS site. The intermittent stream that flows into Make-Up Pond A has a drainage area of approximately 156 ha (385 ac).

The dam impounding Make-Up Pond B, an earthen structure with its crest elevation at 179.8 m (590 ft) above MSL, was constructed during the 1970s for the abandoned Cherokee Nuclear Station. The spillway elevation is 173.7 m (570 ft) above MSL, which also indicates full pool elevation with a storage capacity of 4,933,927 m^3 (4000 ac-ft) at a surface area of 61 ha (150 ac). Make-Up Pond B is divided into two sections by a submerged dam with a crest elevation of approximately 164.6 m (540 ft) above MSL. Make-Up Pond B has an average depth of 9.6 m (31.4 ft) and a maximum depth of 18.1 m (59.3 ft).

The applicant stated that the outlet structure for Make-Up Pond B is adequately sized. Since the pond is not located on a large stream or river, the applicant expects minimal potential for significant blockage from debris collected at the outlet during flood events. The applicant reported that floating debris has not caused any problems in the past and the spillway has not been clogged. However, the applicant would create a shoreline management program along the banks of Make-Up Pond B. The program would consist of annual inspection of the shoreline and would remove trees that could potentially fall into the pond and trees that may be down on the ground. The applicant would also inspect the spillway for debris accumulation after rainfall events greater than 7.6 cm (3 in.) per hour. The applicant would also install a debris barrier system that rises and falls with the water level in the pond approximately 107 m (350 ft) from the spillway. The applicant stated that the debris barrier system is not considered a safety-related system.

An embankment within Make-Up Pond B creates the Upper Arm Pond, which is connected to Make-Up Pond B by a 137 centimeter (cm) (54 inch (in.)) culvert; the pond has a maximum depth of 9.8 m (32.2 ft), average depth of 9.6 m (31.4 ft), total storage capacity of 124,582 m^3 (101 acre-feet (ac-ft)), a normal pool elevation of 175.3 m (575 ft) above MSL, and a surface area of 3.7 ha (9.1 ac) at full pool. The embankment that impounds the Upper Arm Pond has a crest elevation of 179.8 m (590 ft) above MSL.

Make-Up Pond A was created in the 1970s during the construction of the abandoned Cherokee Nuclear Station by installing an earthen dam, which has a crest elevation varying from 169.9 to 169.2 m (557.5 to 555 ft) above MSL. The full pool elevation of Make-Up Pond A is 166.7 m (547 ft) above MSL; the pond has a surface area of about 25 ha (62 ac) and an estimated volume of 1,757,712 m^3 (1,425 ac-ft).

A small impoundment, named Hold-Up Pond A, is located north of the proposed reactor units and was also created in the 1970s by installing two dams with a crest elevation of 164.5 m (539.7 ft) above MSL. Hold-Up Pond A has a storage volume of about 69,568 m^3 (56.4 ac-ft) at a full pool elevation of 163.4 m (536 ft) above MSL and a surface area of 1.8 ha (4.4 ac).

Make-Up Pond C would be located approximately 2 mi west of the WLS site on London Creek, formed by an earthen dam impounding London Creek just upstream of its confluence with Little London Creek. The Make-Up Pond C Dam crest elevation would be at 201.2 m (660 ft) above MSL with a normal pool elevation of 198.1 m (650 ft) above MSL, a surface area of approximately 251 ha (620 ac), and a total storage capacity of 27,136,600 m^3 (22,000 ac-ft). The usable storage in Make-Up Pond C would be approximately 21,585,932 m^3 (17,500 ac-ft). The drainage area upstream of Make-Up Pond C would be 1,003 ha (2,479 ac).

There are about 132 dams upstream of the WLS site, six of which, Make-Up Pond C Dam, Whelchel Dam, Kings Mountain Reservoir or Moss Lake Dam, Lake Adger or Turner Shoals Dam, Lake Lure Dam, and Lake Summit Dam, impound about 88 percent of total storage in the Broad River Basin. Cherokee Falls Dam and Gaston Shoals Dam, both run-of-river structures, are located on the Broad River immediately upstream of the WLS site and are used for hydroelectric power generation but not for flood control. Cherokee Falls Dam was the first dam constructed in the Upper Broad River Basin in 1826. Two reservoirs located downstream of the WLS site are the Ninety-Nine Islands Reservoir and the Lockhart Reservoir. Dams impounding these two reservoirs are also run-of-river structures and not used for flood control.

The U.S. Army Corps of Engineers (USACE) and the Cleveland County Water (CCW) (previously Cleveland County Sanitary District [CCSD]) proposed to construct a dam on the First Broad River, a tributary of the Broad River upstream of the WLS site, approximately 1.6 km (1 mi) north of Lawndale, NC. The applicant reported that initial feasibility studies estimate that the dam may be approximately 25.3 m (83 ft) high with a 379.5-m (1,245 ft) bottom width and a 304.8 m (1,000 ft) wide spillway. The applicant stated that the surface area of the impoundment would be approximately 909 ha (2,245 ac), covering areas lower than 262.1 m (860 ft) above MSL.

The Piedmont aquifer system mainly consists of two sloped layers. The shallow unconfined layer, the water table aquifer, is composed of saprolite and residual soils. The deeper layer, the bedrock aquifer, is composed of weathered and unweathered crystalline igneous and metamorphic rocks. In the bedrock aquifer, water is stored and transmitted through fractures. The shallow aquifer is unconfined. The fracture system of the bedrock aquifer increases upward in prevalence of fractures as the crystalline rock transitions into saprolite. Due to the increased permeability of the transition zone, the saprolite and bedrock zones function as a single, interconnected aquifer system.

The applicant stated that although there is no single, widespread aquifer in the Piedmont region, local aquifer systems are hydraulically connected. The main source of recharge in the area is infiltration of local precipitation. Local groundwater flow directions can vary depending on topography, fracture characteristics and rock texture.

During the 1973 investigation for the abandoned Cherokee Nuclear Station, several springs and seeps were identified; they were located within valleys that directed surface runoff to the north and to the southeast. During site grading for construction of the abandoned Cherokee Nuclear Stations, these springs and seeps were cut and filled to level the site. Undisturbed topographic features on the WLS site are generally rounded hilltops and narrow valleys. Elevations on the site range from approximately 155.8 m (511 ft) above MSL at the Broad River to approximately 246.9 m (810 ft) above MSL on top of McKowns Mountain, located west of the nuclear power block area and between the two arms of Make-Up Pond B.

The applicant stated that the maximum water use from the Broad River during plant operation is estimated to be 1.8 m^3/s (63 cfs), which is approximately three percent of the average annual mean discharge in the river. The applicant also stated that groundwater would not be used as a primary source for any purpose and for any safety-related purposes for WLS and water for temporary fire protection, concrete batching, and other construction uses would be provided by the Draytonville Water District.

The Staff's Technical Evaluation

To review the hydrosphere description and to verify that the analyses in subsequent WLS COL FSAR sections are appropriate, in RAI 818, Question 02.04.01-2, the staff requested that the applicant provide spatially referenced data sets that were used to delineate subbasins and to derive surface and subsurface hydrologic and geologic properties.

In an October 10, 2008, response to RAI 818, Question 02.04.01-2, the applicant provided the geographic information system (GIS) layers for the Broad River watershed including sub-basins, major streams, stream gauge locations, and dam locations. The applicant also provided GIS

layers for local site drainage including elevation contours and details of the plant layout. The staff used these data to review the applicant's method to determine flooding in the Broad River watershed, flooding in the drainage areas of Make-Up Ponds A, B, and C, and flooding during the local intense precipitation event. The staff's review is described in subsequent sections herein. The applicant also provided soils search results from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey website at and near the site. Based on its review of the data provided by the applicant, the staff concluded that the applicant provided sufficient information for staff to proceed with its review. Accordingly, the staff considers RAI 818, Question 02.04.01-2, resolved.

To review the appropriateness of COL applicant's methods, in RAI 818, Question 02.04.01-5, the staff requested that the applicant describe the method used to fill gaps in the 81-year streamflow record for the Broad River. In a November 18, 2008, response to RAI 818, Question 02.04.01-5, the applicant stated that it derived the 81-year daily average streamflow record for the Broad River near the WLS site from three USGS stream gauges: the Broad River gauge near Gaffney, SC, located just upstream of the site and with an associated drainage area of 1,490 mi^2; the Broad River gauge near Blacksburg, SC, located approximately 5.0 river km (3.1 river miles) upstream of the Gaffney gauge and with an associated drainage area of 3,341 km^2 (1,290 mi^2); and the Broad River gauge near Boiling Springs, NC, located approximately 26.1 river km (16.2 river miles) upstream of the Gaffney gauge and with an associated drainage area of 2,266 km^2 (875 mi^2). The applicant stated that streamflow data were available for the Gaffney gauge from 1938 to 1971 and from 1986 to 1990, for the Blacksburg gauge from 1997 to 2006, and for the Boiling Springs gauge from 1926 to 2006. The applicant stated that it estimated the 81-year streamflow record for the Gaffney gauge, from 1926 to 2006, by pro-rating the available streamflow data at other gauges by the respective drainage area ratios to fill data for absent years. The applicant estimated the streamflow data at the Gaffney gauge for absent years using the Blacksburg gauge first because that gauge is closer to the Gaffney gauge. The applicant used data from the Boiling Springs gauge for the years that did not have measurements at Gaffney and Blacksburg gauges.

The staff reviewed the applicant's method for estimating the 81-year streamflow record near the site and concluded that it is a commonly used method in hydrologic engineering and therefore, is acceptable. Accordingly, the staff considers RAI 818, Question 02.04.01-5, resolved.

To clarify the description of Make-Up Pond B and changes that may be made to it, the staff issued RAI 818, Question 02.04.01-6. In a November 18, 2008, response to RAI 818, Question 02.04.01-6, the applicant stated that the two sub-basins of the Make-Up Pond B refer to a bathymetric feature of the pond. During the construction of the pond in 1970s, a cofferdam was emplaced to facilitate construction of the Make-Up Pond B Dam. After the pond filled with water, the cofferdam was submerged, creating a division within the pond. The applicant stated that the cofferdam appears as two approximately parallel elevation contours at 164.6 m (540 ft) above MSL midway between the McKowns Mountain and the Make-Up Pond B Dam. The applicant also stated that this cofferdam would be removed during construction of WLS Units 1 and 2 to allow full communication between the two currently existing bathymetric divisions of Make-Up Pond B. The applicant stated that the Make-Up Pond B only provides water storage to support plant operations and has no safety-related function. The staff reviewed the applicant's response and concludes that the applicant provided sufficient information for staff to

proceed with its review. Accordingly, the staff considers RAI 818, Question 02.04.01 6, resolved.

To gain a clear understanding of the significance of Hold-Up Pond A with respect to surface release pathways, the staff issued RAI 818, Question 02.04.01-7. In a November 18, 2008, response to RAI 818, Question 02.04.01-7, the applicant stated that the Hold-Up Pond A would be used as a settling pond for stormwater runoff during pre-construction and construction activities, as the discharge point for maintenance dewatering during plant construction, and as a stormwater detention basin during plant operations. The applicant reported that Hold-Up Pond A has a surface area of 1.7 ha (4.2 ac) with a watershed area of 0.08 km^2 (0.03 mi^2). In WLS COL FSAR Revision 2, the applicant reported that the surface area of Hold-Up Pond A is 1.8 ha (4.4 ac) with a storage volume of 69,568 m^3 (56.4 ac-ft) at a full pool elevation.

The applicant also stated that the underground piping constructed for the Cherokee project would be removed and backfilled during construction of WLS Units 1 and 2, which would eliminate man-made preferential groundwater pathways. The staff concluded that the applicant provided sufficient information for the staff to proceed with its review. Accordingly, the staff considers RAI 818, Question 02.04.01-7, resolved. The staff reviewed the technical validity of the applicant’s response and its effects on groundwater pathways, and the staff’s evaluation is presented in Section 2.4.12 of this report.

To facilitate direct comparison among several elevation values reported in the WLS COL FSAR, in RAI 818, Question 02.04.01-8, the staff requested that the applicant provide clarification regarding consistency of datums used throughout the WLS COL FSAR Section 2.4. In a November 18, 2009, response to RAI 818, Question 02.04.01-8, the applicant provided a list of datums used in WLS COL FSAR figures and has updated the WLS COL FSAR with this information. The staff concluded that the applicant provided sufficient information for staff to proceed with its review. Accordingly, the staff considers RAI 818, Question 02.04.01-8, resolved.

WLS COL FSAR Section 2.4.1.2.3 discusses the existing dams and reservoirs, and also refers to the proposed CCW Dam in WLS COL FSAR Section 2.4.1.2.3.3 “Water Management Changes.” The staff subsequently requested additional information from the applicant, the USACE District Office in Wilmington, NC, and the CCW. The USACE provided some information about design details of the proposed reservoir.

In July 7, 2008, and July 11, 2008, emails to the staff, the USACE stated that the proposed CCW Dam would be an earth-fill structure approximately 25.3 m (83 ft) high and 379.5 m (1,245 ft) wide at the base with a 305 m (1,000 ft) wide emergency spillway. The dam would inundate areas below 262 m (860 ft) MSL upstream of it to create a reservoir with a surface area of approximately 526 ha (1,300 ac). The staff noted that the reservoir surface area value of 526 ha (1,300 ac), stated in the USACE email, differs from 909 ha (2,245 ac), the value stated in the *Federal Register* notice of intent pertaining to this proposed dam action. In WLS COL FSAR Section 2.4.4.1, the applicant stated that the estimated storage volume of the reservoir is approximately 58,590,386 m^3 (47,500 ac-ft). In a January 31, 2012, letter to the staff, McGill Associates provided currently available information regarding the proposed First Broad River Reservoir (impounded by the above-mentioned CCW Dam). The dam would be located approximately 5.6 river kilometers (3.5 river miles) upstream of North Carolina Highway 182 and 3.9 river kilometers (2.4 river miles) upstream of the confluence of Knob Creek with the

First Broad River. The dam would be an earth-filled structure with the normal pool at 260.9 m (856 ft) above MSL; bottom of the dam at 242.3 m (795 ft) above MSL; crest of the dam, although not final yet, at approximately 266.7 m (875 ft) above MSL; spillway crest elevation at 261.5 m (858 ft) above MSL; and storage capacity at full pool elevation of 260.9 m (856 ft) above MSL of 26,153,778 m^3 (6,909,292,000 gal or 21,203 ac-ft). The spillway would be designed to safely pass 50 percent of the probable maximum precipitation (PMP) storm with a 0.9 m (3 ft) freeboard. The State of North Carolina may require the spillway to be designed to safely pass the PMP storm. The reservoir operation policy has not yet been determined.

On January 2, 2014, the staff received additional information regarding the CCW Dam and the First Broad River Reservoir from the USACE. The USACE informed the staff that the physical characteristics of the proposed dam and the First Broad River Reservoir have not changed. However, the USACE is still working to develop a plan for completing its review of the CCW proposal. The USACE also stated that its review of the CCW proposal may possibly find an alternative site that is more suitable in terms of environmental considerations. The staff's evaluation of the proposed CCW Dam and its potential effects on the safety of the WLS units is described in Section 2.4.4 of this report. As stated in Section 2.4.4.4.3 of this report, the staff concluded that a hypothetical failure of the proposed CCW Dam would not affect the safety of the WLS units.

Based on a review of the material presented by the applicant in WLS COL FSAR Section 2.4.1 and the staff's observations of the WLS site during the May 18 to 20, 2008, site audit, and based on the reasons given above, the staff concluded that the applicant has adequately considered the hydrosphere near the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified the hydrologic characteristics of the proposed site with appropriate consideration of the most severe natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.1.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.1.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has demonstrated that the characteristics of the site fall within the site parameters specified in the Design Certification (DC) rule, and that no outstanding information is expected to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.1 herein, that the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This section addressed the major hydrologic features, satisfying

COL Information Item 2.4-1. The staff concluded that the applicant provided sufficient information to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.2 Floods

2.4.2.1 *Introduction*

WLS COL FSAR Section 2.4.2 describes historical flooding at the proposed site or in the region contiguous with the WLS site. The information summarizes and identifies 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. The discussion also covers the potential effects of local intense precipitation.

Section 2.4.2 of this report provides a review of the following specific areas: (1) a description of the flood history; (2) flood design considerations; and (3) the effects of local intense precipitation.

2.4.2.2 *Summary of Application*

This section of the WLS COL FSAR describes information about site-specific flooding. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19 related to floods as follows:

AP1000 COL Information Item

- COL Information Item 2.4-2 Floods

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19.

> Combined License applicants referencing the AP1000 certified design will address the following site-specific information about historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - Probable Maximum Flood (PMF) on Streams and Rivers – Site-specific information that will be used to determine the design basis flooding at the site. This information will include the PMF on streams and rivers.
> - Dam Failures – Site-specific information about potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information about probable maximum surge and seiche flooding.
> - Probable Maximum Tsunami Loading – Site-specific information about probable maximum tsunami loading.
> - Flood Protection Requirements – Site-specific information about flood protection requirements or verification that flood protection is not required to meet the site parameter for flood level.

In WLS COL FSAR Section 2.4.2, the applicant addresses the effects of local intense precipitation including the local PMF at the site. Other causes of floods and their effects are discussed in subsequent WLS COL FSAR sections. No further action is required for sites within the bounds of the site parameter for flood level.

2.4.2.3 *Regulatory Basis*

The relevant requirements of NRC regulations for the identification of floods and flood design considerations, and the associated acceptance criteria, are described in NUREG-0800, Section 2.4.2.

The applicable regulatory requirements for identifying floods are as follows:

- 10 CFR 52.79(a)(1)(iii), "Contents of applications; technical information in final safety analysis report," as it relates to the hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, "Reactor Site Criteria," as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.2:

- RG 1.59, "Design Basis Floods for Nuclear Power Plants," as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized

- RG 1.102, "Flood Protection for Nuclear Power Plants," as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

- RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," as it relates to the contents of a COL application

2.4.2.4 *Technical Evaluation*

The staff reviewed COL Information Item 2.4-2 related to the provision of site-specific information about historical flooding and potential flooding factors at the plant site included under WLS COL FSAR Section 2.4. Additional aspects of this information item are addressed in Sections 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, and 2.4.10 of this report.

To ensure that the design basis flood is based on the most conservative of plausible conceptual models, in RAI 820, Question 02.04.02-1, the staff requested that the applicant describe the process followed to determine the conceptual models for floods from local intense precipitation, PMF in the drainage area upstream of the site, surges, seiche, tsunami, seismically induced

dam failures, landslides, and ice effects. In an October 27, 2009, response to RAI 820, Question 02.04.02-1, the applicant stated that the conceptual models to determine the design basis flooding follow the recommendations of RG 1.206 and RG 1.59 and the design basis flooding was determined based on guidance provided in American National Standards Institute/American Nuclear Society standard, ANSI/ANS-2.8-1992, “Determining Design Basis Flooding at Power Reactor Sites.”

The applicant’s analysis of local intense precipitation used the Rational Method to determine runoff. This was appropriate because the area being analyzed is a small developed area. The applicant obtained the precipitation and intensity from the National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Reports (HMRs) 51 and 52 for a point and assumed the site drainage system would be non-functional during the local intense precipitation event. The applicant estimated the water-surface elevations using the USACE Hydrologic Engineering Center-River Analysis System (HEC-RAS) standard step backwater analysis software. The applicant also stated that flow restrictions were maximized by representing the building structures as obstructions to flow and assuming that they do not provide any flood storage. The applicant also performed a sensitivity analysis by varying the values of Manning’s roughness coefficient.

The applicant stated that the process followed to determine conceptual models for floods from a PMF in the drainage area upstream of the site would be discussed in response to RAI 821, Question 02.04.03-1, those for floods from surges and seiches in response to RAI 823, Question 02.04.05-1, those for floods from tsunami and landslides in response to RAI 824, Question 02.04.06-1, and those for floods from dam failures in response to RAI 822, Question 02.04.04-1.

The applicant consulted the USACE ice jam database and obtained river temperature data from the USGS stream gauge database to determine the conceptual models for floods from ice effects. The applicant stated that because no water is required from the Broad River or from Make-Up Ponds A and B to support safety-related functions of the two proposed units, any potential icing of water supply would have no effects on safety-related facilities.

Subsequently, the applicant decided to install Make-Up Pond C to address low-water conditions related to normal operations of the proposed units. Water stored in Make-Up Ponds B and C would be used, in that order, to provide water to Make-Up Pond A for CWS cooling water during low-flow conditions in the Broad River. Since the water pumped from the Broad River to the three Make-Up Ponds would only provide cooling during normal operations, the staff concluded that none of this water is safety-related. The UHS for the AP1000 units is the atmosphere.

The staff reviewed the applicant’s response to RAI 820, Question 02.04.02-1, and concluded that the applicant provided sufficient description of the process followed to determine conceptual models of flooding at and near the site. Therefore, the staff considers RAI 820, Question 02.04.02-1, resolved. The staff used the information provided by the applicant to evaluate the flooding analyses in subsequent sections of this report.

2.4.2.4.1 Flood History

Information Submitted by the Applicant

The applicant stated that floods on the Broad River occur primarily as a result of precipitation runoff over the watershed. Since dams located upstream of the WLS site are used for water supply and not for flood control, peak discharges in the Broad River near the WLS site are not affected significantly by the dams.

The Gaffney USGS streamflow gauge, (Gauge Number 02153500 with contributing area of 3,859 km^2 (1,490 mi^2)), is located about 8 river km (5 river mi) upstream of the WLS site. The applicant reported that the contributing area of the Broad River upstream of the WLS site is about 4,014 km^2 (1,550 mi^2). The applicant stated that the highest water elevation near the WLS site caused by historical floods (159.3 m (522.5 ft) at USGS Gaffney Station on August 14, 1940, and 156.6 m (513.6 ft) at the Ninety-Nine Islands Reservoir during May 1972) are substantially below the designed nuclear island finished floor elevation of 180.7 m (593 ft) above MSL. The applicant also stated that no historical data exist regarding flooding due to surges, seiches, tsunamis, dam failures, or landslides.

The Staff's Technical Evaluation

The staff reviewed the data presented by the applicant in WLS COL FSAR Section 2.4.2 regarding historical flooding and conducted its own analysis. The staff obtained peak streamflow data for USGS streamflow gauges in the Upper Broad River Basin. There are 30 gauges where peak streamflow data are available in the Upper Broad River Basin. Of these 30 gauges, 14 are located upstream of the site (Figure 2.4.2-1 of this report). Table 2.4.2-1 of this report shows the historical maximum peak streamflow reported for each of these streamflow gauges and the corresponding date. The historical maximum peak discharge at the USGS Gaffney Station, 3,373 m^3/s (119,100 cfs), occurred on August 14, 1940. Based on these data, the staff concluded that the flood history presented by the applicant is accurate.

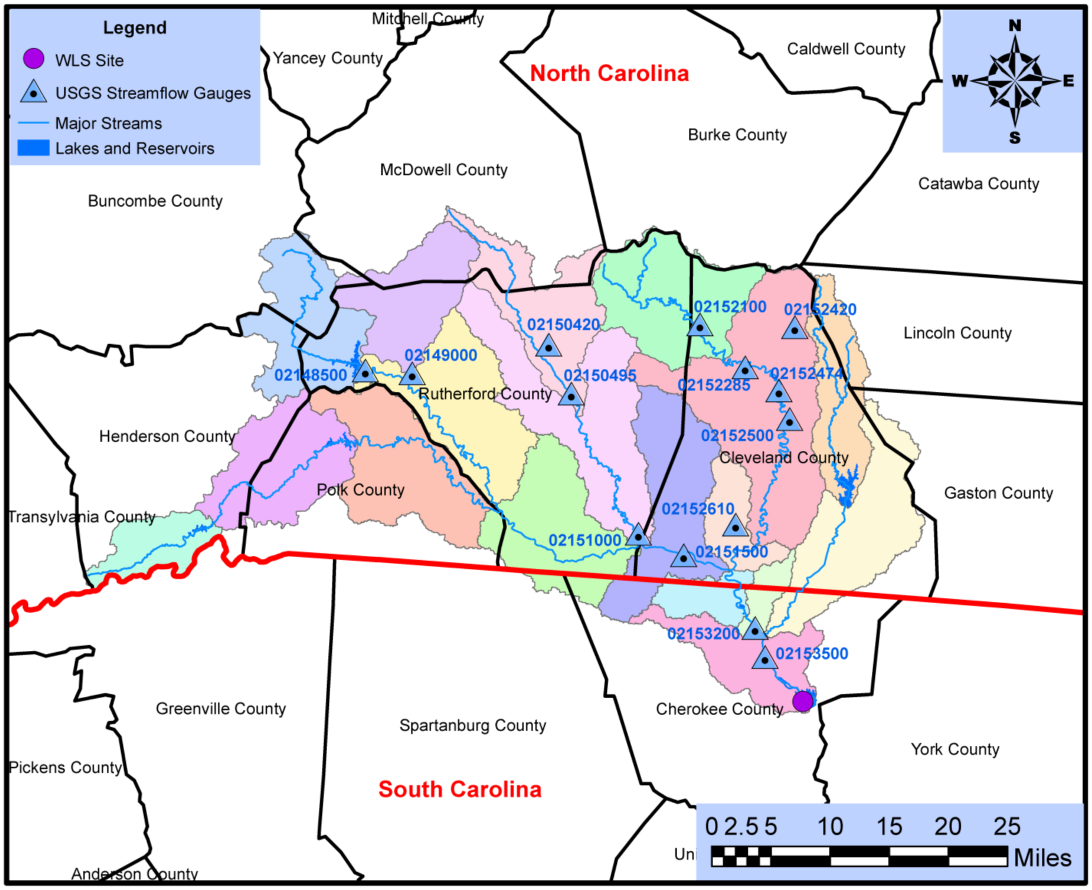

Figure 2.4.2-1 Map of the Upper Broad River Basin Showing Streamflow Stations Used to Describe Historical Flood in the Basin and Showing Adjacent Counties

Table 2.4.2-1 Historical Maximum Peak Streamflow at USGS Streamflow Gauges Upstream of the Site

USGS Streamflow Gauge	Peak Streamflow (m^3/s (cfs))	Date
02148500 Broad River near Chimney Rock, NC	736 (26,000)	1928-08-15
02149000 Cove Creek near Lake Lure, NC	200 (7,050)	1957-06-05
02150420 Camp Creek near Rutherfordton, NC	38 (1,350)	1957-06-04
02150495 Second Broad River near Logan, NC	136 (4,810)	2010-01-25
02151000 Second Broad River at Cliffside, NC	425 (15,000)	1940-08-14
02151500 Broad River near Boiling Springs, NC	2,076 (73,300)	1928-08-16
02152100 First Broad River near Casar, NC	354 (12,500)	2004-09-08
02152285 First Broad River at Sr1512 near Lawndale, NC	84 (2,970)	2009-01-07
02152420 Big Knob Creek near Fallston, NC	96 (3,400)	1970-08-10
02152474 First Broad River at Lawndale, NC	246 (8,690)	2010-01-25
02152500 First Broad River near Lawndale, NC	920 (32,500)	1940-08-14
02152610 Sugar Branch near Boiling Springs, NC	31 (1,110)	1971-10-16
02153200 Broad River near Blacksburg, SC	949 (33,500)	2010-01-25
02153500 Broad River near Gaffney, SC	3,370 (119,000)	1940-08-14

The staff examined a hazard mitigation study conducted by Gaston County. The hazard mitigation study mentions that within Gaston County tsunami and storm surge events are unlikely, landslides (mass earth movements) are unlikely, and snow and ice events are possible; owever, with an average annual snowfall of approximately 7.8 cm (3 in.) flooding due to snow and ice events are unlikely. Based on this study and its independent review of historical data, the staff agreed with the applicant that floods due to tsunami, storm surge, landslide, or snow and ice events are unlikely to pose credible flooding hazards at the proposed WLS nuclear reactor site.

The staff reviewed the flood history information provided by the applicant in WLS COL FSAR Section 2.4.2 and independently obtained data from USGS to conclude that the information provided is sufficient to establish the history of flooding at and near the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated hydrological features of the site. Since the flood history provided by the applicant can be used as baseline information to compare with the estimated design bases for safety-related SSCs, the staff also concluded that the applicant adequately determined of hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and

with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been recorded, are met.

2.4.2.4.2 Flood Design Considerations

Information Submitted by the Applicant

The applicant stated that the design basis flood elevation at the WLS site was determined from several scenarios including the effects of local intense precipitation, PMF on streams and rivers, and potential dam failures, and that these flood scenarios are described in their respective WLS COL FSAR sections. The applicant also considered the combinations of appropriate conditions with flooding scenarios such as wind-generated waves. The applicant stated that because of the inland location of the WLS site, consideration of ocean-front surges, seiches, and tsunamis is not necessary. The applicant also stated that consideration of snowmelt and ice effects is not necessary because the WLS site is located in a temperate region.

The applicant estimated that the maximum flood water-surface elevation at the WLS site would result from a local intense precipitation event; the maximum flood water-surface elevation at the WLS site would be 180.6 m (592.6 ft) above MSL. The safety-related plant elevation is 180.7 m (593 ft) above MSL. The applicant has stated that this water-surface elevation, 179.72 m (589.62 ft) above MSL, is identified as a site characteristic.

The Staff's Technical Evaluation

The staff reviewed the description of flooding mechanisms provided by the applicant in WLS COL FSAR Sections 2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, and 2.4.7. The staff's review of these individual flooding mechanisms and their flooding potential is described in detail in the associated sections herein. The staff observed that in the November 22, 2011, revised flooding analysis the applicant changed the design basis flood source mechanism from probable maximum flooding in the watershed of Make-Up Pond B with coincident wind waves to onsite flooding from local intense precipitation. The staff agreed with the applicant that the design basis flood elevation would be caused by local intense precipitation near the site and would be below ground-floor elevation of safety-related SSCs at the WLS site. More details of the design basis flood are described in Section 2.4.3.4.5 of this report.

Based on a review of the applicant's information contained in the WLS COL FSAR, the staff concluded that the applicant appropriately considered flood-causing phenomena and their combinations that are relevant for the WLS site. Based on the reasons given above, the staff found that the requirements of 10 CFR 100.20(c), as they relate to identifying and evaluating hydrological features of the site, are met. The staff agreed that the combinations of flood-causing phenomena considered by the applicant are appropriate for the WLS site. Based on the reasons given above, the staff concluded that the requirements of 10 CFR 52.79(a)(1)(iii) are met, as they relate to the determination of hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.2.4.3 Effects of Local Intense Precipitation

Information Submitted by the Applicant

The applicant estimated the local intense PMP for the WLS site by following the guidance in HMRs 51 and 52. The applicant obtained the 2.6 km^2 (1 mi^2) PMP values from HMR 52 for durations of 1 hour and less. For durations of 6 to 72 hours, the applicant obtained the PMP values from HMR 51 for a 25.6 km^2 (10 mi^2) area. The applicant's estimate of local intense precipitation at the WLS site is shown in Table 2.4.2-2 below.

Table 2.4.2-2 COL Applicant's Estimates of Cumulative Local Intense Precipitation Depths at the WLS Site

	Duration								
	5 min	**15 min**	**30 min**	**1 hr**	**6 hr**	**12 hr**	**24 hr**	**48 hr**	**72 hr**
PMP (cm [in.])	15.7 (6.2)	24.6 (9.7)	35.6 (14.0)	48.0 (18.9)	75.9 (29.9)	90.2 (35.5)	102.6 (40.4)	112.5 (44.3)	118.9 (46.8)

The applicant noted that the AP1000 site parameter for PMP is 52.6 cm (20.7 in.) per hour. Therefore, the local intense precipitation depth at the WLS site is lower than the AP1000 site parameter.

The applicant stated that elevations immediately adjacent to the nuclear power block areas enclosed by a roadway, range from the nominal plant grade of 180.4 m (592 ft) to 179.8 m (590 ft) above MSL. Farther away from this area, the grade is flat from the roadway to the plant side of the vehicle barrier system at 179.8 m (590 ft) above MSL. The outer bank of the vehicle barrier system is at an elevation of 179.2 m (588 ft) above MSL. Farther outside the vehicle barrier system, the WLS site is flat at an approximate elevation of 179.2 m (588 ft) above MSL before steeper slopes that form the banks of the adjacent water bodies including Make-Up Ponds A and B, Hold-Up Pond A, and the Broad River. The WLS site drainage area is shown in Figure 2.4.2-2 of this report.

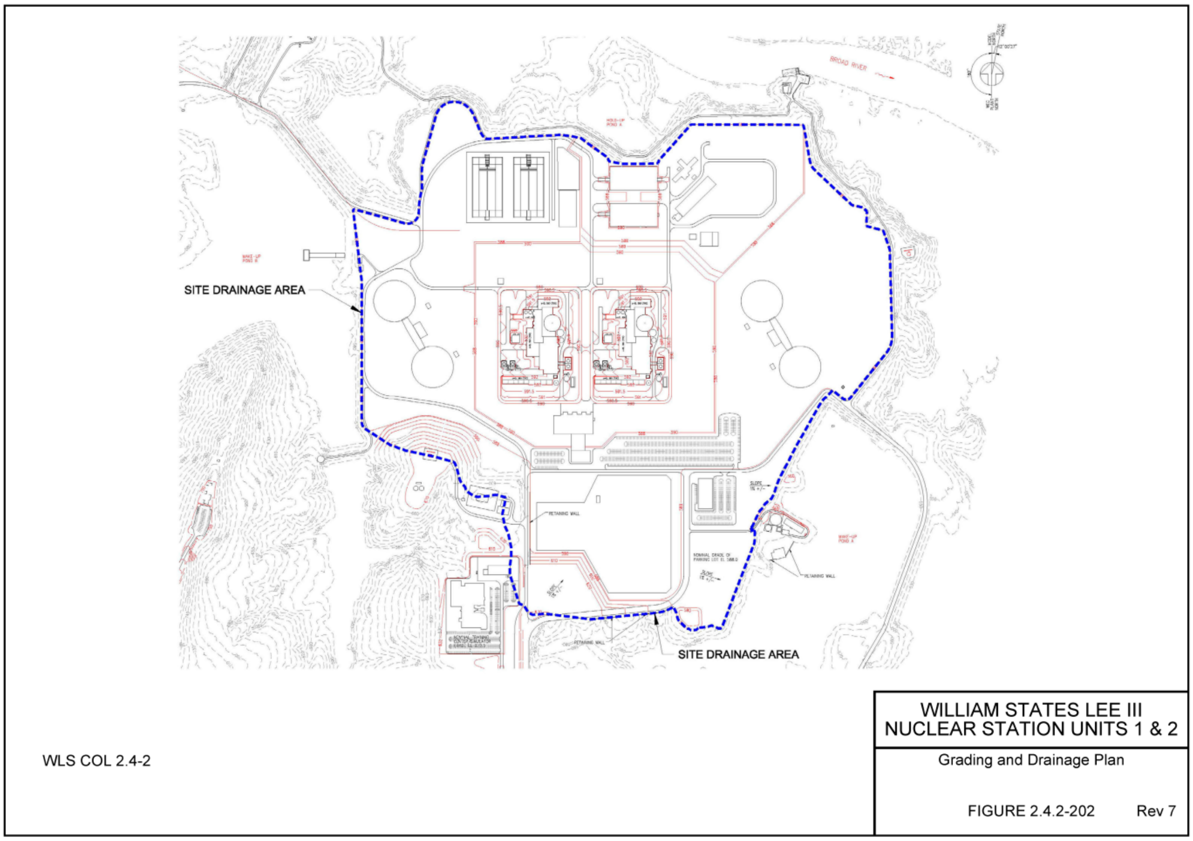

Figure 2.4.2-2 The Site Drainage Area at the WLS Site (Adapted from WLS COL FSAR Revision 7, Figure 2.4.2-202)

The applicant represented the WLS site areas at an elevation of 179.2 m (588 ft) above MSL as an idealized dry reservoir with an elevation-discharge-storage relationship. The applicant refers to this idealized reservoir as the idealized reservoir for the overall site. The storage was estimated using the elevation-area relationship within the drainage area excluding nuclear power block areas that are bounded by the vehicle barrier system, an area north of WLS Unit 2 that slopes from 179.8 m (590 ft) to 179.2 m (588 ft) above MSL, and areas where plant structures and the switchyard are located. The applicant developed the discharge relationship for this reservoir by representing its outer boundary, at an elevation of 179.2 m (588 ft) above MSL, as a broad-crested weir. The weir length is the total length of the 179.2 m (588 ft) above MSL contour minus the length of sections that are deemed ineffective because of less steep downstream slopes. The water-surface elevations in the downstream water bodies provide the downstream boundary conditions for the weir flow. The applicant stated that tailwater conditions would not affect the discharge over the weir; however, the applicant stated that it selected a conservatively low weir discharge coefficient of 2.0. The idealized dry reservoir model was implemented in the USACE Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) software Version 3.5.

The applicant simulated two local intense precipitation storms. The first storm used PMP depths for a 72-hour duration with a precipitation interval of 1 hour and the second storm used

PMP depths for a 6-hour duration with a precipitation interval of 5 minutes. The applicant estimated the runoff discharge by multiplying the precipitation intensity during each interval by the drainage area; the applicant noted that this approach is equivalent to using the Rational Method with a runoff coefficient of 1 where no losses occur. The applicant used the estimated runoff discharge as inflow to the overall site reservoir model and simulated the resulting water-surface elevation in the reservoir using level-pool routing with the outflow from the reservoir determined by the broad-crested weir equation. The applicant used the water-surface elevation resulting from the 72-hour duration storm as the starting reservoir elevation for the 6-hour duration storm. The applicant reported that the maximum water-surface elevation in the overall site idealized reservoir would be 179.5 m (588.8 ft) above MSL. The applicant used this water-surface elevation as the downstream boundary condition to analyze the WLS site area upstream of the vehicle barrier system.

Similar to the overall site idealized reservoir, the applicant developed an idealized reservoir model for the WLS site area upstream of the vehicle barrier system. The nuclear power block areas bounded by the 179.8 m (590 ft) above MSL contour are not included and all structures provide no storage. The applicant used the broad-crested weir equation to estimate the outflow from the reservoir with the length of the weir determined by the length of the 178.9 m (590 ft) above MSL contour, reduced by the lengths of sections that were deemed ineffective because of the presence of structures. The applicant used a weir discharge coefficient of 2.0. In its analysis, the applicant did not identify any tailwater effects.

Similar to the overall site idealized reservoir, the applicant used two local intense precipitation storms for the idealized reservoir model representing the WLS site area upstream of the vehicle barrier system. Estimation of runoff discharge included no losses. The applicant used the water-surface elevation resulting from the 72-hour duration storm as the starting reservoir elevation for the 6-hour duration storm. Using level-pool routing, the applicant estimated that the maximum water-surface elevation in the reservoir for the 6-hour duration storm would be 180 m (590.6 ft) above MSL. The applicant used this water-surface elevation as the downstream boundary condition to analyze the nuclear power block area of the two units.

For the nuclear power block areas of the two units, the applicant analyzed the runoff from local intense precipitation using four channels within each nuclear power block area (Figure 2.4.2-3 of this report), using a steady-state, backwater analysis in HEC-RAS software version 4.1.0. The applicant did not allow any precipitation losses; the peak runoff discharge used in the steady-state, backwater analysis results from a PMP intensity of 15.7 cm (6.2 in.) in 5 min. The applicant obtained the four channels' cross-section characteristics from the site grading and drainage plan. Structures in the nuclear power block area provide no storage and act as obstructions to open-channel flow. The applicant used a Manning's roughness coefficient of 0.026, appropriate for gravel-lined channels, as a bounding value for ground-cover types in the nuclear power block areas. The applicant reported that the maximum water-surface elevation at the upstream cross section occurred in channels B1 and B2 of the two nuclear power block areas, respectively. The applicant estimated the maximum water-surface elevation to be 180.6 m (592.6 ft) above MSL. The applicant noted that all safety-related structures are located at or above an elevation of 180.7 m (593 ft) above MSL.

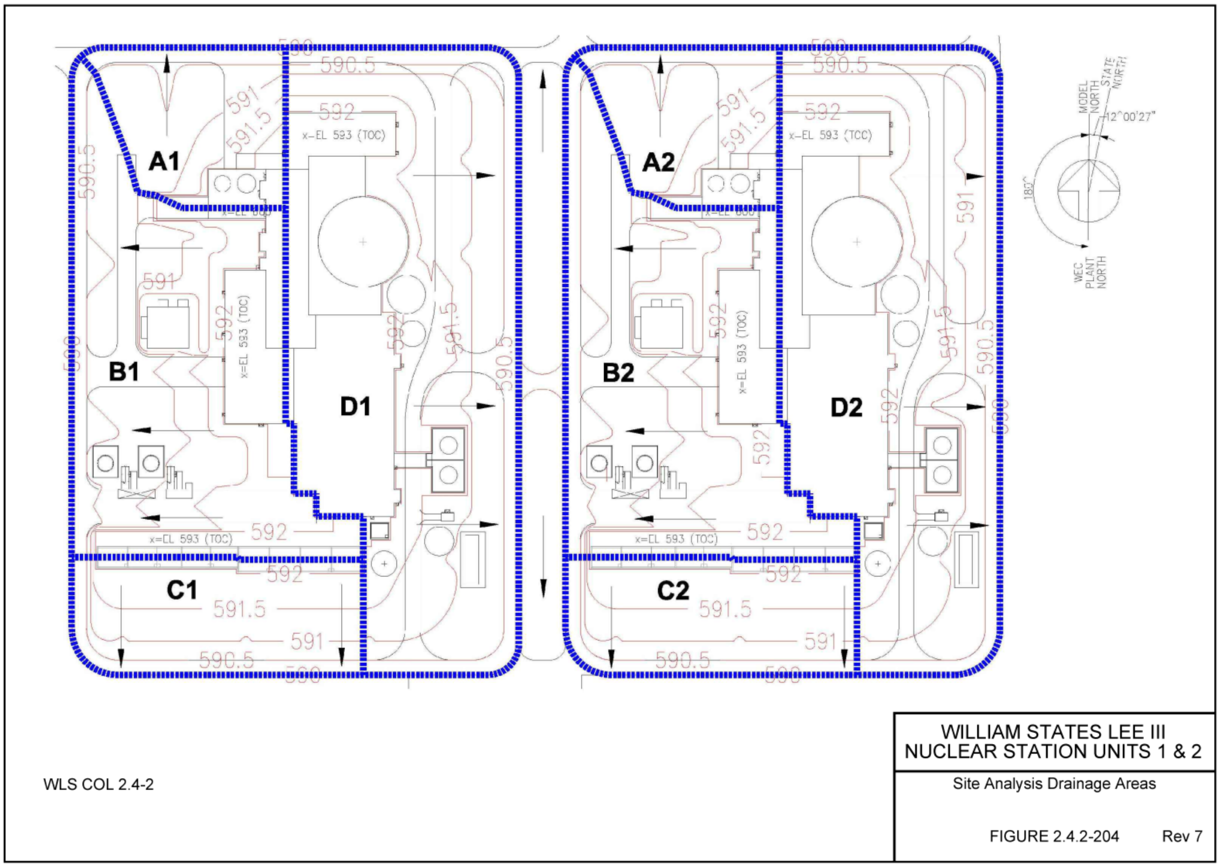

Figure 2.4.2-3 Drainage Pattern within the Nuclear Power Block Areas of the Two Units

The Staff's Technical Evaluation

The staff independently estimated the local intense precipitation at the site from NOAA HMRs 51 and 52. The staff-estimated values are shown in Table 2.4.2-3 of this report. The staff compared its independently estimated values of the local intense precipitation at the site to those stated by the applicant and determined that there are small differences in the two estimates. The largest of these differences, approximately 1.6 percent, occurred for the cumulative precipitation depth corresponding to the duration of 48 hours. The staff concluded that these differences are minor and would not significantly affect the estimation of water-surface elevations during site flooding under the local intense precipitation. The staff concluded, therefore, that the applicant's estimate of the local intense precipitation, shown in Table 2.4.2-2 of this report, is acceptable and would be used as a site characteristic.

Table 2.4.2-3 Cumulative Local Intense Precipitation Depths Independently Estimated by the Staff

	Duration								
	5 min	15 min	30 min	1 hr	6 hr	12 hr	24 hr	48 hr	72 hr
PMP (cm [in.])	15.7 (6.2)	24.4 (9.6)	35.6 (14.0)	48.0 (18.9)	76.2 (30.0)	90.7 (35.7)	104.1 (41.0)	114.3 (45.0)	119.4 (47.0)

The following discussion tracks the staff's review of the applicant's local intense precipitation-induced analysis in WLS COL FSAR Revisions 0 through 7. As described above in the subsection, "Information Submitted by the Applicant," the applicant has updated its analysis of flooding in the WLS site area under local intense precipitation after the nominal site grade for WLS Units 1 and 2 nuclear power block and the nuclear island finished floor elevations were raised to 180.4 m (592 ft) and 180.7 m (593 ft) above MSL, respectively.

To understand the analysis performed by the applicant related to the runoff from and water-surface elevations on site drainage areas under local intense precipitation, in RAI 820, Question 02.04.02-2, the staff requested that the applicant: (1) provide input files used in the HEC-RAS analysis described in WLS COL FSAR Section 2.4.2.3; (2) provide details of the iterative process used with the HEC-RAS model to determine water-surface elevations during the local intense precipitation event described in WLS COL FSAR Section 2.4.2.3; (3) provide details of how the times of concentration for the site drainage areas were determined; and (4) provide the locations of safety-related structures where the maximum water-surface elevations for each of the site drainage areas occurred. In an October 27, 2008, response to RAI 820, Question 02.04.02-2, the applicant stated that HEC-RAS and HEC-HMS electronic input and output files were provided to the NRC. The staff used these files to review the applicant's analysis described in WLS COL FSAR Section 2.4.2 and to perform independent confirmatory analyses. The applicant stated that the AP1000 safety-related structures are the containment building and the auxiliary building. The applicant identified these structures on a figure provided with the RAI response.

The staff evaluated the applicant's responses to the RAIs and determined that the applicant has adopted a reasonable approach to identify the effects of local intense precipitation. The staff reviewed the proposed post-construction elevation contour map of the site extending out from the nuclear power block area and determined that the identification of the four subareas based on the site grading plan and the location of safety-related SSCs conform to the elevation contours. The applicant used the Rational Method with an assumption of no losses to estimate the discharges in the four subareas. The applicant used the HEC-RAS hydraulic simulation software to estimate water-surface elevations under steady conditions. The staff concluded that these are conservative approaches and therefore, the applicant's methods for determination of discharges and water-surface elevations during the local intense precipitation event are adequate. Accordingly, the staff considers RAI 820, Question 02.04.02-2, resolved.

However, the staff noted that the applicant's use of the values of Manning's roughness coefficients for grass and for gravel, 0.035 and 0.015, respectively, were potentially not conservative for the corresponding groundcover. A higher value of Manning's roughness coefficient typically results in a greater depth of flow for the same discharge and same channel geometry. Chow (1959) suggested that the value of Manning's roughness coefficient ranges from 0.025 to 0.035 for short grass and from 0.030 to 0.050 for high grass. Since the applicant did not specify which grass type would be prevalent in the grassed areas on the site, the staff conservatively selected a Manning's n value of 0.048. Similarly, because the recommended value for lined or built-up channels with gravel bottom and formed concrete side ranges from 0.017 to 0.025 (1959), the staff selected the value of 0.025 as a conservative value. The applicant used values of 0.035 for grass and 0.015 for paved surfaces. The staff independently performed a HEC-RAS simulation for the northeast subarea of the local site drainage using the input files provided by the applicant. In this analysis, the staff started with the final, converged HEC-RAS simulation performed by the applicant. The only changes made to the HEC-RAS inputs were the Manning's roughness coefficients for grass and for gravel. The staff did not perform any iteration to accurately estimate the time of concentration. The staff's analysis was only meant to estimate how much, if any, effect conservatively selected Manning's roughness coefficients may have on the simulated velocities and water-surface elevations. Table 2.4.2-4 of this report shows the difference in HEC-RAS predictions for flow velocities and those for water-surface elevations for all subareas at cross sections near which safety-related SSC would be located.

Table 2.4.2-4 Difference in Simulated Flow Velocities and Water-Surface Elevations at Cross Sections Near Safety-Related SSCs Due to Change in Manning's Roughness Coefficient

Sub-area	Cross Section	Flow Velocities (m/s [(ft/s])		Water-Surface Elevations (m [ft] Above MSL)	
		COL Applicant	Staff	COL Applicant	Staff
NE	XS10	0.08 (0.25)	0.06 (0.2)	179.47 (588.82)	179.53 (589.01)
NW	XS7	0.17 (0.55)	0.14 (0.45)	179.52 (588.96)	179.58 (589.18)
SE	XS9	0.11 (0.37)	0.10 (0.33)	179.44 (588.7)	179.49 (588.87)
SW	XS8	0.02 (0.06)	0.02 (0.05)	179.63 (589.34)	179.70 (589.58)

As shown in Table 2.4.2-4 above, although the water-surface elevations did not change significantly, the velocities did change by up to 20 percent (at cross-section XS10 in the northeast (NE) subarea), which in turn would require iterations to refine the estimate of the time of concentration. The staff noted, based on the results described above, that the effects of local intense precipitation on the safety-related facilities should be re-evaluated by the applicant using more appropriate values for Manning's roughness coefficient or provide a justification why the base values of Manning's roughness coefficient used in the WLS COL FSAR analysis are conservative. Therefore, in supplemental RAI 72, Question 02.04.02-3, the staff requested that the applicant re-evaluate the effects of local intense precipitation based on more appropriate

values of Manning's roughness coefficient, or to justify why the base values of Manning's roughness coefficient used in the WLS COL FSAR analysis were conservative.

In a July 17, 2008, response to RAI 72, Question 02.04.02-3, the applicant stated that a re-evaluation of the effects of the local intense precipitation analysis had been performed with a Manning's roughness coefficient value of 0.050 for grass cover areas and a value of 0.025 for paved and gravel cover areas. The applicant acknowledged the minor increase of the maximum water-surface elevation (from 179.63 m (589.34 ft) above MSL to 179.70 m (589.57 ft) above MSL for the southwest drainage area) due to the local intense precipitation effects. The re-estimated maximum water-surface elevation remained below the plant elevation of all WLS safety-related structures (179.8 m (590 ft) above MSL).

The staff evaluated the applicant's responses to the RAIs and concluded that the applicant has adopted a conservative approach by using the larger values for Manning's roughness coefficient in the HEC-RAS model. Therefore, the staff considers RAI 72, Question 02.04.02-3, resolved.

As described above, the applicant revised the analysis for site flooding under local intense precipitation in response to the staff's RAI 484, Question 10.04.05-2. The staff reviewed the applicant's description of changes to site grading and the applicant's calculations to support the updated site flood analysis. The staff concluded that the applicant's revised analysis that idealizes the site as a dry and shallow reservoir is reasonable because the site area is characterized by gentle slopes and the nuclear power block areas are surrounded by raised roadway that the accumulated runoff would overtop. The staff also concluded that the applicant's analysis to determine water-surface elevations in the nuclear power block areas adjacent to SSCs important to safety is conservative because of the following assumptions and their effects on the water-surface elevation in the idealized reservoir.

- The estimation of runoff ignores all precipitation losses to maximize volume of storage and corresponding water-surface elevation in the idealized reservoir.

- Depression storage was ignored, thereby maximizing the volume of runoff and increase water-surface elevation in the idealized reservoir.

- Plant structures provided obstruction to the flow but no storage, thereby minimizing surface area of the idealized reservoir that would result in higher water-surface elevation for the same storage volume.

- The sheet flow after overtopping could run off the site in all directions, but was assumed to be restricted to three channels that convey runoff to Make-Up Pond B, and the Broad River would result in reduced conveyance and therefore increase storage and corresponding water-surface elevation in the idealized reservoir.

- The downstream boundary conditions in Make-Up Pond B and the Broad River were assumed to be results of their respective PMF events even though the two PMF events would be extremely unlikely to occur concurrently.

The staff also reviewed the parameters the applicant used in the analysis to specify downstream boundary conditions (Manning's n and weir discharge coefficients) and finds them reasonable and conservative. The applicant also used multiple temporal distributions for the local intense

precipitation and chose the most conservative results. Therefore, the staff concluded that the applicant's revised analysis for the effects of local intense precipitation on the water-surface elevation within and near the nuclear power block areas is reasonable and conservative. The staff concluded that the applicant-estimated water-surface elevation of 179.72 m (589.62 ft) above MSL that would occur on the west side of each of the proposed units in the area between the Annex Building and the Diesel Generator Building is conservative and acceptable as a site characteristic maximum water-surface elevation. For comparison, this estimate is slightly higher than that reported by the applicant, 179.70 m (589.57 ft) above MSL, in its original analysis.

After raising the nominal site grade for WLS Units 1 and 2 nuclear power block and the nuclear island finished floor elevation to 180.4 m (592 ft) and 180.7 m (593 ft) above MSL, respectively, the applicant updated its analysis of flooding in the WLS site area under a local intense precipitation event. The staff described the applicant's updated analysis above in the subsection, "Information Submitted by the Applicant." The staff reviewed the information provided in Revisions 6 and 7 of the WLS COL FSAR and reviewed the applicant's calculation packages in the reading room.

The staff reviewed the applicant's description of the revised analysis and concluded that the applicant implemented the WLS site area in hydrologic and hydraulic modeling software that is currently accepted in standard engineering practice. The applicant's models incorporate several conservative assumptions:

- No runoff losses are allowed, thereby maximizing the runoff volume, discharge, and the resulting water-surface elevations.
- The two areas modeled using idealized dry reservoirs promote detention of runoff within the reservoirs resulting in higher water-surface elevation.
- The selected value of the weir discharge coefficient would result in smaller discharge from the reservoirs and therefore maximize water-surface elevations within the reservoirs.
- The initial water-surface elevations for the two idealized reservoirs were set to an elevation that would result from a 72-hour-duration local intense precipitation before using the 6-hour, 5-minute local intense precipitation inflow into the reservoirs; this assumption is equivalent to assuming that a 72-hour PMP event was followed by a 6-hour PMP event at the WLS site, which is extremely conservative because it assumes two extreme precipitation events occurring in sequence.
- The Manning's roughness coefficient value of 0.026 is an appropriate maximum value for gravel bottom built-up channels with sides that have random stones in mortar; this assumption would result in a higher water-surface elevation within the nuclear power block areas.

Therefore, the staff concluded that the applicant's revised local intense precipitation-induced flood analysis is reasonable and conservative and would result in conservatively estimated water-surface elevations near the safety-related SSCs. Based on a review of the applicant's information in WLS COL FSAR Revisions 0 through 7, the staff concluded that the applicant has appropriately considered flood-causing phenomena related to local intense precipitation for the

WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated hydrological features of the site. The staff agreed that the flood-causing phenomena associated with local intense precipitation considered by the applicant are appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.2.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.2.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information related to individual types of flood-producing phenomena, and combinations of flood-producing phenomena, considered in establishing the flood design bases for safety-related plant features. The information also covered the potential effects of local intense precipitation. The staff also confirmed that there is no outstanding information required to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.2 of this report, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This partially addresses COL Information Item 2.4-2. The staff concludes that the applicant has provided sufficient information with respect to the flood history, flood design considerations, and the effects of local intense precipitation to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.3 Probable Maximum Flood on Streams and Rivers

2.4.3.1 *Introduction*

WLS COL FSAR Section 2.4.3 describes the hydrologic site characteristics affecting any potential hazard to the plant's safety-related facilities as a result of the effect of the PMF on streams and rivers.

Section 2.4.3 herein provides a review of the following specific areas: (1) regional PMPs and their losses; (2) runoff and stream course models; (3) PMF; (4) flood water-surface elevations including effects of coincident wind waves; (5) consideration of other site-related evaluation criteria; and (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts of 10 CFR Part 52.

2.4.3.2 *Summary of Application*

This section of the WLS COL FSAR describes the site-specific PMFs on streams and rivers. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19 related to PMF as follows:

<u>*AP1000 COL Information Item*</u>

- COL Information Item 2.4-2

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Section 2.4.1.2, Revision 19.

> Combined License applicants referencing the AP1000 certified design will address the following site-specific information about historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - PMF on Streams and Rivers – Site-specific information that will be used to determine the design basis flooding at the site. This information will include the PMF on streams and rivers.
> - Dam Failures – Site-specific information about potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information about probable maximum surge and seiche flooding.
> - Probable Maximum Tsunami Loading – Site-specific information about probable maximum tsunami loading.
> - Flood Protection Requirements – Site-specific information about flood protection requirements or verification that flood protection is not required to meet the site parameter for flood level.

In WLS COL FSAR Section 2.4.3, the applicant addressed the effects of PMF on streams and rivers. Other causes of floods and their effects are discussed in related WLS COL FSAR sections. No further action is required for sites within the bounds of the site parameter for flood level.

2.4.3.3 *Regulatory Basis*

The relevant requirements of NRC regulations for the identification of floods and flood design considerations, and the associated acceptance criteria, are described in NUREG-0800, Section 2.4.3.

The applicable regulatory requirements for identifying probable maximum flooding on streams and rivers are as follows:

- 10 CFR 52.79(a)(1)(iii), “Contents of applications; technical information in final safety analysis report,” as it relates to identifying hydrologic site characteristics with appropriate

consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, "Reactor Site Criteria," as it relates to identifying and evaluating hydrological features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c).
- 10 CFR 100.23(d), "Geologic and Seismic Siting Factors," sets forth the criteria to determine the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.3:

- RG 1.59, "Design Basis Floods for Nuclear Power Plants," supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized
- RG 1.102, "Flood Protection for Nuclear Power Plants," as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site
- RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," as it relates to the contents of a COL application

2.4.3.4 *Technical Evaluation*

In this section, the staff reviewed the applicant's analysis of PMF on streams and rivers near the WLS site including in the Broad River, in the McKowns Creek and Make-Up Pond B, in the Intermittent Stream and Make-Up Pond A, and in the London Creek and Make-Up Pond C. The staff's independent analysis is also described.

The staff reviewed COL Information Item 2.4-2 related to the provision of site-specific information about the PMF at the plant site included under WLS COL FSAR Section 2.4. Additional aspects of this information item are addressed in Sections 2.4.2. 2.4.4, 2.4.5, 2.4.6, 2.4.7, and 2.4.10 of this report.

To ensure that the design basis flood is based on the most conservative of plausible conceptual models, in RAI 821, Question 02.04.03-1, the staff requested that the applicant describe the process followed to determine the conceptual models for floods in streams and rivers and in the site drainage system. In an October 27, 2008, response to RAI 821, Question 02.04.03-1, the applicant stated that conceptual models used to determine the design basis flood are consistent with the guidance of RG 1.206 and RG 1.59. The applicant stated that the flood estimation approach is consistent with the current state of the practice guidance described in ANSI/ANS-2.8-1992.

The applicant estimated the effects of flooding in Make-Up Ponds A and B using the point PMP values from HMRs 51 and 52. The applicant analyzed several time distributions of the PMP to estimate the most severe flooding effects in the makeup ponds. The applicant used the Soil Conservation Service (SCS) unit hydrograph method to estimate runoff. The applicant maximized the runoff by assuming wet antecedent conditions and no precipitation losses.

The applicant stated that the PMP for the Broad River Basin was estimated using HMRs 51 and 52 and that the PMP over the Broad River Basin was maximized by evaluating several storm centers, storm sizes, and storm orientations. The applicant derived the unit hydrographs for use in the PMF estimation from USGS unit hydrographs for the region. The applicant stated that antecedent storm conditions were chosen to maximize runoff and noted that a PMF in the Broad River Basin was combined with coincident wind-wave activity.

The staff reviewed the applicant's October 27, 2008, response to RAI 821, Question 02.04.03-1, and concluded that the description of the process followed to arrive at conceptual models of floods in streams and rivers is adequate. Therefore, the staff considers RAI 821, Question 02.04.031, resolved. The staff's review of flooding on the WLS site and the nuclear power block areas due to local intense precipitation is described in Section 2.4.2 of this report.

2.4.3.4.1 Probable Maximum Precipitation

Information Submitted by the Applicant

The applicant estimated the PMP for the watershed above the WLS site defined by HMRs 51 and 52 based on an existing study for Ninety-Nine Islands Dam. The applicant optimized the orientation of the PMP storm over the Broad River Basin using the HMR 52 computer software. The applicant used 18 sub-basins in the Broad River Basin upstream of the WLS site. The applicant modified the PMP analysis to include antecedent storm conditions, as specified by RG 1.59, Appendix A and estimated the critical 72-hour storm PMP rainfall total to be 64.7 cm (25.5 in.) for the entire watershed. The applicant used HMR 53 to estimate the winter PMP for the Broad River Basin. The applicant examined the combined event of winter PMP coincident with a 100-year snowpack and stated that snowmelt is not considered to be a factor in modeling the PMF event because the sum of winter PMP and 100-year snowpack is approximately 70 percent of the all-season PMP.

The applicant stated that the PMP for the McKowns Creek and Make-Up Pond B watershed, the Intermittent Stream and Make-Up Pond A watershed, and the London Creek and Make-Up Pond C watershed is the local intense precipitation previously estimated in WLS COL FSAR Section 2.4.2.3.

The Staff's Technical Evaluation

To understand the analysis performed by the applicant related to the estimation of PMP on the drainage basin above the Ninety-Nine Islands Dam, in RAI 821, Question 02.04.03-2, the staff requested that the applicant describe the relevance of HMR 53 for determination of the PMP in the Broad River Basin.

In an October 27, 2008, response to RAI 821, Question 02.04.03-2, the applicant stated that the winter PMP for the Broad River Basin is estimated by multiplying the all-season PMP value

obtained from HMR 52 by the ratio of the 25.9 km^2 (10 mi^2) winter PMP obtained from HMR 53 to the 25.9 km^2 (10 mi^2) all-season PMP obtained from HMR 51. The applicant estimated the ratio to be approximately 0.567 (66.3 cm/116.8 cm [26.1 in/46.0 in]). Using this ratio, the applicant estimated that the winter PMP over the Broad River Basin for a 72-hour duration would approximately be 36.7 cm (14.5 in.) (0.567 × 64.7 cm (25.5 in.)). The applicant further stated that the 100-year snowpack is estimated to be 43.2 cm (17.0 in.) of snow with a water equivalent of 8.6 cm (3.4 in.) and is described in WLS COL FSAR Section 2.3.1.2.7.1. The applicant subsequently estimated, assuming that the 100-year antecedent snowpack would completely melt during the winter PMP event, that the combined potential runoff during the PMP-on-snowpack event would be 45.5 cm (17.9 in.) (36.0 cm (14.5 in.) winter PMP + 8.6 cm (3.4 in.) 100-year snowpack water equivalent), which is approximately 70 percent of the estimated all-season, 72-hour PMP depth of 64.7 cm (25.5 in.) over the whole Broad River Basin. The applicant concluded, therefore, that snowmelt would not be a significant factor in generation of a controlling PMF event in the Broad River Basin.

The staff evaluated the procedure used by the applicant for the estimation of winter PMP in the Broad River Basin. The applicant's approach is based on the assumption that the ratio of the 25.9 km^2 (10 mi^2) winter precipitation (given in HMR 53) to the 25.9 km^2 (10 mi^2) all-season PMP (given in HMR 51) at a given location remains the same for other drainage areas and times of occurrences. The staff independently obtained the 25.9 km^2 (10 mi^2) PMP depths for the months of December through April from HMR 53 for durations equal to 6, 24, and 72 hours at the WLS site. The staff also independently obtained the all-season PMP depths from HMR 51 for the same durations at the WLS site. These values are shown in Table 2.4.3-1. The staff estimated the ratios of HMR 53 PMP for the months of December through April to the HMR 51 all-season PMP depth. These values are shown in Table 2.4.3-2 of this report.

Based on the data shown in Tables 2.4.3-1 and 2.4.3-2 of this report, the staff concluded that the month-wise ratios of HMR 53 PMP depend on the selected duration of the PMP. There is a clear increasing trend for the value of the ratio with increasing duration of the PMP. The staff also noted that the mean of these ratios for the winter months for the 72-hour duration, 0.569, is very close to that used by the applicant, 0.567.

Table 2.4.3-1 Seasonal PMP Depths from HMR 53 and All-Season PMP Depths from HMR 51 at the WLS Site

Duration (hr)	HMR 53 PMP Depth (cm [in.])					HMR 51 All-Season PMP Depth (cm [in.])
	December	January	February	March	April	
6	36.3 (14.3)	33.0 (13.0)	33.0 (13.0)	36.3 (14.3)	43.2 (17.0)	75.7 (29.8)
24	53.6 (21.1)	50.8 (20.0)	50.8 (20.0)	54.9 (21.6)	61.0 (24.0)	102.1 (40.2)
72	68.1 (26.8)	63.5 (25.0)	63.5 (25.0)	68.1 (26.8)	74.2 (29.2)	118.6 (46.7)

Table 2.4.3-2 Ratio of Seasonal PMP Depths from HMR 53 to the All-Season PMP Depths from HMR 51 at the WLS Site

Duration (hr)	HMR 53 to HMR 51 PMP Depth Ratio					
	December	January	February	March	April	Mean
6	0.480	0.436	0.436	0.480	0.570	0.481
24	0.525	0.498	0.498	0.537	0.597	0.531
72	0.574	0.535	0.535	0.574	0.625	0.569

The staff also noted that the winter PMP values obtained from HMR 53 are appropriate for a 25.9 km^2 (10 mi^2) drainage area. Since the PMP depth for a given duration at a given location decreases with increasing drainage area, the staff concluded that the use of 25.9 km^2 (10 mi^2) winter PMP depths for the Broad River Basin, which is approximately 4,014 km^2 (1,550 mi^2) in size above the Ninety-Nine Islands Dam, is conservative. Therefore, the staff concluded that the applicant's approach for estimation of winter PMP depths over the Broad River Basin is conservative. Accordingly, the staff considers RAI 821, Question 02.04.03-2, resolved.

The staff also determined that the addition of the 100-year snowpack, which is assumed to completely melt during the winter PMP event, to the winter PMP depth over the Broad River Basin results in a combined PMP-on-snow event depth that is less than the all-season PMP depth estimated below. Therefore, the staff agreed with the applicant that the flood generated by a PMP-on-snow event would be less severe than the all-season PMF estimated for the Broad River Basin and does not require further consideration.

The staff independently estimated the all-season PMP over the Broad River Basin using the HMR 52 software developed by the USACE. The staff used a GIS layer of the Broad River Basin and its sub-basin boundaries to estimate normalized coordinates for input to the HMR 52 software. The depth-area-duration values from the all-season PMP for durations of 6, 12, 24, 48, and 72 hours, and drainage areas of 25.9, 518, 2,590, 12,950, 25,900, 51,800 km^2 (10, 200, 1,000, 5,000, 10,000 and 20,000 mi^2) from HMR 51 were also input into the software. The HMR 52 software automatically finds the optimal orientation of the PMP storm pattern over the input drainage basin. The staff-estimated PMP storm pattern and PMP depths closely agreed with those reported by the applicant. Therefore, the staff considers the applicant's PMP estimates acceptable.

Based on a review of the applicant's information in WLS COL FSAR Revisions 0 through 7, the staff concluded that the applicant has appropriately considered the local intense precipitation for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme precipitation events at the site. The staff agreed that the local intense precipitation considered by the applicant is appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determinated hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.3.4.2 Precipitation Losses

Information Submitted by the Applicant

The applicant estimated the precipitation losses for Broad River sub-basins and London Creek watershed upstream of Make-Up Pond C based on an existing study using the USDA SCS (now the NRCS) curve number method. The precipitation losses for each sub-basin are provided in the WLS COL FSAR. The applicant's precipitation losses range from approximately 2.5 to 7.3 cm (1 to 2.9 in.) during the 72-hour PMP event. For McKowns Creek watershed upstream of Make-Up Pond B and the Intermittent Stream watershed upstream of Make-Up Pond A, the applicant assumed that no precipitation loss occurs and therefore all rainfall is transformed to runoff.

The Staff's Technical Evaluation

The staff reviewed the method followed by the applicant to estimate precipitation loss rates for the PMF estimation in the Broad River Basin and in the watersheds of Make-Up Ponds A, B, and C. The staff determined that the method used to estimate loss rate for the Broad River Basin and the London Creek watershed upstream of Pond C is commonly used in practice. However, the applicant stated that this method resulted in rainfall losses ranging from 37 to 71 percent with a mean of 51 percent during the antecedent storm and in precipitation losses ranging from 3 to 19 percent with an average of 8 percent during the full PMP storm.

The staff evaluated the effect of loss rates estimated by the applicant on the predicted PMF water-surface elevations near the site by independently estimating the sensitivity of the predictions to this parameter. The staff used the HEC-HMS input files provided by the applicant to perform an analysis for the Broad River Basin such that no precipitation losses were allowed. The staff's analysis resulted in a peak discharge of 22,342 m^3/s (789,000 cfs) at the Ninety-Nine Islands Dam compared to the approximately 21,011 m^3/s (742,000 cfs) discharge estimated by the applicant. The staff used the discharges estimated by HEC-HMS model in the HEC-RAS model provided by the applicant to estimate the corresponding water-surface elevations under the no-loss scenario. The staff's evaluation of the Broad River PMF water-surface elevations is described in Section 2.4.3.4.5 of this report.

The staff agreed with the applicant that the no-loss approach used for the drainage areas of Make-Up Ponds A and B is an appropriately conservative approach for determination of the PMF water-surface elevations in the makeup ponds.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately considered precipitation losses at and near the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. The staff agreed that the precipitation losses considered by the applicant are appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.3.4.3 Runoff and Stream Course Models

Information Submitted by the Applicant

The applicant developed the Broad River runoff and stream course model based on an existing HEC-1 study with modifications to include the antecedent rainfall conditions. The applicant used the USACE HEC-HMS Version 3.0.1 modeling software for estimating the runoff and routing calculations and USACE HEC-RAS Version 3.1.3 modeling software to route hydrographs from above Gaston Shoals Dam to Lockhart Dam.

To account for nonlinear basin response at high rainfall rates, the applicant increased the peak of the unit hydrograph by 20 percent and reduced the time to peak by approximately 33 percent. The applicant used the SCS unit hydrograph method as a basis for a modified unit hydrograph to transform rainfall to runoff for the Make-Up Pond C sub-basin. The applicant obtained the HEC-RAS cross sections from an existing study and modified as necessary and used Manning's roughness coefficients given in published tables by Chow.

For McKowns Creek and Make-Up Pond B, the applicant used the USACE HEC-HMS modeling software for estimating runoff and storage routing calculations. To account for nonlinear basin response at high rainfall rates, the applicant increased the peak of the unit hydrograph by 20 percent and reduced the time to peak by approximately 33 percent. The applicant used the SCS unit hydrograph method as a basis for a modified unit hydrograph to transform rainfall to runoff. The applicant estimated the drainage area, length of watercourse, and average slope of the watershed from aerial topography of the area and calculated the lag time using the standard SCS curve number regression equation. The applicant estimated the base flow to have a constant rate of 0.05 m^3/s (1.8 cfs) using the minimum average monthly flow of the Gaffney and Ninety-Nine Island gauges (USGS No. 02153500 and 02153551) with correction on the basis of a ratio of drainage basin areas. The applicant developed the Make-Up Pond B outflow structure rating curve using standard weir and orifice flow equations with coefficients of 3.5 and 0.8, respectively and estimated the available storage based on aerial topography. The applicant assumed a full pond elevation of 174 m (570 ft) above MSL for antecedent conditions.

For McKowns Creek and Make-Up Pond B, the applicant used the USACE HEC-HMS modeling software for estimating runoff and storage routing calculations. To account for nonlinear basin response at high rainfall rates, the applicant increased the peak of the unit hydrograph by 20 percent and reduced the time to peak by approximately 33 percent. The applicant used the SCS unit hydrograph method as a basis for a modified unit hydrograph to transform rainfall to runoff. The applicant estimated the drainage area, length of watercourse, and average slope of the watershed from aerial topography of the area and calculated the lag time using the standard SCS curve number regression equation. The applicant estimated the base flow to have a constant rate of 0.05 m^3/s (1.8 cfs) using the minimum average monthly flow of the Gaffney and Ninety-Nine Island gauges (USGS No. 02153500 and 02153551) with correction on the basis of a ratio of drainage basin areas. The applicant developed the Make-Up Pond B outflow structure rating curve using standard weir and orifice flow equations with coefficients of 3.5 and 0.8, respectively and estimated the available storage based on aerial topography. The applicant assumed a full pond elevation of 174 m (570 ft) above MSL for antecedent conditions.

<u>The Staff's Technical Evaluation</u>

In RAI 821, Question 02.04.03-3, the staff requested that the applicant explain why unit hydrographs calibrated using observed runoff events produced by precipitation depths much smaller than the PMP event in the Broad River Basin were appropriate to estimate the PMF in the basin or to update the PMF analysis with techniques recommended by other Federal agencies or those used in standard practice.

In an October 28, 2008, response to RAI 821, Question 02.04.03-3, the applicant stated that the impact of nonlinear basin response is examined as a sensitivity study for Make-Up Pond B watershed. The applicant stated that the SCS unit hydrograph, used to transform rainfall to runoff, was modified to increase the peak discharge by 20 percent and to decrease the time base by approximately 33 percent. The applicant stated that the intermediate ordinates of the unit hydrograph were adjusted to maintain the area under the curve equal to 2.5 cm (1 in.) of rainfall excess. The applicant estimated that the maximum water-surface elevation in Make-Up Pond B would be higher using the modified unit hydrographs. The applicant stated that there would be no significant change in wind-wave activity because the increase in the water-surface elevation in Make-Up Pond B was not large enough to significantly affect wind-wave characteristics. The applicant stated that the higher maximum water-surface elevation estimate in Make-Up Pond B for PMP and coincident wind-wave effects was only provided as a sensitivity analysis and would not supersede the flood elevation previously reported.

The staff evaluated the applicant's response to RAI 821, Question 02.04.03-3, and determined that accounting for nonlinearity of basin response should not be viewed only as a sensitivity effect. The final water-surface elevation used for the design basis must be based on an appropriate analysis that includes the effects of nonlinear basin response to account for the most conservative plausible runoff generation scenario. In RAI 69, Question 02.04.03-6, the staff requested that the applicant provide an analysis of Make-Up Pond B flood water-surface elevation that included the effects of nonlinear basin response.

The staff also noted that the coincident wind-wave activity described above was based on the previously estimated water-surface elevation in Make-Up Pond B. The staff concluded that the new estimate of water-surface elevation should be used to re-estimate wind waves. Therefore, in RAI 69, Question 02.04.03-7, the staff requested that the applicant re-estimate coincident wind waves with the flood stillwater-surface elevation estimated from the analysis that includes the effects of nonlinear basin response. In an October 27, 2008, response to RAI 821, Question 02.04.03-3, the applicant stated that a comparison of maximum flood water-surface elevation in the Broad River and the Make-Up Pond B with the maximum flood water-surface elevation in Make-Up Pond B showed a significant amount of freeboard. Based on this significant amount of freeboard, the applicant concluded that accounting for nonlinear basin response in the Broad River Basin would not increase the maximum flood water-surface elevation in the river or in the Make-Up Pond A enough to exceed the maximum flood water-surface elevation estimated for the Make-Up Pond B.

The staff agreed with the applicant that there appears to be a significant amount of freeboard available between the maximum flood water-surface elevation estimated for the Make-Up Pond B and the maximum flood water-surface elevations estimated for the Broad River and the Make-Up Pond A. The staff determined that it is likely, if nonlinear basin response were accounted for in runoff generation during the Broad River Basin PMF event that the flood water-

surface elevation would be higher and therefore, would result in a longer fetch length in the inundated areas of the river floodplain. The staff concluded therefore, that a more detailed analysis that includes the effects of nonlinear basin response and the effects of coincident wind waves is needed to conclusively determine that the design basis flood would result from a PMF in the Make-Up Pond B watershed and not in the Broad River Basin. Therefore, in RAI 69, Question 02.04.03-8, the staff requested that the applicant re-estimate wind waves in the Broad River and in Make-Up Pond A with the flood stillwater-surface elevation that accounted for the nonlinear basin response.

In a June 19, 2009, response to RAI 69, Questions 02.04.03-6, 02.04.03-7, and 02.04.03-8, the applicant re-analyzed the flooding scenario for Make-Up Pond B by calculating the effects of wind-driven waves from a still water elevation that includes the nonlinear basin response effects. The staff examined the applicant's analysis and concluded that the applicant's new flood analysis includes nonlinear basin response for Make-Up Pond A and coincident wind-wave effects and, therefore, finds that the applicant's analysis is conservative. Accordingly, the staff considers RAI 820, Question 02.04.03-3 and RAI 69, Questions 02.04.03-6, 02.04.03-7, and 02.04.03-8, resolved.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately considered the characteristics of the streams and rivers near the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. The staff agreed that the local intense precipitation considered by the applicant is appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.3.4.4 Probable Maximum Flood Flow

Information Submitted by the Applicant

The applicant estimated the peak PMF discharge at the WLS site as 23,311 m^3/s (823,212 cfs) resulting from the 2,590 km^2 (1,000 mi^2) storm centered near the centroid of the Gaston Shoals Dam drainage basin.

The applicant estimated the peak PMF runoff to be 567 m^3/s (20,039 cfs) and the routed discharge to be 183 m^3/s (6,471 cfs) from a 6-hour two-thirds peaking storm event for the McKowns Creek watershed upstream of Make-Up Pond B. However, the applicant stated that the controlling water-surface elevation occurred during a 72-hour end-peaking storm event with a peak PMF runoff of 536 m^3/s (18,937 cfs) and a routed discharge of 237 m^3/s (8,386 cfs).

The applicant estimated the peak PMF runoff to be 330 m^3/s (11,644 cfs) and a routed discharge to be 279 m^3/s (9,847 cfs) from a 6-hour storm event for the Intermittent Stream watershed upstream of Make-Up Pond A.

The applicant estimated the peak PMF runoff to be 826 m^3/s (29,167 cfs) and a routed discharge to be 300 m^3/s (10,577 cfs) from a 72-hour end-peaking storm event for the London Creek watershed upstream of Make-Up Pond C.

The Staff's Technical Evaluation

The staff reviewed the HEC-HMS model files provided by the applicant and determined that the approach used by the applicant for estimating the PMF flood discharge is appropriate. The staff performed a sensitivity analysis on the PMF discharge by changing the loss rate for the Broad River Basin PMF estimation as described in Section 2.4.3.4.2 of this report. As expected, the PMF discharge near the site increased under the no-loss scenario investigated by the staff. The water-surface elevations corresponding to the no-loss scenario were also estimated by the staff. The staff's evaluation is described in Section 2.4.3.4.5 of this report.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately estimated the PMF discharge in streams and rivers near the WLS site using approaches currently used in standard practice. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. The staff agreed that the PMF discharge estimated by the applicant is appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.3.4.5 Water-Elevation Determinations

Information Submitted by the Applicant

The applicant estimated that the maximum stillwater flood elevation near the WLS site from a PMF in the Broad River Basin would be 168.1 m (551.5 ft) above MSL. The applicant estimated that the maximum flood elevation near the WLS site from a PMF in the McKowns Creek watershed upstream of Make-Up Pond B would be 178.1 m (584.4 ft) above MSL. The applicant stated that Make-Up Pond B is not located on a large river or stream and that the impoundment is confined within a small watershed area. The applicant also stated that it did not consider blockage of the outlet structure in its analysis of the PMF routed through Make-Up Pond B because the outlet structure is sized adequately and there is minimal potential for significant amount of debris to be picked up by floodwaters during the PMF event and subsequently transported to the outlet structure. The applicant stated that its shoreline management program would consist of removing trees from the area around the perimeter of Make-Up Pond B extending 15.2 m (50 ft) beyond contour elevation of 178.3 m (585 ft) above MSL. The applicant stated that this area would be maintained as a grassed, paved, or covered by some other suitable material throughout the operational life of the plant. The maximum water-surface elevation in Make-Up Pond B results from the Upper Arm culvert being non-functional while allowing overtopping and discharge into Make-Up Pond B. During the same event, the applicant estimated that the maximum water-surface elevation in the Upper Arm Pond would be 180.5 m (592.3 ft). The ridges on the east of the Upper Arm Pond separate it from the WLS site.

The applicant estimated the maximum water-surface elevation of Make-Up Pond A from a PMF in the Intermittent Stream watershed as 170.1 m (558.2 ft). The applicant stated that because the PMF discharge flow from Make-Up Pond C is bounded by the PMF discharge in the Broad River Basin, spillover from Make-Up Pond C during a PMF event is not a limiting event for flooding at the WLS site when taken as an isolated event.

The Staff's Technical Evaluation

To understand the applicant's rationale behind the selection of the design basis flood elevation at the WLS site and whether any special safety-related structures or systems, particularly a debris collection boom near the Make-Up Pond B spillway, may be needed for flood protection, the staff issued RAI 821, Question 02.04.03-4. In an October 27, 2008, response to RAI 821, Question 02.04.03-4, the applicant stated that the maximum flood water-surface elevation from a PMF event in the watershed of Make-Up Pond B and the coincident effects of wind-induced waves would be significantly below the WLS site grade. The applicant also provided a description of a shoreline management plan with this RAI response. The applicant stated that the shoreline management program would remove trees from the water's edge around Make-Up Pond B. The applicant also stated that this area would be maintained as grassy, paved, or with other suitable cover throughout the operational life of the plant. The applicant concluded that because of the shoreline management plan, blockage of Make-Up Pond B's outlet structure from debris during a PMF event would not be credible.

The staff evaluated the applicant's October 27, 2008, response to RAI 821, Question 02.04.03-4, and concluded that the proposed shoreline management program would limit debris accumulation at the outlet structure during the PMF event in the watershed of Make-Up Pond B. Therefore, the staff concluded that the approach and the method adopted for estimation of the PMF in the watershed of Make-Up Pond B is adequate. However, the staff noted that the applicant needed to include details of the Shoreline Management Plan in WLS COL FSAR Section 2.4.3 because it provides important information related to the justification of the PMF estimation approach for the watershed of Make-Up Pond B. Therefore, in RAI 69, Question 02.04.03-10, the staff requested that the applicant address this need. In a June 19, 2009, response to RAI 69, Question 02.04.03-10, the applicant stated that the details provided in response to the staff's RAI 821, Question 02.04.03-4, were included in WLS COL FSAR Revision 1. The applicant stated that the shoreline management program would remove all trees from the water's edge. The applicant stated that this area would be maintained as paved or grassed or covered with other suitable alternative material throughout the operational life of the plant. The staff reviewed the applicant's response and determined that sufficient detail regarding the shoreline management program has not been provided in the WLS COL FSAR. Because the success of the shoreline management program is essential for maintaining the PMF water-surface elevation in Make-Up Pond B below the AP1000 DCD maximum flood level, the staff determined that the applicant needs to provide additional details of the shoreline management program in the WLS COL FSAR including frequency of inspection, criteria for determination of the need to perform maintenance, and the frequency of maintenance throughout the operational life of the plant. The applicant did not provide any additional details of the shoreline management program in Revision 5 of the WLS COL FSAR. In Revision 7 of the WLS COL FSAR, the applicant stated that the shoreline management program would annually inspect the shoreline around Make-Up Pond B and remove trees that may have fallen on the ground and trees that may be about to fall. The applicant would also inspect the spillway

for debris after rainfall events that exceed an intensity of 7.6 cm/hr (3 in/hr). The applicant would install a secondary debris barrier system, approximately 107 m (350 ft) from the Make-Up Pond B spillway. The staff reviewed the details of the applicant's shoreline management program and the secondary barrier system. Since an effective implementation of the shoreline management program would minimize debris available for transport with the PMF and the secondary debris barrier system would be in place, the staff concluded that the combination of the shoreline management program and the debris barrier system would prevent the blockage of the Make-Up Pond B spillway. The staff considers implementation of the shoreline management program and the installation of debris barrier system commitments on the part of the applicant. Accordingly, the staff considers RAI 821, Question 02.04.03-4, and RAI 69, Question 02.04.03-10, resolved.

The staff estimated the PMF discharges in the Broad River Basin under a no precipitation loss HEC-HMS scenario performed to investigate the sensitivity of the PMF water-surface elevations near the site to the value of the selected loss rate. The discharge hydrographs predicted by HEC-HMS were input by the staff into the HEC-RAS model of the Broad River Basin provided by the applicant. The staff's HEC-RAS simulation used combined inflow into the Gaston Shoals Dam as the upstream unsteady boundary condition. Flood discharges from reaches and sub-basins located downstream from the Gaston Shoals Dam were input into the HEC-RAS model as lateral inflows. The staff was able to successfully perform the unsteady simulation. However, based on the description of the HEC-RAS model in the WLS COL FSAR and the additional details provided in RAI responses, the staff was unable to determine location of the cross section near the site. The staff required more information regarding the HEC-RAS model setup to verify the sensitivity of the PMF water-surface elevation to precipitation loss rates. Therefore, in RAI 69, Question 02.04.03-9, the staff requested that the applicant identify the cross section in the HEC-RAS setup that is located directly across from the WLS site.

In a June 19, 2008, response to RAI 69, Question 02.04.03-9, and in a subsequent telephone conversation with the applicant, the staff obtained clarification on the location of the above-mentioned cross section and withdrew RAI 69, Question 02.04.03-9. Accordingly, the staff considers RAI 69, Question 02.04.03-9, resolved. During the staff's simulation of a no precipitation loss scenario, the maximum PMF water-surface elevation in the Broad River at the HEC-RAS cross section located directly across from the WLS site was 168.7 m (553.4 ft) above MSL. The increase in the PMF water-surface elevation near the WLS site under the no precipitation loss scenario was relatively minor, about 0.6 m (1.9 ft), compared to the difference between the PMF water-surface elevation and the WLS site grade, which is about 12.2 m (40 ft). Therefore, the staff concluded that the PMF in the Broad River would not cause water-surface elevations near the WLS site that would affect the safety of the WLS units.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately estimated the PMF water-surface elevations in streams and rivers near the WLS site using approaches currently used in standard practice. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. The staff agreed that the PMF water-surface elevations estimated by the applicant are appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and

surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.3.4.6 Coincident Wind-Wave Activity

Information Submitted by the Applicant

The applicant evaluated the coincident wind-wave activity for the Broad River, Make-Up Pond A, Make-Up Pond B, and Make-Up Pond C. The applicant stated that effects of wind waves for Broad River, Make-Up Pond A, and Make-Up Pond B are addressed in WLS COL FSAR Section 2.4.4.

The applicant stated that Make-Up Pond C is located on a tributary of the Broad River such that wind waves in the pond would not affect the WLS site. The applicant reported that wind-wave activity coincident with PMF in the Broad River Basin and a concurrent failure of Make-Up Pond C Dam is evaluated in WLS COL FSAR Section 2.4.4, which bounds the wind-wave activity in Make-Up Pond C.

The Staff's Technical Evaluation

To obtain estimates of coincident wind-wave activity to be included in the estimation of the design basis flood water-surface elevation, the staff issued RAI 821, Question 02.04.03-5.

In an October 27, 2008, response to RAI 821, Question 02.04.03-5, the applicant stated that the effects of wind-wave activity were estimated for flood events in the Broad River and Make-Up Ponds A and B.

The applicant provided an update to the WLS COL FSAR Section 2.4.3.6. The applicant estimated fetch lengths using the longest straight-line fetch from USGS topographic maps. The applicant stated that wave height, wave setup, and wave runup were estimated using the procedures described by USACE. The applicant estimated the 2-year annual extreme mile wind speed using ANSI/ANS-2.8-1992 guidance to be 22.4 m/s (50 mph). The applicant updated the WLS COL FSAR text to reflect changes in wind-wave estimation in response to RAI 69, Questions 02.04.03-6, 02.04.03-7, and 02.04.03-8. The staff evaluated the applicant's response to RAI 821, Question 02.04.03-5, and concluded that the process used to estimate the coincident wind-wave activity is currently used in standard engineering practice and is therefore adequate. Therefore, the staff considers RAI 821, Question 02.04.03-5, resolved.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately estimated the effects of coincident wind waves in streams and rivers near the WLS site using approaches currently used in standard practice. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. The staff agreed that the coincident wind-wave activity estimated by the applicant is appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.3.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.3.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to PMF on streams and rivers, and that there is no outstanding information required to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.3 of this report, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL Information Item 2.4-2 with regard to the PMF. The staff concludes that the applicant has provided sufficient information on hydrologic site characteristics affecting any potential hazard to the plant's safety-related facilities as a result of the effect of the PMF on streams and rivers to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.4 Potential Dam Failures

2.4.4.1 *Introduction*

WLS COL FSAR Section 2.4.4 describes potential dam failures to ensure that any potential hazard to safety-related structures due to failure of onsite, upstream, and downstream water-control structures is considered in the plant design.

Section 2.4.4 of this report presents the staff's review of the estimation of flood level caused by different dam failures. The specific areas of review are as follows: (1) dam-failure permutations; (2) unsteady-flow analysis of potential dam failures; (3) water-level determination; and (4) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.4.2 *Summary of Application*

This section of the WLS COL FSAR describes the site-specific information about floods from potential dam failures. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19 related to potential dam failures as follows:

AP1000 COL Information Item

- COL Information Item 2.4-2

In addition, this section addresses the following COL Information Item 2.4-2 (COL Action Item 2.4.1-1) identified in AP1000 DCD Section 2.4.1.2.

Combined License applicants referencing the AP1000 certified design will address the following site-specific information on historical flooding and potential flooding factors, including the effects of local intense precipitation.

- PMF on Streams and Rivers – Site-specific information that will be used to determine the design basis flooding at the site. This information will include the PMF on streams and rivers.
- Dam Failures – Site-specific information on potential dam failures.
- Probable Maximum Surge and Seiche Flooding – Site-specific information on probable maximum surge and seiche flooding.
- Probable Maximum Tsunami Loading – Site-specific information on probable maximum tsunami loading.
- Flood Protection Requirements – Site-specific information on flood protection requirements or verification that flood protection is not required to meet the site parameter for flood level.

In WLS COL FSAR Section 2.4.4, the applicant addressed the effects of floods caused by potential dam failures. Other causes of floods and their effects are discussed in related WLS COL FSAR sections. No further action is required for sites within the bounds of the site parameter for flood level.

2.4.4.3 *Regulatory Basis*

The relevant requirements of NRC regulations for the identification of floods, flood design considerations and potential dam failures, and the associated acceptance criteria, are described in NUREG-0800, Section 2.4.4.

The applicable regulatory requirements for identifying the effects of dam failures are as follows:

- 10 CFR 52.79(a)(1)(iii), "Contents of applications; technical information in final safety analysis report," as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100, "Reactor Site Criteria," as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).
- 10 CFR 100.23(d), "Geologic and seismic siting factors," sets forth the criteria to determine the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.4:

- RG 1.59, “Design Basis Floods for Nuclear Power Plants,” supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized

- RG 1.102, “Flood Protection for Nuclear Power Plants,” as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

- RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition),” as it relates to the contents of a COL application

2.4.4.4 *Technical Evaluation*

The staff reviewed WLS COL FSAR Section 2.4.4 and checked the referenced AP1000 DCD to ensure that the combination of the AP1000 DCD and the COL application represents the complete scope of information relating to this review topic. The staff’s review confirmed that the information in the application and incorporated by reference addresses the required information relating to the potential dam failure.

The staff reviewed the information in the WLS COL FSAR:

AP1000 COL Information Item

- COL Information Item 2.4-2

In its independent review, the staff also considered a breach of the proposed CCW Dam and subsequent flows and resulting water-surface elevation in the Broad River adjacent to the site. The staff concluded that these scenarios were conservative and neither scenario would exceed the design-basis flood elevation. The applicant and the staff used the guidance provided in ANSI/ANS-2.8-1992 to quantify flood water elevations at the site resulting from postulated dam failures.

To ensure that the most conservative of plausible conceptual models has been identified, in RAI 822, Question 02.04.04-1, the staff requested that the applicant describe the process to determine the conceptual models for flood waves from severe breaching of upstream dams, domino-type or cascading failures of dams, dynamic effects on safety-related SSCs, loss of safety-related water supplies, sediment deposition and erosion, and failure of onsite water control or storage structures.

In an October 27, 2008, response to RAI 822, Question 02.04.04-1, the applicant stated that the conceptual models to determine flood waves generated from failures of water-control structures conform to the guidance of RG 1.206 and RG 1.59 and the determination of the flood follows the recommendations of ANSI/ANS-2.8-1992.

The applicant maximized the flood generated by upstream failure of dams by assuming that the failures were coincident with the peak discharge of the PMF and were further enhanced by

coincident wind-wave activity. The applicant stated that it selected the dam breach parameters conservatively based on USACE guidance. The applicant assumed that Tuxedo and Turner Shoals dams would fail in a cascade because they are located on the same tributary.

The applicant noted that no water is required for any safety-related purpose for the proposed units from the Broad River or from Make-Up Ponds A, B, and C and therefore, no safety-related facilities would be affected by sediment deposition and erosion. The applicant also stated that there are no onsite water-control or -storage structures, failures of which may produce floods that may affect safety-related SSCs.

The staff reviewed the applicant's October 27, 2008, response to RAI 822, Question 02.04.04-1, and concluded that the approach for determination of upstream single and cascading dam-failure-generated floods near the site is sufficiently conservative because the applicant assumed that the dam failures would coincide with the peak discharge at those locations during the PMF event. The staff also concluded that the applicant's evaluation of cascading failure combinations is adequate because a cascading failure of dams on the same tributary is used. Accordingly, the staff considers RAI 822, Question 02.04.04-1, resolved.

The staff conducted a hydrology site audit during the period of May 18 to 20, 2008. The site audit included a visit to the WLS site and a tour of Make-Up Pond B, the dam impounding the south section of the east arm of Make-Up Pond B, Make-Up Pond A, and the Ninety-Nine Islands Dam. The applicant and staff also reconnoitered the Broad River in the vicinity of the site during a boat tour. The staff did not visit any of the dams located upstream of the WLS site in the Broad River Basin.

2.4.4.4.1 Dam-Failure Permutation

Information Submitted by the Applicant

The applicant stated that the overtopping failure of upstream dams during the PMF event in the Broad River Basin would result in more severe flooding than that caused by seismic failures (failure of dams under safe shutdown earthquake coincident with a 25-year flood and failure of dams under the operating basis earthquake coincident with a one-half PMF or the 500-year flood) because the PMF event is a more severe flood than the coincident floods used for seismic failure scenarios. Therefore, the applicant did not evaluate floods resulting from seismic failure of dams coincident with floods that are lesser in magnitude than the PMF.

The applicant assumed that both Cherokee Falls and Gaston Shoals dams would be overtopped during the PMF event and the dam failure would coincide with the peak PMF discharge. The applicant assumed Cherokee Falls Dam to fail completely in 0.5 hour and the middle section of the Gaston Shoals Dam to fail in 0.5 hour along with the failure of embankment abutments separating the latter dam's three sections.

The applicant estimated that failure of the Gaston Shoals Dam only, coincident with the peak PMF discharge, would result in a discharge of 2,333 m^3/s (824,000 cfs) and a corresponding water-surface elevation of 168.1 m (551.5 ft) above MSL at the WLS site. The applicant also estimated that failures of both Gaston Shoals and the Cherokee Dams, coincident with the peak PMF discharge, would result in the same discharge and water-surface elevation at the WLS site because of small reservoir volumes compared to the PMF discharge.

The applicant reported that major upstream structures include Lake Lure, impounded by a dam on the Broad River; Lake Summit, impounded by the Tuxedo Dam on Green River; Lake Adger, impounded by the Turner Shoals Dam; Kings Mountain Reservoir Dam or Moss Lake Dam located on Buffalo Creek; and Lake Whelchel Dam located approximately 12.9 km (8 mi) northwest of the WLS site on Cherokee Creek. The applicant stated that Lake Lure Dam, Tuxedo Dam, and Turner Shoals Dam are designed to withstand overtopping and assumed that dam failure during overtopping would coincide with the peak PMF discharge. For Kings Mountain Reservoir Dam, the applicant postulated a piping failure with the consequent dam failure coinciding with the peak PMF discharge.

The CCW has applied for a permit to construct a water-supply reservoir on the First Broad River approximately 1.6 km (1 mi) north of Lawndale, North Carolina, approximately 42 km (26 mi) northeast of the WLS site. The proposed dam is expected to be approximately 379 m (1,245 ft) long and 25 m (83 ft) high with an impoundment surface area of approximately 908.5 hectare (2,245 ac) and may inundate areas lower in elevation than 262 m (860 ft) above MSL. The applicant stated that its storage would be approximately 58,590,386 m^3 (47,500 ac-ft). The applicant assumed that the dam would be designed to not fail during a PMF event. Since the proposed dam and reservoir are comparable to the Kings Mountain Reservoir, the applicant assumed that seismic failure of the proposed dam coincident with floods of magnitudes lesser than the PMF would be no worse than that estimated for the Kings Mountain Reservoir. Since the dam-failure analysis includes the failure of Kings Mountain Reservoir, the applicant assumed that the effects of failure of the proposed dam would be less than those estimated for existing dams.

The applicant stated that Make-Up Pond C is located on London Creek. The applicant also stated that Lake Cherokee is located on a tributary to London Creek upstream of Make-Up Pond C. The applicant considered the dams impounding Lake Cherokee and Make-Up Pond C to fail in a cascade. The applicant has considered the failures of Lake Lure Dam, Tuxedo Dam, Turner Shoals Dam, Lake Whelchel Dam, Kings Mountain Reservoir Dam, Lake Cherokee Dam, and Make-Up Pond C Dam coincident with the PMF as the critical dam-failure event in the Broad River Basin upstream of the WLS site. The applicant estimated that the peak dam-failure discharge coincident with a PMF event in the Broad River Basin would be 52,386 m^3/s (1,850,000 cfs).

The applicant also analyzed the failures of Lake Cherokee Dam and Make-Up Pond C Dam during a PMF event in the Make-Up Pond C watershed. The PMF event in the Make-Up Pond C watershed would result from a more intense PMP event compared to the Broad River Basin PMP because of the smaller drainage area of Make-Up Pond C watershed. The applicant determined that the peak discharge during this dam-failure permutation would be 37,831 m^3/s (1,336,000 cfs), which is less than the peak discharge estimated for the Broad River with the postulated upstream dam failures. Therefore, the applicant did not consider the cascading failure of Lake Cherokee and Make-Up Pond C Dams further. The applicant considered the failure of Upper Arm Pond Dam located within Make-Up Pond B. The maximum peak discharge resulting from a 6-hour tail end-peaking storm was 672 m^3/s (23,726 cfs).

The applicant stated that there are no safety-related facilities that would be affected by loss of water supply due to failures of dams and there are no onsite water-control or -storage structures that are located above site grade.

<u>The Staff's Technical Evaluation</u>

The staff evaluated the applicant's October 27, 2008, response to RAI 822, Question 02.04.04-1, and concluded that the process used by the applicant to determine dam-failure permutations upstream of the site is adequate. Lake Summit Dam (also called the Tuxedo Dam) and Lake Adger Dam (also called the Turner Shoals Dam) are located on the Green River and their impoundments have storage capacities of 10,410,586 m^3 (8,440 ac-ft) and 14,431,737 m^3 (11,700 ac-ft), respectively at their corresponding normal pool elevations. Lake Lure Dam is located on the Broad River with a storage of approximately 39,835,295 m^3 (32,295 ac-ft) at normal pool elevation. Green River flows downstream from Lakes Summit and Adger and joins the Broad River that flows downstream of Lake Lure. Therefore, the staff concluded that a cascading failure of Lake Summit and Lake Adger dams on the Green River is possible.

Downstream of the confluence of the Green River with the Broad River, Gaston Shoals Dam and Cherokee Falls Dam are located on the Broad River with storage capacities of approximately 3,083,705 m^3 (2,500 ac-ft) and 246,696 m^3 (200 ac-ft), respectively. Two more dams, the Kings Mountain Reservoir Dam on Buffalo Creek, with a storage capacity of approximately 54,273,199 m^3 (44,000 ac-ft) and the Lake Whelchel Dam on Cherokee Creek, with a storage capacity of approximately 7,154,194 m^3 (5,800 ac-ft), are located upstream of the Cherokee Falls Dam. However, the creeks that flow downstream from these two dams join the Broad River downstream of the Gaston Shoals Dam but upstream of the Cherokee Falls Dam. Therefore, staff noted that cascading failures of Kings Mountain Reservoir Dam and Cherokee Falls Dam and those of Lake Whelchel Dam and Cherokee Falls Dam are also plausible. However, the staff concluded that the small impoundment capacity of Cherokee Falls Dam would not significantly enhance the cascading effects of any flood generated by a dam failure upstream of it.

Since the dam impounding Lake Cherokee is located upstream on a tributary to London Creek on which Make-Up Pond C is located, the staff concluded that a cascading failure of these two dams is possible. On the mainstem of the Broad River, a cascading failure of Gaston Shoals and Cherokee Falls Dams is also possible. However, because these dams have small storage impoundments, the increase in the discharge that causes overtopping, especially that of the PMF would be minor. Therefore, the staff concluded that the dam-failure scenario analyzed by the applicant, in which Lake Lure Dam, Lake Summit Dam, Lake Adger Dam, Kings Mountain Reservoir Dam, and Lake Whelchel Dam failed coincident with peak discharges at those locations during the PMF event, is conservative.

The applicant considered the failure of the Upper Arm Pond Dam, which is located within Make-Up Pond B. Since there are no other dams upstream of Make-Up Pond B dam, no other dam-failure permutations need evaluation. Based on the above review, the staff considers RAI 822, Question 02.04.04-1, resolved.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately considered dam-failure permutations in the Broad River upstream of the WLS site using approaches currently used in standard practice. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. The staff agreed that the dam-failure permutations considered by the applicant are appropriate for the WLS site. Therefore, based on

the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.4.4.2 Unsteady-Flow Analysis of Potential Dam Failures

Information Submitted by the Applicant

The applicant used the same HEC-RAS unsteady-flow model previously used in the PMF water-surface elevation calculations, but modified it to use the HEC-RAS dam breach feature. The applicant used the peak PMF discharge, estimated by the HEC-HMS model at the Ninety-Nine Islands Dam, as input into the HEC-RAS model to perform a steady-state analysis to determine the water-surface elevation at the WLS site.

The Staff's Technical Evaluation

The steady-state simulations performed by the applicant with the peak PMF discharge would result in a water-surface elevation that would be asymptotically approached by an unsteady-flow simulation performed with the complete discharge hydrograph. Therefore, the staff determined that the methods used by the applicant are adequately conservative and the water-surface elevation in the Broad River near the site would be conservatively determined by the approach adopted by the applicant.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately analyzed dam-failure flood flow in the Broad River upstream of the WLS site using approaches currently used in standard practice. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. The staff agreed that the dam-failure flood flow analyzed by the applicant is appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.4.4.3 Water Level at the Plant Site

Information Submitted by the Applicant

The applicant used the HEC-RAS model described above to estimate the water-surface elevation near the WLS site corresponding to a steady-state discharge of 52,386 m^3/s (1,850,000 cfs) in the Broad River near the WLS site. The applicant reported an estimated stillwater-surface elevation of 175.7 m (576.5 ft) above MSL, approximately 5 m (16.5 ft) below the safety-related plant grade of 180.7 m (593 ft) above MSL.

The applicant evaluated the wind-wave activity during the PMF event in the Broad River near the WLS site using the USACE Coastal Engineering Manual. The applicant used a 2-year

coincident wind speed of 80 km/h (50 mph), a fetch length of 4.5 km (2.8 mi), and a slope of 40 percent to estimate a combined flood water-surface elevation of 178.2 m (584.8 ft) above MSL.

The applicant used the HEC-HMS model to determine the maximum water-surface elevation in Make-Up Pond B considering failure of the Upper Arm Pond Dam. The maximum water-surface elevations in Make-Up Pond B and Upper Arm Pond were 178.3 m (585.1 ft) and 180.5 m (592.3 ft) above MSL, respectively. The applicant stated that the ridge on the east of Upper Arm Pond separates it from the WLS site and at water-surface elevations above 179.8 m (590 ft) above MSL, discharge from Upper Arm Pond occurs directly to Make-Up Pond B.

The Staff's Technical Evaluation

As stated above, the staff concluded that the methods used by the applicant are adequately conservative and the water-surface elevation in the Broad River near the site would be conservatively determined by the approach adopted by the applicant. To assess the impact of wind-induced waves on the flood water-surface elevation under the multiple dam-failure scenarios described by the applicant, in RAI 822, Question 02.04.04-2, the staff requested that the applicant provide wind-induced wave heights coincident with the controlling dam breach flooding scenario.

In an October 27, 2008, response to RAI 822, Question 02.04.04-2, the applicant stated that WLS COL FSAR Section 2.4.4.3 was updated to provide the effects of wind-wave activity coincident with the dam breach scenario investigated for the Broad River. The applicant also included two new figures in the WLS COL FSAR that showed the fetch lengths for the Broad River and Make-Up Pond A during the dam breach flooding scenario.

The applicant stated in the updated WLS COL FSAR text that the wind-wave activity was evaluated for the Broad River to coincide with the PMF including the effects of dam failures. The applicant estimated the critical, longest straight-line fetch length to be approximately 4.5 km (2.8 mi). The applicant stated that the maximum water-surface elevation in the Broad River from the PMF, including the effect of dam failures and the effect of wind-wave activity, would be approximately 178.2 m (584.8 ft) above MSL. Since the safety-related plant grade is at 180.7 m (593 ft) above MSL, the applicant concluded that the site would be safe from flooding due to a PMF including the effects of upstream dam failures and coincident wind-wave activity in the Broad River.

The applicant further stated that during severe flooding events, Make-Up Pond A is inundated by backwaters of the Broad River. Therefore, the applicant evaluated the effects of wind-wave activity in Make-Up Pond A during the PMF event that included the effects of dam failure. The applicant estimated the critical, straight-line fetch length to be approximately 4.3 km (2.7 mi). The applicant reported the 2-year annual extreme mile wind speed to be 22.4 m/s (50 mph) based on the recommendations of ANSI/ANS-2.8-1992. The applicant estimated the critical duration to be 53 minutes and adjusted the wind speed to be 22.3 m/s (49.9 mph). The applicant estimated the significant wave height to be 0.8 m (2.8 ft) and the maximum wave height to be 1.4 m (4.6 ft). The applicant estimated the wind setup to be approximately 0.02 m (0.07 ft) and the maximum runup, using the 47 percent slope along the banks of the Make-Up Pond A near the site, to be approximately 2.88 m (8.9 ft). Therefore, the applicant considered the total wind-wave activity to be approximately 2.7 m (9.53 ft) for Make-Up Pond A. The

applicant stated that the maximum water-surface elevation in the Make-Up Pond A from the Broad River PMF including the effect of dam failures and the effect of wind-wave activity would be approximately 178.4 m (585.4 ft) above MSL. Since the safety-related plant grade is at 180.7 m (593 ft) above MSL, the applicant concluded that the site would be safe from flooding due to the Broad River PMF including the effects of upstream dam failures and coincident wind-wave activity in the Make-Up Pond A.

The staff evaluated the applicant's October 27, 2008, response to RAI 822, Question 02.04.04-2, and subsequent changes to the WLS COL FSAR up to and including Revision 7 with respect to the methods used to determine the maximum flood water-surface elevation in the Broad River. The staff concluded that the applicant has used appropriate and conservative methods to estimate the flood water-surface elevation in the Broad River. Accordingly, the staff considers RAI 822, Question 02.04.04-2, resolved. Since the dam failures were postulated to coincide with the peak discharge of the PMF, the staff concluded that this scenario is more conservative than the flood generated only by dam failures or only by a PMF in the Broad River Basin.

The staff noted that a dam is proposed by the CCW (the CCW Dam) on the First Broad River in Cleveland County, NC. The estimated storage of the CCW Dam impoundment would be approximately 58,590,386 m^3 (47,500 ac-ft). Downstream of the proposed CCW Dam, the First Broad River joins the Broad River upstream of the Gaston Shoals Dam. The applicant assumed that the dam would be designed to not fail during a PMF event. The applicant stated in the WLS COL FSAR that because the proposed dam and reservoir are comparable in size to the Kings Mountain Reservoir, a hypothetical seismic failure of the proposed dam coincident with floods of magnitudes lesser than the PMF would be no worse than those estimated for the Kings Mountain Reservoir. The applicant assumed that the effects of failure of the proposed dam would be less than those estimated for existing dams. The staff investigated a hypothetical dam-failure scenario for the proposed CCW Dam, similar to that used for the other dams in the Broad River Basin, as a sensitivity study to determine if the flood water-surface elevation in the river near the site would be significantly affected. As stated in Section 2.4.1.4.2 of this report, the staff received information regarding the proposed CCW Dam from McGill Associates on January 31, 2012, and from the USACE on January 2, 2014.

The staff reviewed the HEC-HMS and HEC-RAS files provided by the applicant and performed an independent simulation to estimate the sensitivity of the flood water-surface elevation by specifying no precipitation loss during the PMP event to maximize the PMF. The staff also used the modified unit hydrographs for the sub-basins of the Broad River Basin to account for nonlinear runoff generation response during the PMF and included a hypothetical failure scenario for the proposed CCW Dam.

Using the HEC-HMS input files provided by the applicant, the staff added a hypothetical CCW Dam located on the First Broad River to modify the Broad River model used by the applicant for dam breach simulations. The staff used the applicant-reported dam height of 25.3 m (83 ft) in the simplified dam breach equation to estimate the peak dam breach discharge of 20,763 m^3/s (733,242 cfs). The height of the CCW Dam according to information received by the staff from McGill Associates on January 31, 2012, is approximately 24.4 m (80 ft). Since the staff used a larger value of dam height, 25.3 m (83 ft), the estimate of peak dam breach discharge is conservative. The staff simulated the modified Broad River dam breach model with concurrent

PMF conditions similar to the applicant's approach. The other dams in the Broad River Basin upstream of the WLS site were assumed to fail in a manner identical to the approach used by the applicant.

The staff independently estimated the peak outflow near the WLS site due to dam breaches concurrent with a PMF in the Broad River Basin to be approximately 1,019 m^3/s (36,000 cfs) larger than that estimated by the applicant. The staff used the HEC-RAS model to simulate the water-surface elevation near the WLS site resulting from a steady-state, but increased, discharge. The staff-estimated stillwater elevation near the WLS site was approximately 0.3 m (1 ft) higher than the applicant's estimate.

The staff also evaluated the coincident wind-wave activity for the Broad River with the maximum water-surface elevation resulting from the dam failures concurrent with a PMF event. Using the USGS topographic quadrangles near the WLS site, the staff estimated the longest straight-line fetch length as 4.7 km (2.9 mi).

Using the procedures described by USACE, the staff estimated the maximum wave runup to be 1.6 m (5.1 ft) and a wind setup to be 0.03 (0.1 ft). Therefore, the staff estimated the total dam failure with concurrent PMF water-surface elevation including the effects of coincident wind-wave activity to be 1.9 m (6.1 ft) higher than the applicant's estimate. The staff's conservatively estimated water-surface elevation in the Broad River during the postulated dam-failure permutation, combined with the postulated failure of the CCW Dam and wind waves, was 3.2 m (10.4 ft) lower than the safety-related WLS site grade of 180.7 m (593 ft) above MSL.

As stated in Section 2.4.1.4.2 of this report, the USACE is reviewing the CCW proposal at this time. As stated in this section, the staff evaluated the CCW's proposed site for the First Broad River Reservoir. In a June 1, 2009, letter to the CCW, the USACE identified three alternative reservoir locations in addition to the proposed CCW location. These alternative locations were on Knob Creek, Upper Crooked Run Creek, and Lower Crooked Run Creek. In a more recent communication to the staff, the USACE stated that in its current review, an alternative side stream reservoir on the Upper Crooked Run Creek is being evaluated.

It is possible that the USACE, during its review of the CCW proposal and preparation of an environmental impact statement, may find the alternative Upper Crooked Run Creek site to be environmentally preferable to the CCW's proposed site. To allow for this possibility, the staff evaluated the potential flood at the WLS site produced by a hypothetical failure of a dam similar in characteristics to the CCW Dam located in the Upper Crooked Run Creek drainage. Since the proposed location of the CCW Dam is below the confluence of the Upper Crooked Run Creek and the First Broad River, the staff concluded that the alternative dam location would be farther upstream than the proposed location of the CCW Dam in the First Broad River drainage. The staff also noted that the alternative reservoir being evaluated by the USACE would be an off-stream storage reservoir and therefore may not require construction of a dam on the Upper Crooked Run Creek. However, the staff conservatively assumed that a dam similar to the proposed CCW Dam would be constructed on the Upper Crooked Run Creek because a hypothetical failure of a dam on the Upper Crooked Run Creek would generate a more severe flood in the First Broad River and at the WLS site.

Since the alternative dam location on the Upper Crooked Run Creek is upstream of the CCW Dam's proposed location that the staff analyzed previously in this section and the characteristics

of the dam at the two locations are assumed to be similar, the dam failure-generated flood discharge at the two locations would be similar. However, the dam failure-generated flood discharge would need to travel downstream from the two locations to the WLS site via the First Broad River and the Broad River. Since the distance the flood wave would have to travel to the WLS site is greater for the Upper Crooked Run Creek alternative site than for the CCW's proposed site, the attenuation of the peak discharge for the Upper Crooked Run Creek alternative site would be greater. Therefore, the flood effects would be greater if the CCW Dam were located at the CCW's proposed site. Based on this review and analysis, the staff concluded that its analysis of the flood effects from a hypothetical failure of a future CCW Dam described earlier in this section is conservative.

Since the conservatively estimated flood water-surface elevation near the WLS site from dam failures with a concurrent PMF event and coincident wind waves in the Broad River Basin is lower than the safety-related site grade of 180.7 m (593 ft) above MSL, the staff concluded that the safety-related SSCs of the proposed units at the WLS site are unaffected by flooding due to dam failures.

The staff reviewed the applicant's analysis of the failure of the Upper Arm Pond Dam. The staff determined that the applicant used conservative assumptions to estimate the highest water-surface elevations in Make-Up Pond B and the Upper Arm Pond. Since the ridge on the east side of the Upper Arm Pond prevents flood waters from spilling over into the WLS site area without first draining over the Upper Arm Pond Dam into Make-Up Pond B, the staff concluded that the failure of the culvert or overtopping failure of the Upper Arm Pond would not affect the WLS site.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately analyzed dam-failure flood water-surface elevations in the Broad River upstream of the WLS site, Make-Up Pond B, and Upper Arm Pond using approaches currently used in standard practice. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. The staff agreed that the dam-failure flood water-surface elevations estimated by the applicant are appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.4.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.4.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to potential dam failures, and that no outstanding information is expected to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.4 of this report, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addressed potential dam failures in COL Information Item 2.4-2. The staff concludes that the applicant provided sufficient information on hazards from extreme flooding events at the site to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.5 Probable Maximum Surge and Seiche Flooding

2.4.5.1 *Introduction*

WLS COL FSAR Section 2.4.5 describes probable maximum surge and seiche flooding to ensure that any potential hazard to the safety-related SSCs at the proposed site has been considered in compliance with NRC regulations.

Section 2.4.5 of this report presents the evaluation of the following topics based on data provided by the applicant in the WLS COL FSAR and information available from other sources: (1) probable maximum hurricane (PMH) that causes the probable maximum surge as it approaches the site along a critical path at an optimum rate of movement; (2) probable maximum wind storm (PMWS) from a hypothetical extratropical cyclone or a moving squall line that approaches the site along a critical path at an optimum rate of movement; (3) a seiche near the site, and the potential for seiche wave oscillations at the natural periodicity of a water body that may affect flood water-surface elevations near the site or cause a low water-surface elevation affecting safety-related water supplies; (4) the potential effects of seismic and non-seismic information on the postulated design bases and how they relate to a surge and seiche in the vicinity of the site and the site region; and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

As stated in Section 2.4 above, hydrologic characteristics associated with conditions that would result in a loss of external water supply and seismic design considerations of water-supply structures are not relevant for the AP1000 design. Therefore, the low-water aspect of item (3) above was not part of the staff's review.

2.4.5.2 *Summary of Application*

This section of the WLS COL FSAR describes the site-specific information on probable maximum surge and seiche flooding in terms of effects on structures and water supply. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19 related to probable maximum surge and seiche flooding as follows:

<u>AP1000 COL Information Item</u>

- COL Information Item 2.4-2

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Section 2.4.1.2, Revision 19.

> Combined License applicants referencing the AP1000 certified design will address the following site-specific information about historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - PMF on Streams and Rivers – Site-specific information that will be used to determine the design basis flooding at the site. This information will include the PMF on streams and rivers.
> - Dam Failures – Site-specific information about potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information about probable maximum surge and seiche flooding.
> - Probable Maximum Tsunami Loading – Site-specific information about probable maximum tsunami loading.
> - Flood Protection Requirements – Site-specific information about flood protection requirements or verification that flood protection is not required to meet the site parameter for flood level.

In WLS COL FSAR Section 2.4.5, the applicant addressed the effects of floods caused by probable maximum surge and seiche. Other causes of floods and their effects are discussed in related WLS COL FSAR sections. No further action is required for sites within the bounds of the site parameter for flood level.

2.4.5.3 *Regulatory Basis*

The relevant requirements of NRC regulations for consideration of the effects of probable maximum surge and seiche, and the associated acceptance criteria, are described in NUREG-0800, Section 2.4.5.

The applicable regulatory requirements for identifying surge and seiche hazards are as follows:

- 10 CFR 52.79(a)(1)(iii), “Contents of applications; technical information in final safety analysis report,” as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100, “Reactor Site Criteria,” as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).
- 10 CFR 100.23(d), “Geologic and seismic siting factors,” sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.5:

- RG 1.59, “Design Basis Floods for Nuclear Power Plants,” supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized

- RG 1.102, “Flood Protection for Nuclear Power Plants,” as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

- RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition),” as it relates to the contents of a COL application

2.4.5.4 *Technical Evaluation*

In this section of the report, the staff reviewed the applicant’s assessment of the probable maximum surge and seiche flooding. The staff’s independent analysis, where needed for the review, is also described.

Information Submitted by the Applicant

The applicant followed the regulatory guidance prescribed by RG 1.59, which describes the probable maximum surge and seiche based on a PMH, a PMWS, or a moving squall line. The applicant stated that RG 1.59 recommends consideration of a PMH for areas within 322 km (200 mi) of coastal areas and the WLS site is located approximately 282 km (175 mi) from the Atlantic Ocean on the southeast bank of the Broad River.

Following the recommendation for Folly Island in RG 1.59, the applicant estimated the PMH storm surge to be 8.1 m (26.5 ft) above MSL, which includes a 0.3 m (1.0 ft) sea level anomaly known to occur for predicted tides at Charleston, SC. The applicant also reported that the maximum storm surge along the Atlantic Coast since 1975, the most recent year for which data was included in RG 1.59, caused by hurricane Hugo, was approximately 6.1 m (20 ft) high.

Since the safety-related plant grade at 180.7 m (593 ft) above MSL is approximately 25 m (81.9 ft) higher than the normal water-surface elevation in the Broad River near the WLS site, (511.1 ft) above MSL, the applicant concluded that the PMH surge of 8.1 m (26.5 ft) would not flood the site, even if the surge were to translate to the site from the coast without any attenuation. The applicant also concluded that based on the location of the site and its elevation, safety-related facilities at the WLS site would not be affected by surge and seiche flooding.

The applicant stated resonance at natural periodicity, lake reflection, and harbor resonance are characteristics of harbors, estuaries, and large lakes and are generally not associated with river sites. The COL applicant did not present any specific descriptions and analyses of wave action during surge and seiche events.

The applicant used the USACE approach to estimate surge in Make-Up Ponds A and B under extreme winds. The COL applicant used the 100-year water-surface elevations, 169.5 m

(556.1 ft) and 175.6 m (576.2 ft) above MSL for Make-Up Ponds A and B, respectively, as the initial elevations. Using the maximum wind speeds identified in WLS COL FSAR Section 2.3.1.2.8, the applicant estimated maximum crest-to-trough wave heights of 1.2 m (3.8 ft) and 2.1 m (6.9 ft) for Make-Up Ponds A and B, respectively. The total high-speed wind-wave activity for Make-Up Ponds A and B were 1.7 m (5.6 ft) and 2.4 m (7.8 ft), respectively. Therefore, the applicant estimated that the flood water-surface elevation in Make-Up Ponds A and B during extreme wind events would be 171.2 m (561.7 ft) and 178 m (583.9 ft) above MSL, respectively. The applicant concluded that the high-speed wind-wave activity would not affect the WLS site because the maximum water-surface elevations in Make-Up Ponds A and B during the extreme wind events would be below the safety-related plant grade of 180.7 m (593 ft) above MSL.

The applicant stated that Make-Up Pond C is located on a tributary of the Broad River, west of the WLS site. The applicant further stated that a postulated failure of the dam impounding Make-Up Pond C would release waters to the Broad River and not directly to the WLS site and therefore flooding from surges and seiches in Make-Up Pond C would be bounded by the postulated failure of Make-Up Pond C Dam described in WLS COL FSAR Section 2.4.4.

The Staff's Technical Evaluation

The staff reviewed COL Information Item 2.4-2 related to the provision of site-specific information about the PMF at the plant site included under WLS COL FSAR Section 2.4. Additional aspects of this information item are addressed in Sections 2.4.2. 2.4.3, 2.4.4, 2.4.6, 2.4.7, and 2.4.10 of this report. To ensure that the most conservative of plausible conceptual models has been identified, in RAI 823, Question 02.04.05-1, the staff requested that the applicant describe the process followed to determine the conceptual models for PMH, PMWS, seiche and resonance, wave runup, and sediment erosion and deposition.

In an October27, 2008, response to RAI 823, Question 02.04.05-1, the applicant stated that the conceptual models to determine floods from PMH, PMWS, seiche and resonance, and wave runup are consistent with the guidance of RG 1.206 and RG 1.59 and the estimation methods used conform to the guidance provided by ANSI/ANS-2.8-1992. The applicant stated that the maximum hurricane storm surge produced on the Atlantic Coast was transposed to the site without accounting for the travel distance and the presence of any instream structures. The applicant stated that maximum wind speeds were used in the determination of wind-wave effects for water bodies adjacent to the site. The applicant stated that the resulting flood waves did not exceed the water-surface elevation produced by the design basis flood.

The applicant also stated that the natural fundamental periods of oscillation of the water bodies adjacent to the site are determined to be significantly shorter than meteorologically induced wave periods. The applicant concluded, therefore, that there is no potential for resonance of the seiche in the water bodies near the site that could result in flooding at the site. The applicant further stated that no safety-related water is required by the proposed units from the Broad River or from Make-Up Ponds A and B. The applicant concluded, therefore, that no safety-related SSCs of the proposed units would be affected by sediment deposition or erosion.

The staff evaluated the applicant's October 27, 2008, response to RAI 823, Question 02.04.05-1, and concluded that the approach adopted by the applicant in the

evaluation of storm surge and seiche hazards at the site is appropriate and sufficiently conservative. Accordingly, the staff considers RAI 823, Question 02.04.05-1, resolved.

Seiches can be caused in lakes and reservoirs by meteorological or seismic forcing. To review the effects of meteorologically or seismically induced seiches near the WLS site, in RAI 823, Question 02.04.05-1, the staff requested that the applicant provide an assessment of meteorologically and seismically induced seiches in Make-Up Ponds A and B. In and October 27, 2008, response to RAI 823, Question 02.04.05-2, the applicant stated that an assessment of meteorologically induced waves in Make-Up Ponds A and B is carried out by estimating the wave periods for high-speed wind waves and the natural fundamental periods of oscillation for the two ponds. The applicant stated that the natural fundamental periods of oscillation of Make-Up Ponds A and B are 2.7 and 8 minutes, respectively. The applicant also reported that the wave periods of high-speed wind waves for Make-Up Ponds A and B, estimated coincident with a 100-year water-surface elevation within the ponds, are 1.8 and 2.7 seconds, respectively. The applicant stated that the wave periods are much shorter than the natural fundamental period of oscillation of the two ponds.

The applicant further stated that the natural fundamental periods of oscillation of the two ponds are significantly shorter than meteorologically induced wave periods such as synoptic storm pattern frequency and dramatic reversal in steady wind direction. The applicant concluded therefore, that a meteorologically induced seiche would not be set up in the two makeup ponds. The applicant also considered the possibility of seismically induced seiches in Make-Up Ponds A and B in response to the staff's RAI 823, Question 02.04.05-2, but provided the details with its response to the staff's RAI 824, Question 02.04.06-2,. The applicant stated that there are no capable tectonic sources within a 25 mile radius of the site as described in WLS COL FSAR Section 2.5.3. The applicant concluded, therefore, that a seismically generated seiche in Make-Up Ponds A and B is unlikely.

The staff evaluated the October 27, 2008, response to RAI 823, Question 02.04.05-2, and updates to the WLS COL FSAR up to and including Revision 7 to determine that the methods used by the applicant to postulate seiching mechanisms and resulting water-surface elevations near the site are adequate. The staff agreed with the applicant that if the natural fundamental periods of oscillation of the two ponds are significantly different from those that can be induced by meteorological events, that meteorologically induced seiches in the two ponds are not likely. The staff agreed with the applicant that in absence of a nearby capable tectonic source, a seismically generated seiche in the makeup ponds is unlikely.

The staff concluded that, due to the location of the site, approximately 282 km (175 mi) inland from the Atlantic Coast any hurricane-induced storm surge in the Atlantic Ocean would dissipate before reaching the site and, therefore, would not affect the site. Due to of the location of Make-Up Pond C on a tributary of the Broad River away from the WLS site, the staff also agreed with the applicant that surge and seiche flooding in the pond would be bounded by the flood generated by a postulated failure of its dam. Accordingly, the staff considers RAI 823, Question 02.04.05-2, resolved.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately analyzed flood water-surface elevations caused by surge and seiche near the WLS site using approaches currently used in standard practice. Therefore, based on the reasons given above, the staff concluded that the applicant adequately

identified and evaluated extreme flood events at the site. The staff agreed that the surge and seiche flood water-surface elevations estimated by the applicant are appropriate for the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.5.5 *Post Combined License Activities*

There are no post COL activities related to this section

2.4.5.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to probable maximum surge and seiche flooding, and that there is no outstanding information required to be addressed in the WLS COL FSAR related to this section/

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.5, herein, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addressed the probable maximum surge and seiche flooding in WLS COL Information Item 2.4-2. The staff concludes that the applicant provided sufficient information on flood hazards related to storm surge and seiches to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.6 Probable Maximum Tsunami Hazards

2.4.6.1 *Introduction*

WLS COL FSAR Section 2.4.6 describes probable maximum tsunami hazards to ensure that any potential tsunami hazard to the safety-related SSCs at the proposed site has been considered in compliance with NRC regulations.

Section 2.4.6 of this report presents an evaluation of the following topics based on data provided by the applicant in the WLS COL FSAR and information available from other sources: (1) historical tsunami data; (2) probable maximum tsunami (PMT) that may pose hazards to the site; and (3) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.6.2 *Summary of Application*

This section of the WLS COL FSAR addresses the site-specific information about PMT hazards in terms of effects on structures and water supply. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19 related to PMT hazards as follows:

AP1000 COL Information Item

- COL Information Item 2.4-2

In addition, this section of the WLS COL FSAR addresses the following COL-specific information identified in AP1000 DCD Section 2.4.1.2, Revision 19.

> Combined License applicants referencing the AP1000 certified design will address the following site-specific information about historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - PMF on Streams and Rivers – Site-specific information that will be used to determine the design basis flooding at the site. This information will include the PMF on streams and rivers.
> - Dam Failures – Site-specific information about potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information about probable maximum surge and seiche flooding.
> - PMT Loading – Site-specific information about PMT loading.
> - Flood Protection Requirements – Site-specific information about flood protection requirements or verification that flood protection is not required to meet the site parameter for flood level.

In WLS COL FSAR Section 2.4.6, the applicant addressed the effects of floods caused by PMT. Other causes of floods and their effects are discussed in related WLS COL FSAR sections. No further action is required for sites within the bounds of the site parameter for flood level.

2.4.6.3 *Regulatory Basis*

The relevant requirements of NRC regulations on consideration of the effects of PMT hazards, and the associated acceptance criteria, are described in NUREG-0800, Section 2.4.6.

The applicable regulatory requirements for tsunami hazards are as follows:

- 10 CFR 52.79(a)(1)(iii), “Contents of applications; technical information in final safety analysis report,” as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100, “Reactor Site Criteria,” as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), "Geologic and seismic siting factors," sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.6:

- RG 1.59, "Design Basis Floods for Nuclear Power Plants," supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized

- RG 1.102, "Flood Protection for Nuclear Power Plants," as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

- RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," as it relates to the contents of a COL application

2.4.6.4 *Technical Evaluation*

In this section of the report, the staff reviewed the applicant's analysis of PMT. The staff's independent analysis, where needed for the review, is also described.

Information Submitted by the Applicant

The applicant stated that no specific tsunami hazard maps are available for the east coast of the United States. The applicant used a general tsunami risk map developed by the USACE to identify a tsunami wave height of 1.5 m (5 ft) for the east coast of the United States. The applicant reported that NOAA tsunami database includes a maximum recorded tsunami height of 6.1 m (20 ft) at Daytona Beach, FL, on July 3, 1992, which was probably meteorologically induced. The applicant stated that the WLS site is located approximately 282 km (175 mi) inland from the Atlantic Ocean and the safety-related plant elevation is 180.7 m (593 ft) above MSL. Based on historical tsunami data and the location and elevation of the WLS site, the applicant concluded that safety-related facilities would not be affected by tsunami flooding.

The applicant stated that hill-slope failure-induced landslides that generate significant waves in Make-Up Ponds A and B are implausible. The applicant stated that field investigations reported in WLS COL FSAR Section 2.5.1.1 noted no irregular weathering conditions or natural landslide hazards and there is no documented evidence of significant landslides at the WLS site or adjacent to the Make-Up Ponds. The applicant stated that landslides of limited size in shallow soil or fill may occur, but would be of insufficient volume and would occur at too low of velocities to cause any significant water waves. The applicant further stated that the slopes around Make-Up Ponds A and B are either natural and have existed since the Holocene age or resulted from cut and fill during the Cherokee Nuclear Station construction. The applicant stated that these slopes are stable and show no visual evidence of groundwater seepage, past failures, or movement or creep.

The applicant stated that because there are no capable tectonic sources within 40 km (25 mi) of the WLS site, surface fault ruptures from seismic waves are not plausible. The applicant

concluded that seismically generated water waves in Make-Up Ponds A and B would be insignificant compared to the freeboard in these ponds.

The applicant stated that Make-Up Pond C is located on a tributary of the Broad River, west of the WLS site. The applicant further stated that a postulated failure of the dam impounding Make-Up Pond C would release waters to the Broad River and not directly to the WLS site and, therefore, flooding from seismically induced water waves in Make-Up Pond C would be bounded by the postulated failure of Make-Up Pond C Dam described in WLS COL FSAR Section 2.4.4.

The Staff's Technical Evaluation

The staff reviewed COL Information Item 2.4-2 related to the provision of site-specific information about the PMF at the plant site included under WLS COL FSAR Section 2.4. Additional aspects of this information item are addressed in Sections 2.4.2. 2.4.3, 2.4.4, 2.4.5, 2.4.7, and 2.4.10, herein.

To ensure that the most conservative of plausible conceptual models have been identified, in RAI 824, Question 02.04.06-1, the staff requested that the applicant describe the process followed to determine the conceptual models for PMT, tsunami propagation, wave runup, inundation and drawdown, hydrostatic and hydrodynamic forces, debris and water-borne projectiles, and sediment erosion and deposition. In an October 27, 2008, response to RAI 824, Question 02.04.06-1, the applicant stated that the conceptual models used to determine flood waves generated by PMT and other tsunami-like waves follow the requirements of RG 1.206 and RG 1.59. The applicant compared the historical maximum recorded tsunami wave heights and the maximum wave heights reported in a tsunami risk map for the east coast of the U.S. to the available freeboard of the WLS site above the Broad River. The applicant concluded that the resulting flood waves are less than the design-basis flood. Therefore, the applicant concluded that there is no potential for inundation, hydrostatic and hydrodynamic forces, debris, or water-borne projectiles that may affect safety-related facilities.

The applicant also stated that there are no capable tectonic sources in the vicinity of the site as described in WLS COL FSAR Section 2.5.3. The applicant concluded, therefore, that a seismically induced water wave near the site is not plausible. The applicant further stated that there are no irregular conditions or natural landslide hazards in the vicinity of the site. The applicant concluded, therefore, that landslide-induced tsunami-like waves near the WLS site are not plausible.

Based on a review of the applicant's October 27, 2008, response to RAI 824, Question 02.04.06-1, the staff concluded that the process used to determine the conceptual models for tsunamis and tsunami-like waves in the vicinity of the WLS site is adequately described. Accordingly, the staff considers RAI 824, Question 02.04.06-1, resolved. The staff used this information in its safety review combined with observations made during the site audit.

The staff performed a search of the NOAA National Geophysical Data Center (NGDC) Historical Tsunami Database for tsunami runup events reported on the east coast of the U.S. The maximum runup reported in the database on the east coast of the United States is 6.0 m (19.7 ft) above MSL at Daytona Beach, FL, on July 3, 1992, due to a meteorological cause. The staff concluded, based on its independent search and the applicant's RAI responses, that credible seismic and landslide tsunamigenic sources in the vicinity of the site do not exist. The

staff also determined that the site is located approximately 282 km (175 mi) from the Atlantic Ocean. For a tsunami generated by a near or a far-field oceanic source to affect the site, the runup would need to travel this distance, 282 km (175 mi), inland from the coast. Historically, maximum horizontal extent of inundation is reported to be less than approximately 8.1 km (5 mi). Since the site is located at least one order of magnitude farther than the maximum horizontal inland distance reported for historical tsunamis, the staff concluded that a PMT in the Atlantic Ocean would not pose a hazard at the site.

In RAI 824, Question 02.04.06-2, the staff requested that the applicant provide an assessment of landslide and slope-failure potential on the shores of Make-Up Ponds A and B and an assessment of tsunami-like waves that may be generated by the potential landslides or slope failures in these ponds. In an October 27, 2008, response to RAI 824, Question 02.04.06-2, the applicant stated that no irregular weathering or natural landslides were identified during field investigations in the region. Therefore, the applicant concluded that landslide-generated tsunami-like waves are not plausible for Make-Up Ponds A and B.

The staff determined that there are no active or passive volcanoes located near the site the eruption of and resulting pyroclastic flows from which may generate a tsunami-like wave in any water bodies near the site. The staff evaluated the applicant's information in the WLS COL FSAR and concluded that the process used by the applicant to estimate source generator characteristics with respect to landslide-generated tsunami-like waves is adequate. The staff also agreed with the applicant's assessment that a landslide-generated tsunami-like wave in the water bodies near the site is not likely. The staff concluded that a tsunami or a tsunami-like wave in the vicinity of the site is an unlikely event. Therefore, the staff determined that a more detailed tsunami analysis is not needed. Based on its review, the staff considers RAI 824, Question 02.04.06-2, resolved.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately analyzed the potential for floods caused by tsunamis near the WLS site using approaches currently used in standard practice. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identifued and evaluated extreme flood events at the site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.6.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.6.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to PMT hazards, and that there is no outstanding information required to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.6 of this report, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addressed the probable maximum tsunami hazard in COL Information Item 2.4-2. The staff concludes that the applicant has provided sufficient information on PMT hazards to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.7 Ice Effects

2.4.7.1 *Introduction*

WLS COL FSAR Section 2.4.7 describes ice effects to ensure that safety-related facilities and water supply are not affected by ice-induced hazards.

Section 2.4.7 of this report presents an evaluation of the following topics based on data provided by the applicant in the WLS COL FSAR and information available from other sources: (1) regional history and types of historical ice accumulations (i.e., ice jams, wind-driven ice ridges, floes, frazil ice formation, etc.); (2) potential effects of ice-induced, high- or low-flow levels on safety-related facilities and water supplies; (3) potential effects of ice to produce forces on, or cause blockage of, safety-related facilities; and (4) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

As stated in Section 2.4 above, hydrologic characteristics associated with conditions that would result in a loss of external water supply and seismic design considerations of water-supply structures are not relevant for the AP1000 design. Therefore, low-water conditions related to topics listed above were not part of the staff's review.

2.4.7.2 *Summary of Application*

This section of the WLS COL FSAR addresses the site-specific information on ice effects. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19 related to ice effects as follows:

AP1000 COL Information Item

- COL Information Item 2.4-2

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Section 2.4.1.2, Revision 19:

> Combined License applicants referencing the AP1000 certified design will address the following site-specific information about historical flooding and potential flooding factors, including the effects of local intense precipitation.

- Probable Maximum Flood (PMF) on Streams and Rivers – Site-specific information that will be used to determine the design basis flooding at the site. This information will include the PMF on streams and rivers.

- Dam Failures – Site-specific information about potential dam failures.

- Probable Maximum Surge and Seiche Flooding – Site-specific information about probable maximum surge and seiche flooding.

- Probable Maximum Tsunami Loading – Site-specific information about probable maximum tsunami loading.

- Flood Protection Requirements – Site-specific information about flood protection requirements or verification that flood protection is not required to meet the site parameter for flood level.

In WLS COL FSAR Section 2.4.7, the applicant addressed ice effects on high water at the site. Other causes of floods and their effects were discussed in subsequent WLS COL FSAR sections. No further action is required for sites within the bounds of the site parameter for flood level.

2.4.7.3 *Regulatory Basis*

The relevant requirements of NRC regulations for the identification and evaluation of ice effects, and the associated acceptance criteria, are described in NUREG—800, Section 2.4.7.

The applicable regulatory requirements for identifying ice effects are as follows:

- 10 CFR 52.79(a)(1)(iii), "Contents of applications; technical information in final safety analysis report," as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, "Reactor Site Criteria," as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), "Geologic and seismic siting factors," sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.7:

- RG 1.59, "Design Basis Floods for Nuclear Power Plants," supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized

- RG 1.102, “Flood Protection for Nuclear Power Plants,” as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site
- RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition),” as it relates to the contents of a COL application

2.4.7.4 *Technical Evaluation*

In this section of the report, the staff reviewed the applicant’s analyses regarding ice effects. The staff’s independent analysis, where needed for the review, is also described.

Information Submitted by the Applicant

The applicant reported that winter water temperatures range from 0 to 9 ºC (32 to 48.2 ºF) between 1962 and 1981 at 10 USGS gauging stations on the Broad River and tributaries upstream of the WLS site. The applicant also reported that the lowest recorded water temperature near the WLS site from 1959 to 2005 is 2 ºC (35.6 ºF) according to the EPA STORET database and the values vary from 1 to 4 ºC (33.8 to 39.2 ºF) from 1995 to 2000 as stated in the measurements by the North Carolina Department of Environmental and Natural Resources at nine stations located near the 10 USGS stations. Based on these water temperature records, the applicant concluded that historical observations suggest the Broad River water temperatures consistently remain above freezing. The applicant also concluded that flooding of the WLS site from an ice jam is a remote possibility based on historical data from the USACE Cold Regions Research and Engineering Laboratory historical ice jam database. Since no safety-related water storage is required for WLS, the applicant concluded that ice-induced low flow would not affect its safety.

The Staff’s Technical Evaluation

The staff reviewed COL Information Item 2.4-2 related to the provision of site-specific information about the PMF at the plant site included under WLS COL FSAR Section 2.4. Additional aspects of this information item are addressed in Sections 2.4.2. 2.4.3, 2.4.4, 2.4.5, 2.4.6, and 2.4.10 of this report.

The staff searched the NOAA National Climatic Data Center (NCDC) Storm Events database to search for snow and ice events for the counties in which the majority of the Upper Broad River Basin lies. This search yielded the storm and ice events listed in Table 2.4.7-1 of this report.

Table 2.4.7-1 Snow and Ice Events in the Upper Broad River Basin and Its Adjoining Areas Between 1993 and 2008

County	Number of Snow and Ice Events	Number of Ice Storms
Buncombe Co., NC	144	8
Henderson Co., NC	87	13
Polk Co., NC	50	7
McDowell Co., NC	79	12
Rutherford Co., NC	51	6
Cleveland Co., NC	44	7
Gaston Co., NC	37	8
Lincoln Co., NC	43	9
Cherokee Co., SC	50	10

Based on the storm and ice events in the Upper Broad River Basin, the staff determined that ice events are frequent during winters near the WLS site. The staff also searched the USACE ice jam database for ice jam or ice dam formation on the Broad River. No historical records exist of ice jams or dams on the Broad River. As stated in the USACE ice jam database, there are only two records of ice jam or ice dam formation in the State of North Carolina. An ice jam formed in the Neuse River upstream of the USGS streamflow gauge at Kinston, NC, on January 26, 1940, that lasted for 4 days. An ice gorge was reported in the Missouri River at Williston, NC, on February 24, 1925. The ice jam database does not list any events for the State of South Carolina.

Based on the search of the USACE ice jam database, the staff concluded that formation of ice jams and ice dams has not been reported for the Broad River. Therefore, the staff concluded that ice dams and ice jams are not a credible hazard near the WLS site.

The staff downloaded air temperature data for three cooperative stations located near the WLS site from NOAA NCDC. These three stations are Shelby 2 NNE, Gastonia, and Ninety-Nine Islands. The period of record at these stations are 1893−1895 and 1936-present (Shelby), 1930-present (Gastonia), and 1960-present (Ninety-Nine Islands). Using this air temperature data, the staff performed independent analysis to determine some characteristics of minimum daily mean air temperature near the site. These characteristics for the three stations are shown in Table 2.4.7-2 of this report.

Table 2.4.7-2 Some Characteristics of Mean Daily Air Temperature at NOAA NCDC Cooperative Stations Near the Site

Characteristic	Shelby 2 NNE	Gastonia	Ninety-Nine Islands
Minimum daily mean air temperature (date)	-13ºC (8ºF) (02/08/1895)	-12ºC (11ºF) (01/21/1985)	-12ºC (11ºF) (01/21/1985)
Number of days below freezing (total number of days for which data are available)	768 (27,818)	1076 (26,678)	740 (17,566)
Maximum number of consecutive days daily mean air temperature remains at freezing or below	13	11	9
Maximum number of consecutive days daily mean air temperature remains at 18ºF or below	3	2	2

The minimum daily mean air temperature at Shelby, Gastonia, and the Ninety-Nine Islands stations are -13ºC, -12ºC, -12ºC (8ºF, 11ºF, and 11ºF), respectively. The average number of days per year that the stations' daily mean air temperature was below freezing are approximately 10, 15, and 15, respectively. The longest sequences of days that the daily mean air temperature was at or below freezing for the three stations are 13, 11, and 9 days for Shelby, Gastonia, and Ninety-Nine Islands stations, respectively. Based on these characteristics of the daily mean air temperature, the staff concluded that the air temperature near the WLS site can fall below freezing for moderately long periods of time. However, the sequences are not long enough to cause extensive freezing of water bodies near the WLS site.

The staff also concluded the length of sequences of days during which the daily mean air temperature remained at or below -8ºC (18ºF). The reason for choosing the threshold of -8ºC (18ºF) is that frazil ice forms in turbulent, non-snow covered waters that undergo supercooling when the air temperature falls to or below -8ºC (18ºF). The staff noted that at Gastonia and Ninety-Nine Islands stations, the maximum span of such sequences was just 2 days and at Shelby it was 3 days. Based on this data, the staff concluded that frazil ice formation at and near the WLS site is possible, although unlikely, given the short duration during which supercooling can occur. However, the proposed reactors at the WLS site would not depend on any external source of water supply for safe shutdown. Therefore, the staff concluded that the safety of the plants will not be affected by formation of frazil ice at and near the WLS site.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately analyzed the potential for ice effects near the WLS site using approaches currently used in standard practice. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been

historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.7.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.7.6 *Conclusion/*

The staff reviewed the application and confirmed that the applicant has addressed site characteristics and other hydrometeorological parameters related to ice formation at or near the plant site, and that there is no outstanding information required to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.7 of this report, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addressed ice effects in COL Information Item 2.4-2. The staff concludes that the applicant has provided sufficient information on flood hazards from ice effects to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.8 Cooling Water Canals and Reservoirs

2.4.8.1 *Introduction*

WLS COL FSAR Section 2.4.8 describes cooling-water supply, made up of canals and reservoirs, used to transport and impound water supplied to the safety-related SSCs.

Section 2.4.8 of this report presents an evaluation of the applicant's submittal related to cooling-water canals and reservoirs. As stated in Section 2.4 above, hydrologic characteristics associated with conditions that would result in a loss of external water-supply and seismic design considerations of water-supply structures are not relevant for the AP1000 design. Therefore, flooding and low-water conditions for canals and reservoirs were not part of the staff's review.

2.4.8.2 *Summary of Application*

This section of the WLS COL FSAR addresses the site-specific information on cooling-water canals and reservoirs. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.3, Revision 19 related to cooling-water canals and reservoirs as follows:

AP1000 COL Information Item

COL Information Item 2.4-3

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Tier 2, Section 2.4.1.3, Revision 19.

> Combined License applicants will address the water supply sources to provide makeup water to the service water system cooling tower.

2.4.8.3 *Regulatory Basis*

The relevant requirements of NRC regulations for the identification of design considerations for cooling-water canals and reservoirs, and the associated acceptance criteria, are described in NUREG-0800, Section 2.4.8.

The applicable regulatory requirements for cooling-water canals and reservoirs are as follows:

- 10 CFR 52.79(a)(1)(iii), "Contents of applications; technical information in final safety analysis report," as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, "Reactor Site Criteria," as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), "Geologic and seismic siting factors," sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.8:

- RG 1.59, "Design Basis Floods for Nuclear Power Plants," supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized

- RG1.102, "Flood Protection for Nuclear Power Plants" as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

- RG1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," as it relates to the contents of a COL application

2.4.8.4 *Technical Evaluation*

In this section of the report, the staff reviewed the applicant's analyses related to cooling-water canals and reservoirs. The staff's independent analysis, where needed for the review, is also described.

Information Submitted by the Applicant

The applicant stated that there are no safety-related cooling-water canals or reservoirs proposed for the WLS site because the UHS is provided by the atmosphere for the proposed AP1000 units.

The *Staff's Technical Evaluation*

The staff reviewed COL Information Item 2.4-3 related to the provision of site-specific information about the cooling-water canals and reservoirs at the plant site included under WLS COL FSAR Section 2.4. Additional aspects of this information item are addressed in Sections 2.4.9. 2.4.11, and 2.4.12 of this report.

The staff reviewed the functioning of the AP1000 UHS. The passive cooling system of the proposed units is assisted by a water spray on the containment vessel provided by a passive containment cooling-water storage tank located on top of the containment building, which holds a 3-day supply of water following a design basis accident. Additional water is stored in a passive containment cooling ancillary water storage tank for an additional 4 days. Technical specifications would ensure that this 7-day supply of water to assist in cooling is always available. The proposed reactors at the WLS site would not depend on any external source of water supply for safe shutdown.

The staff concluded that there are no safety-related cooling-water canals or reservoirs are required for the safe operation of the WLS and, therefore, no further evaluation of safety-related water canals and reservoirs are necessary.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately analyzed the potential for floods caused by cooling-water canals and reservoirs near the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.8.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.8.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to design basis for canal and reservoirs used to transport and impound water supplied to the SSCs, and that there is no outstanding information required to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information relative to the design bases of canals and reservoirs important to the design and siting of the plant. The staff

reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.8 of this report, whether the applicant has met the relevant requirements of 10 CFR 52.79, and 10 CFR Part 100, with respect to determining the acceptability of the site. The information provided on the cooling-water canals and reservoirs addressed COL Information Item 2.4-3. The staff concludes that the applicant has provided sufficient information to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.9 Channel Diversions

2.4.9.1 *Introduction*

WLS COL FSAR Section 2.4.9 describes channel diversions. It includes hydrogeologic and geomorphologic descriptions of the Broad River Basin and an evaluation of the likelihood of diversion of Broad River away from its present course.

Section 2.4.9 of this report presents the staff's evaluation of the applicant's submittal related to channel diversions. As stated in Section 2.4 above, hydrologic characteristics associated with conditions that would result in a loss of external water supply and seismic design considerations of water-supply structures are not relevant for the AP1000 design. Therefore, low-water conditions from channel diversions were not part of the staff's review.

2.4.9.2 *Summary of Application*

This section of the WLS COL FSAR addresses information about site-specific channel diversions. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.3, Revision 19 related to channel diversions as follows:

AP1000 COL Information Item

- COL Information Item 2.4-3

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Tier 2, Section 2.4.1.3, Revision 19.

> Combined License applicants will address the water supply sources to provide makeup water to the service water system cooling tower.

2.4.9.3 *Regulatory Basis*

The relevant requirements of NRC regulations for the identification and evaluation of channel diversions, and the associated acceptance criteria, are described in NUREG-0800, Section 2.4.9.

The applicable regulatory requirements for identifying and evaluating channel diversions are as follows:

- 10 CFR 52.79(a)(1)(iii), "Contents of applications; technical information in final safety analysis report," as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, "Reactor Site Criteria," as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), "Geologic and seismic siting factors," sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.9:

- RG 1.59, "Design Basis Floods for Nuclear Power Plants," supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized

- RG 1.102, "Flood Protection for Nuclear Power Plants," as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

- RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," as it relates to the contents of a COL application

2.4.9.4 *Technical Evaluation*

In this section of the report, the staff reviewed the applicant's analyses related to channel diversions. The staff's independent analysis, where needed for the review, is also described.

Information Submitted by the Applicant

The applicant stated that there is no evidence to suggest diversions or realignments of the Broad River in the past, no unstable steep side slopes are present and there is no record of ice-induced channel diversions. The applicant noted that several shoals are located in the basin but are confined within the natural banks of the river. The applicant concluded that channel diversion due to geothermal activity is not expected in the region. The applicant also concluded that any potential channel diversion would not affect safety-related structures or systems at the WLS site because the passive cooling system for the AP1000 design uses the atmosphere as the UHS and the cooling system does not rely directly on the Broad River for water.

The Staff's Technical Evaluation

The staff reviewed COL Information Item 2.4-3 related to the provision of site-specific information about the channel diversions at the plant site included under WLS COL FSAR

Section 2.4. Additional aspects of this information item are addressed in Sections 2.4.8, 2.4.11 and 2.4.12 of this report.

Based on the applicant's description of the cooling system of the proposed units at the WLS site, the staff concluded that the Broad River would serve as the source for makeup water for normal plant operation of the proposed units. The staff reviewed the functioning of the AP1000 UHS. The passive cooling system of the proposed units is assisted by a water spray on the containment vessel provided by a passive containment cooling-water storage tank located on top of the containment building, which holds a 3-day supply of water following a design basis accident. Additional water is stored in a passive containment cooling ancillary water storage tank for an additional 4 days. Technical specifications would ensure that this 7-day supply of water to assist in cooling is always available. The proposed reactors at the WLS site would not depend on any external source of water supply for safe shutdown.

The staff concluded that no safety-related cooling-water sources required for the safe operation of the WLS. Therefore, the staff determined that a diversion of the Broad River away from the site for any reason would not affect the safety of the plant. Based on the applicant's description of the geology and geomorphology of the Broad River Basin and the available freeboard between normal water-surface elevation in the river and the grade elevation of the WLS site. the staff also determined that a diversion of the Broad River toward the WLS site is unlikely. Therefore, the staff concluded that flooding of the WLS site from a diversion of the Broad River toward the WLS site is not a plausible hazard.

Based on a review of the applicant's information in WLS COL FSAR Revision 9, the staff concluded that the applicant has appropriately analyzed the potential for channel diversions near the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.9.5 *Post Combined License Activities*

There are no post COL activities related to this section

2.4.9.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information to demonstrate that the characteristics of the site fall within the site parameters specified in the AP1000 DC rule, and that there is no outstanding information required to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description ensuring that the plant and essential water supplies will not be adversely affected. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow

the staff to evaluate, as documented in Section 2.4.9 of this report, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This section addressed channel diversions in COL Information Item 2.4-3. The staff concludes that the applicant has provided sufficient information to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.10 Flooding Protection Requirements

2.4.10.1 *Introduction*

WLS COL FSAR Section 2.4.10 describes locations and elevations of safety-related facilities and those of structures and components required for protection of safety-related facilities. These requirements are then compared with design-basis flood conditions to determine whether flood effects need to be considered in the plant's design or in emergency procedures.

Section 2.4.10 of this report presents an evaluation of the flooding protection for the proposed plant site.

2.4.10.2 *Summary of Application*

This section of the WLS COL FSAR addresses the needs for site-specific information on flooding protection requirements. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19 related to flooding protection requirements as follows:

AP1000 COL Information Item

- COL Information Item 2.4-2

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19.

> Combined License applicants referencing the AP1000 certified design will address the following site-specific information about historical flooding and potential flooding factors, including the effects of local intense precipitation.
>
> - Probable Maximum Flood (PMF) on Streams and Rivers – Site-specific information that will be used to determine the design basis flooding at the site. This information will include the PMF on streams and rivers.
> - Dam Failures – Site-specific information about potential dam failures.
> - Probable Maximum Surge and Seiche Flooding – Site-specific information about probable maximum surge and seiche flooding.
> - Probable Maximum Tsunami Loading – Site-specific information about probable maximum tsunami loading.

- Flood Protection Requirements – Site-specific information about flood protection requirements or verification that flood protection is not required to meet the site parameter for flood level.

In WLS COL FSAR Section 2.4.10, the applicant addressed the flood protection requirements at the site. The causes of floods and their effects were discussed in other WLS COL FSAR sections. No further action is required for sites within the bounds of the site parameter for flood level.

2.4.10.3 *Regulatory Basis*

The relevant requirements of NRC regulations for the identification and evaluation of flooding protection requirements, and the associated acceptance criteria, are described in NUREG-0800. Section 2.4.10

- 10 CFR 52.79(a)(1)(iii), "Contents of applications; technical information in final safety analysis report," as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, "Reactor Site Criteria," as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), "Geologic and seismic siting factors," sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

The staff also used the following regulatory guides for the acceptance criteria identified in NUREG-0800, Section 2.4.10:

- RG 1.59, "Design Basis Floods for Nuclear Power Plants," supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized

- RG 1.102, "Flood Protection for Nuclear Power Plants," as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

- RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," as it relates to the contents of a COL application

2.4.10.4 *Technical Evaluation*

In this section of the report, the staff reviewed the applicant's analyses related to flooding protection requirements. The staff's independent analysis, where needed for the review, is also described.

Information Submitted by the Applicant

The applicant stated that all safety-related facilities at the WLS site are located above the maximum flood level based on the design-basis flood evaluate in earlier sections of the WLS COL FSAR. Therefore, the applicant concluded that flood protection measures and emergency procedures are not required.

The Staff's Technical Evaluation

The staff reviewed COL Information Item 2.4-2 related to the provision of site-specific information about the PMF at the plant site included under WLS COL FSAR Section 2.4. Additional aspects of this information item are addressed in Sections 2.4.2. 2.4.3, 2.4.4, 2.4.5, 2.4.6, and 2.4.7 of this report.

The staff determined that the site characteristic maximum flood water-surface elevation near the WLS site from several flooding mechanisms described in earlier sections of this report remains below the site grade and meets the AP1000 DCD site parameter. Therefore, the staff concluded that flooding protection of safety-related SSCs at the WLS site is not needed.

Based on a review of the applicant's information in WLS COL FSAR Revisions 0 through 7, the staff concluded that the applicant has appropriately analyzed the need for flooding protection at the WLS site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately identified and evaluated extreme flood events at the site. Therefore, based on the reasons given above, the staff concluded that the applicant adequately determined hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.10.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.10.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information to demonstrate that the characteristics of the site fall within the site parameters specified in the AP1000 DC rule, and that no outstanding information is required to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information relative to the flood protection measures important to the design and siting of this plant. The staff concluded that the applicant considered the appropriate site phenomena in establishing the flood protection measures for SSCs. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.10 of this report, whether the applicant met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addressed flooding protection requirements in

COL Information Item 2.4-2. The staff concludes that the applicant provided sufficient information to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.11 Low Water Considerations

2.4.11.1 *Introduction*

WLS COL FSAR Section 2.4.11 describes natural events that may reduce or limit the available safety-related cooling-water supply. The applicant ensures that an adequate water supply will exist to shut down the plant under conditions requiring safety-related cooling.

Section 2.4.11 of this report presents an evaluation of the effects of low water-surface elevations caused by various hydrometeorological events.

As stated in Section 2.4 above, hydrologic characteristics associated with conditions that would result in a loss of external water supply and seismic design considerations of water-supply structures are not relevant for the AP1000 design. Therefore, low-water conditions were not part of the staff's review.

2.4.11.2 *Summary of Application*

This section of the WLS COL FSAR addresses the impacts of low water on water supply. The applicant addressed the information item identified in AP1000 DCD Tier 2, Section 2.4.1.2, Revision 19 related to low-water considerations as follows:

AP1000 COL Information Item

- COL Information Item 2.4-3

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Section 2.4.1.3, Revision 19.

> Combined License applicants will address the water supply sources to provide makeup water to the service water system cooling tower.

2.4.11.3 *Regulatory Basis*

The relevant requirements of NRC regulations for the low-water considerations, and the associated acceptance criteria, are described in NUREG-0800, Section 2.4.11.

The applicable regulatory requirements for identifying the effects of low water are as follows:

- 10 CFR 52.79(a)(1)(iii), "Contents of applications; technical information in final safety analysis report," as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, “Reactor Site Criteria,” as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).
- 10 CFR 100.23(d), “Geologic and seismic siting factors,” sets forth the criteria to determine the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

2.4.11.4 *Technical Evaluation*

The following material in this section describes the staff’s review of information provided and analyses carried out by the applicant in its WLS COL FSAR. The staff’s independent analysis, where needed for the review, is also described.

The staff reviewed COL Information Item 2.4-3 related to the provision of site-specific information about low-water considerations at the plant site included under WLS COL FSAR Section 2.4. Additional aspects of this information item are addressed in Sections 2.4.8, 2.4.9, and 2.4.12 of this report.

To ensure that the site characteristics related to low-water events are based on the most conservative of plausible conceptual models, in RAI 825, Question 02.04.11-1, the staff requested that the applicant describe the process followed to determine the conceptual models for low water from drought and from other phenomena and the effects of low water on safety-related water supplies under possible water-use limits. In an October 27, 2008, response to RAI 825, Question 02.04.11-1, the applicant stated that it characterized low-flow conditions in the Broad River using the 10-year return period 7-day flow (7Q10) at the Gaffney, SC, USGS streamflow gauge. The applicant noted that it supplemented the available streamflow record at the Gaffney gauge by additional periods of streamflow data from two upstream gauges at Blacksburg, SC and Boiling Springs, NC. The applicant estimated the 7Q10 flow from a Log-Pearson Type III distribution fitted to the annual 7-day low flow for each year in the record. The applicant stated that the estimated 7Q10 flow for the Broad River at the Gaffney gauge is 13.6 m^3/s (479 cfs), which is approximately the same as the Federal Energy Regulatory Commission (FERC) minimum flow requirement of 13.7 m^3/s (483 cfs) for the Ninety-Nine Islands Hydroelectric Station.

The applicant defined a minimum discharge of 15.2 m^3/s (538 cfs), the sum of the minimum FERC requirement of 13.7 m^3/s (483 cfs) and the expected consumptive water use of 1.6 m^3/s (55 cfs) for the proposed units, which are needed to support current water use and quality downstream of the site. When the Broad River discharge falls below 15.2 m^3/s (538 cfs), onsite water storage would supplement makeup water from the Broad River for the proposed units. When the Broad River discharge falls below 13.7 m^3/s (483 cfs), only Make-Up Ponds B and C would supply makeup water to the proposed units. The staff reviewed the applicant’s October 27, 2008, response to RAI 825, Question 02.04.11-1, and subsequent updates to the WLS COL FSAR up to and including Revision 7 to conclude that the applicant’s process to determine the conceptual models for low flow are adequately described. The staff also determined that there are no safety-related systems that can be affected by low water at the WLS site. Accordingly, the staff considers RAI 825, Question 02.04.11-1, resolved.

Low Flow in Rivers and Streams

Information Submitted by the Applicant

The applicant stated that the passive cooling system of the AP1000 design does not rely on the Broad River as a source of water and therefore, no safety-related facilities of the WLS would be affected by low-water conditions in the river.

The Staff's Technical Evaluation

There are no safety-related systems that can be affected by low water at the WLS site.

Low Water Resulting from Surges, Seiches, or Tsunami

Information Submitted by the Applicant

The applicant stated that no safety-related systems can be affected by low water at the WLS site.

The Staff's Technical Evaluation

The staff agreed with the applicant that no safety-related systems can be affected by low water at the WLS site.

Historical Low Water

Information Submitted by the Applicant

The applicant stated that no safety-related systems can be affected by low water at the WLS site.

The Staff's Technical Evaluation

The staff agreed with the applicant that no safety-related systems can be affected by low water at the WLS site.

Future Controls

Information Submitted by the Applicant

The applicant stated that no safety-related systems can be affected by low water at the WLS site.

The Staff's Technical Evaluation

The staff agreed with the applicant that no safety-related systems can be affected by low water at the WLS site.

Plant Requirements

Information Submitted by the Applicant

The applicant stated that no safety-related systems can be affected by low water at the WLS site.

The Staff's Technical Evaluation

The staff agreed with the applicant that no safety-related systems can be affected by low water at the WLS site.

Heat Sink Dependability Requirements

Information Submitted by the Applicant

The applicant reported that the atmosphere provides the UHS for the AP1000 design and the passive containment cooling system does not rely on water from the Broad River. The applicant also stated that no water from the Broad River or from other outside sources is required for safe emergency shutdown because the passive containment cooling-water storage tank stores water required for 72 hours of containment wetting and the passive containment cooling ancillary water storage tank has the capacity to provide containment wetting for an additional 4 days.

The Staff's Technical Evaluation

In RAI 825, Question 02.04.11-2, the staff requested that the applicant describe the term "normal plant shutdown" and to clarify whether any safety-related water would be needed during normal plant shutdown.

In an October 27, 2008, response to RAI 825, Question 02.04.11-2, the applicant stated that a normal plant shutdown is a non-emergency procedure and does not require any safety-related water. The normal shutdown would require approximately 130,749 m^3 (106 ac-ft) of water for the two proposed units and an additional 176,388 m^3 (143 ac-ft) to maintain shutdown conditions for 90 days after a normal shutdown. The applicant stated that Make-Up Pond A, with its usable storage capacity of approximately 1,480,178 m^3 (1,200 ac-ft), would have sufficient water to support a normal plant shutdown and to maintain shutdown conditions for durations that are significantly longer than those of any recorded period of low flow. The applicant also stated that it has no plans to draw down Make-Up Pond A to support plant water needs during power production. The staff notes that the applicant has updated the WLS COL FSAR text.

The staff reviewed the functioning of the AP1000 UHS. The passive cooling system of the proposed units is assisted by a water spray on the containment vessel provided by a passive containment cooling-water storage tank located on top of the containment building, which holds a 3-day supply of water following a design-basis accident. Additional water is stored in a passive containment cooling ancillary water storage tank for an additional 4 days. Technical specifications would ensure that this 7-day supply of water to assist in cooling is always available. The proposed reactors at the WLS site would not depend on any external source of water supply for safe shutdown. The staff evaluated the applicant's October 27, 2008, response

to RAI 825, Question 02.04.11-2, and concluded that the process used by the applicant to determine heat sink dependability requirements is adequate. The staff concluded that there are no safety-related systems that can be affected by low water at the WLS site. Accordingly, the staff considers RAI 825, Question 02.04.11-2, resolved.

2.4.11.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.11.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information required and that no site characteristics related to low-water conditions apply to the AP1000 design.

As set forth above, the applicant has presented and substantiated information relative to the low-water effects important to the design and siting of this plant. The staff found that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs. The staff reviewed the information provided and, for the reasons given above, concluded that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.11 of this report, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addressed low-water considerations in COL Information Item 2.4-3. The staff concludes that the applicant has provided sufficient information to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.12 Groundwater

2.4.12.1 *Introduction*

This section of the WLS COL FSAR describes the hydrogeological characteristics of the site. One of the key objectives of groundwater investigations and monitoring at this site is to evaluate the maximum groundwater-surface elevation at the site, which is used in Section 2.5 of this report to determine the effects of groundwater on the stability of the plant foundations and slopes. The evaluation is performed to ensure that the maximum groundwater-surface elevation remains less than the 29.9 m (98.0 ft) plant elevation. Other significant objectives are to examine whether groundwater provides any safety-related water supply, to determine whether dewatering systems are required to maintain groundwater-surface elevations below the required elevation, and to describe subsurface pathways for potential groundwater contaminants.

The specific areas of review are as follows: (1) identification of the aquifers, types of onsite groundwater use, sources of recharge, present withdrawals and known and likely future withdrawals, flow rates, travel time, gradients, and other properties that affect movement of accidental contaminants in groundwater, groundwater-surface elevations beneath the site, seasonal and climatic fluctuations, monitoring and protection requirements, and man-made changes that have the potential to cause long-term changes in local groundwater regime; (2) effects of groundwater-surface elevations and other hydrodynamic effects of groundwater on the design bases of plant foundations and those of other SSCs important to safety; (3) reliability

of groundwater resources and related systems used to supply safety-related water to the plant; (4) reliability of dewatering systems to maintain groundwater conditions within the plant's design bases; (5) potential effects of seismic and non-seismic information about the postulated worst-case groundwater conditions for the proposed plant site; and (6) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts of 10 CFR Part 52.

2.4.12.2 *Summary of Application*

This section of the WLS COL FSAR addresses groundwater conditions in terms of impacts on structures and water supply. The applicant addressed information related to groundwater as follows:

AP1000 COL Information Item

- COL Information Item 2.4-4

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Section 2.4.1.4, Revision 19.

Combined License applicants referencing the AP1000 certified design will address site-specific information on groundwater. No further action is required for the sites within the bounds of the site parameter for groundwater.

2.4.12.3 *Regulatory Basis*

The relevant requirements of NRC regulations for groundwater, and the associated acceptance criteria, are specified in NUREG-0800, Section 2.4.12.

The applicable regulatory requirements for groundwater are set forth in the following:

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

The staff also used the acceptance criteria identified in NUREG-0800, Section 2.4.12:

- Local and Regional Groundwater Characteristics and Use: The applicant should supply a complete description of regional and local groundwater characteristics and groundwater use, groundwater monitoring and protection requirements, and any man-made changes with a potential to affect regional groundwater characteristics over a long period of time.

- Effects on Plant Foundations and other Safety-Related Structures, Systems, and Components: The applicant should supply a complete description of the effects of groundwater-surface elevations and other hydrodynamic effects on the design bases of plant foundations and other SSCs important to safety.

- Reliability of Groundwater Resources and Systems Used for Safety-Related Purposes: The applicant should supply a complete description of all SSCs important to safety that depends on groundwater, as well as data and analysis regarding the reliability of the groundwater source.

- Reliability of Dewatering Systems: The applicant should supply a complete description of the site dewatering system, including its reliability to maintain groundwater conditions within the groundwater design bases of SSCs important to safety.

- Consideration of Other Site Related Evaluation Criteria: The applicant should supply an assessment of the potential effects of seismic and non-seismic information about the postulated worst-case scenario related to groundwater effects for the proposed plant site.

The regulatory basis of the information incorporated by reference will be addressed in the staff's final safety evaluation report (FSER) related to the AP1000 certified design.

2.4.12.4 *Technical Evaluation*

The staff reviewed WLS COL FSAR Section 2.4.12 Revisions 0 to 7; corrections and additions to the WLS COL FSAR submitted by the applicant as letters; and associated applicant responses to RAIs issued by the staff. The conclusions of the review are current with, and apply to, WLS COL FSAR Revision 7. However, frequent references are made to earlier WLS COL FSAR revisions where necessary to explain the reasons for RAIs. The staff also checked the referenced AP1000 DCD and departures and supplements specified in the WLS COL FSAR.

The staff reviewed COL Information Item 2.4-4 related to the provision of site-specific information about groundwater at the plant site included under WLS COL FSAR Section 2.4.

For clarity, the technical evaluation is organized into six subsections, each addressing a specific issue: conceptual model; offsite wells; aquifer properties; alternative pathways; maximum water table level; and monitoring. Each subsection describes (1) the staff's review of information and analyses that the applicant provided in the WLS COL FSAR, (2) RAIs issued by the staff and the applicant's responses, and (3) the staff's independent analysis, where needed for the review.

Conceptual Model

<u>*Information Submitted by the Applicant*</u>

The applicant described its conceptual model of the hydrogeology of the site in WLS COL FSAR Sections 2.4.12.1, 2.4.12.2, and 2.4.12.3. The site is located in the Piedmont physiographic province and is underlain by metamorphic rocks of volcanic, intrusive, and sedimentary origin.

Groundwater may be obtained from fractures within the bedrock, but near the surface it occurs under unconfined conditions in artificial fill materials, soil and saprolite that overlie bedrock, and (partially weathered rock (PWR)). The PWR tends to have the highest hydraulic conductivity. Groundwater originates from precipitation, which infiltrates in upland areas, then flows mostly within the near-surface materials toward lower areas where it discharges to the Broad River, the makeup ponds, and other small bodies of surface water. Groundwater supplies mostly domestic wells in the area near the site. The applicant does not currently use or plan to use onsite groundwater.

In response to four staff RAIs, the applicant provided additional details and clarifications related to the rationale for the conceptual model, the impact of variable precipitation on groundwater flow and direction, the role of seeps and springs, and the definition of the word “preferential.”

The Staff’s Technical Evaluation

The staff reviewed the applicant’s description of the site conceptual model. To better understand the applicant’s rationale and support for the conceptual model, the staff issued RAI 826, Question 02.04.12-1. In a December 11, 2008, response, the applicant provided an overview of the methodology it used to develop the conceptual model of the site. The applicant utilized regional data, Cherokee-era site data, and data collected as part of the WLS characterization effort to characterize the key materials (i.e., fill; saprolite; residual soil; PWR). When site-specific data did not exist, the applicant used literature values. Using the conceptual model and groundwater well data, the applicant identified five potential flow paths between a postulated leak at the nuclear island and the site boundary. In the initial WLS COL FSAR, the applicant had identified only one path; in the current WLS COL FSAR, because of site grading changes, the applicant reduced the number of plausible pathways from five to four. The applicant provided additional details related to the flow paths in response to other WLS COL FSAR RAIs. The applicant proposed to update the WLS COL FSAR with this new information about conceptual model identification. The staff notes that applicant included this information in WLS COL FSAR Section 2.4.12.2, “Sources.” The staff concluded that the applicant’s December 11, 2008, response to RAI 826, Question 02.04.12-1, was acceptable and considers the question resolved.

To help understand how groundwater elevation and flow direction responded spatially and temporally to precipitation, the staff issued RAI 826, Question 02.04.12-3. In a December 11, 2008, response, the applicant supplemented the onsite precipitation data for December 2005 to November 2006 with data from 1950 to 2008 from the Greenville-Spartanburg Airport, located 72 km (45 mi) to the west. The applicant noted that precipitation was relatively evenly distributed throughout the year, yet groundwater levels increased during the winter, reaching a maximum in April and May, and decreased in summer, reaching a minimum in October and November. The applicant attributed the seasonal effect to evapotranspiration, which is lowest in winter and highest in summer. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.2, “Sources.” The staff concluded that the applicant’s December 11, 2008, response to RAI 826, Question 02.04.12-3, was acceptable and considers the question resolved.

Using precipitation data from the Greenville-Spartanburg Airport, the staff concluded that precipitation in 2005 was 8 percent above average (for the period 1950-2007), 15 percent below average in 2006, and 37 percent below average in 2007. The applicant monitored groundwater

levels from April 2006 to April 2007. The staff concluded that those groundwater levels are reflective of drier than average conditions. This issue is discussed further under the topic "Maximum Water Table Level."

To help understand the role of springs and seeps in groundwater discharge, the staff issued RAI 826, Question 02.04.12-9. In a December 11, 2008, response, the applicant provided a figure showing the locations of springs and seeps in relation to the WLS nuclear island. The applicant stated that, in 1973, springs and seeps were observed in various locations across the site, but predominantly in drainage channels. Cut-and-fill activities associated with the Cherokee Nuclear Plant buried most of those locations. In 2006, springs and seeps were much less prevalent and none was near the proposed site for the nuclear island. The applicant also stated that the number of springs and seeps observed in 2006 may have been affected by the excavation dewatering, which began in December 2005. The figure provided by the applicant helped the staff to recognize the association of seeps with drainages and the proximity of those drainages to the WLS nuclear island. This information was sufficient for the staff to perform and complete its review. The staff concluded that the applicant's December 11, 2008, response to RAI 826, Question 02.04.12-9, was acceptable and considers the question resolved.

To clarify the applicant's usage of the technical term "preferential" with regard to groundwater flow, the staff issued RAI 70, Question 02.04.12-17. In a July 31, 2009, response, the applicant agreed to use the term "limiting" in place of "preferential" when referring to the groundwater flow path that represents the shortest travel time, and to revise the WLS COL FSAR accordingly. The applicant also acknowledged the potential for buried Cherokee pipes to act as preferential flow paths, in the sense that they may provide high-permeability paths for groundwater flow. The applicant evaluated the expected post-construction groundwater surface and determined that the pipe that runs from the nuclear power block area north to Hold-Up Pond A could be below the future groundwater surface and therefore could act as a preferential pathway. The applicant proposed to update the WLS COL FSAR to explain the issue and stated that the buried pipe and bedding material would be removed. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.2, "Sources." The staff concluded that the applicant's July 31, 2009, response to RAI 70, Question 02.04.12-17, was acceptable and considers the question resolved.

Offsite Wells

Information Submitted by the Applicant

The applicant provided information about offsite wells in WLS COL FSAR 2.4.12.2. This information was provided for the staff to identify potential groundwater pathways and determine whether construction and operation of the WLS nuclear plants could affect offsite wells. In response to two staff RAIs, the applicant provided additional information about the locations of groundwater users near the site.

The Staff's Technical Evaluation

The staff reviewed the applicant's information about offsite wells. The staff concluded that additional information was required to complete its evaluation of risks to offsite groundwater users.

To help understand the locations of groundwater users near the site who might be at risk, the staff issued RAI 826, Question 02.04.12-2. In a December 11, 2008, response, the applicant provided information about well depth, well abandonment, and conversion to municipal water. The applicant reported that only 3 of the 50 wells identified in the Cherokee Nuclear Station Environmental Report were drilled deeper than 45.7 m (150 ft). Since 1985, the State of South Carolina reported 22 wells drilled deeper than 45.7 m (150 ft) within 1.6 km (1 mi) of the WLS site property boundary. The applicant provided information from the Draytonville Water District showing that 55 percent of residents within 3.2 km (2 mi) of the reactor buildings had connected to the public water supply and that, based on planned expansion, service would be available to 83 percent of residents in 2009. The applicant stated that it did not detect a trend to abandon existing wells.

The staff noted that all of the public wells are more than 0.8 km (0.5 mi) from the proposed nuclear island. In addition, all of the 22 wells drilled to deeper than 45.7 m (150 ft) since 1985 are more than 1.6 km (1 mi) from the proposed nuclear island and all are separated from the WLS nuclear island by a water body (i.e., the Broad River; Make-Up Pond A; Make-Up Pond B). Therefore, the staff concluded that it is unlikely that groundwater uptake would be directly involved in a groundwater radionuclide pathway. The staff concluded that the applicant's December 11, 2008, response to RAI 826, Question 02.04.12-2, was acceptable and considers the question resolved.

To help understand potential risks to groundwater users near the site, the staff issued RAI 826, Question 02.04.12-7. In a December 11, 2008, response, the applicant stated that WLS COL FSAR Figure 2.4.12-202 was developed using data from the period from 1976 to 1985 during which the Cherokee Nuclear Station was dewatering the excavation. The staff notes that annual precipitation during this period ranged from 72 to 134 percent of normal, suggesting that the groundwater observations span a reasonable range of precipitation conditions. The applicant stated that the [name withheld] well is located 1,524 m (5,000 ft) south of the nuclear island. At that distance, the well is outside the zone of influence of the construction dewatering. The applicant stated that the Piedmont aquifer consists of porous material above continuous bedrock and because there are no confining layers, the [name withheld] well likely produces water from the same unconfined aquifer as that which exists at the WLS site. The applicant proposed adding the offsite well information to the WLS COL FSAR to support the assumptions that offsite wells are not a potential contaminant transport pathway and that the wells would not be affected by construction and operation of the WLS reactors. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.2, “Sources.” The staff concluded that the applicant's December 11, 2008, response to RAI 826, Question 02.04.12-7, was acceptable and considers the question resolved.

Aquifer Properties

<u>*Information Submitted by the Applicant*</u>

The applicant provided information about the properties of aquifers at the site in WLS COL FSAR Section 2.4.12.2.4, and additional information in WLS COL FSAR 2.5.4. Aquifer materials described were the artificial fill, soil and saprolite, PWR, and fractured bedrock. Properties of particular interest to the staff were hydraulic conductivity, total porosity, and

effective porosity. These properties are primary influences on the direction and velocity of groundwater movement in the subsurface, and are among the major influences on movement of radionuclides that move with groundwater. Retardation of radionuclide movement by interaction with aquifer materials is discussed below in Section 2.4.13. In response to four staff RAIs, the applicant provided additional information about the methods used to determine porosity and effective porosity, the decrease of hydraulic conductivity with increasing depth, and the selection of a conservative hydraulic conductivity value for calculations of groundwater velocity.

The Staff's Technical Evaluation

The staff reviewed information provided by the applicant about the hydraulic properties of aquifer materials. The staff concluded that additional information about aquifer properties was required to support its evaluation of maximum groundwater levels and the direction and velocity of radionuclide movement with groundwater.

To clarify the methods used by the applicant to determine porosity, and to allow staff to evaluate the reasonableness of measured and estimated porosity values, the staff issued RAI 826, Question 02.04.12-4. In a December 11, 2008, response and subsequent May 12, 2009, response, the applicant stated that it had estimated the effective porosity for fill and a mix of residual soil and saprolite to be 0.09 and 0.20, respectively, using a USGS method that required particle size data. The applicant estimated the effective porosity for the PWR to be 0.08 by measuring the liquid drained from a single PWR sample. The staff reviewed and confirmed the calculations. The applicant compared the average hydraulic conductivity and effective porosity values of soil/saprolite and PWR at the WLS site to those at the Catawba Nuclear site, which is located in a similar piedmont region about 32 km (20 mi) to the east. Average hydraulic conductivities at the WLS site were 17 and 55 percent less for soil/saprolite and PWR, respectively, than at the Catawba site. The average effective porosity of the soil/saprolite at the WLS site was 77 percent of the value at Catawba. The average effective porosity of the PWR at WLS was 45 percent greater than that at Catawba. The applicant proposed to update WLS COL FSAR Tables 2.4.12-203 and 2.4.12-204. Subsequently, the applicant deleted WLS COL FSAR Table 2.4.12-203 because the information was contained in the text and in WLS COL FSAR Table 2.5.4-211. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.2, "Sources," and WLS COL FSAR Section 2.5.4, "Stability of Subsurface Materials and Foundations." The staff concluded that the applicant's December 11, 2008, and May 12, 2009, responses to RAI 826, Question 02.04.12-4, were acceptable and considers these questions resolved.

The applicant estimated the effective porosity of the PWR by saturating the sample, then allowing it to drain; the volume of the liquid that drains provides a measure of the effective porosity. This method is typically unable to drain all liquid that would normally drain in a field setting, thus the method underestimates effective porosity. The staff notes that the effective porosity of the PWR material is based on the measurement results for a single sample. However, comparison with the effective porosity at other sites shows it to be consistent. The staff concluded that using the effective porosity value, determined using the method described above, would be conservative for use in calculating travel time.

To clarify the source and validity of certain parameter values presented by the applicant, the staff issued RAI 826, Question 02.04.12-5. In the December 11, 2008, response, the applicant identified grain size distribution, specific gravity, unit weight of soil and hydraulic conductivity as

parameters that were measured using American Society for Testing and Materials procedures. The applicant identified total porosity and effective porosity as parameters that were calculated or estimated based on the values of other parameters. Total porosity was estimated using the dry unit weight and specific gravity of the soil and unit weight of water. Effective porosities of fill, soil, and saprolite were estimated using grain size distribution. The effective porosity of PWR was estimated using the saturated and drained unit weights. The staff reviewed the procedures and confirmed the calculations. The applicant proposed to update the WLS COL FSAR with this information about porosity estimation. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.2, “Sources,” and WLS COL FSAR Section 2.5.4, “Stability of Subsurface Materials and Foundations.” The staff concluded that the applicant’s December 11, 2008, response to RAI 826, Question 02.04.12-5, was acceptable and considers the question resolved.

To clarify the basis for an observed decrease in hydraulic conductivity with increasing depth, the staff issued RAI 826, Question 02.04.12-10. In a December 11, 2008, response, the applicant provided two figures, one showing the 1970s hydraulic conductivity data and the other the 2006 data. Both sets of data show that hydraulic conductivity of the PWR decreases with increasing depth. The applicant did not adjust or rectify the depths for different ground-surface elevation during these two periods. The applicant identified conservative values of hydraulic conductivity to be used in calculating travel time. For each material, the applicant defined the conservative hydraulic conductivity to be the geometric mean of all values above the median value for that material. For the PWR, the applicant used a slightly higher value (1.4×10^{-3} cm/s versus 1.0×10^{-3} cm/s (3.97 ft/day to 2.83 ft/day)) that was obtained in 2006 from an aquifer test conducted along the flow path expected to have the shortest travel time (i.e., the one going north from the proposed Unit 2 to the Broad River). The staff examined the figures provided by the applicant and confirmed that conductivity in the PWR decreases with depth. The staff considered the conductivity data and agreed that the value used for the PWR is conservative for travel-time calculations. The applicant proposed to update the discussion of hydraulic conductivity in the WLS COL FSAR. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.2, “Sources.” The staff concluded that the applicant’s December 11, 2008, response to RAI 826, Question 02.04.12-10, was acceptable and considers the question resolved.

To clarify what value of hydraulic conductivity should be used for conservative calculations of groundwater velocity, the staff issued RAI 70, Question 02.04.12-16. In a July 31, 2009, response, the applicant explained that tests conducted in the 1970s for the Cherokee site investigation provided results for unconsolidated material, which was a label that referred to the aquifer material without discriminating between soil, alluvium, saprolite, and PWR. The applicant described the current site conceptual model in terms of specific material (e.g., saprolite, PWR) rather than the bulk “unconsolidated material.” The applicant further explained that the PWR was the most transmissive material and that the hydraulic conductivity value of 1.4×10^{-3} cm/s (3.97 ft/day) was nine times greater than the median value. The applicant proposed to update the discussion of hydraulic conductivity in the WLS COL FSAR and clarify the data support and property estimates. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.2, “Sources.” The staff concluded that the applicant’s July 31, 2009, response to RAI 70, Question 02.04.12-16, was acceptable and considers the question resolved.

Alternative Flow Paths

Information Submitted by the Applicant

The applicant identified a single bounding groundwater pathway that could carry radionuclides from a postulated release to locations where groundwater could discharge to surface water by which members of the public could be exposed. Groundwater originates from precipitation that infiltrates into soil in upland areas. It then moves generally down slopes toward the Broad River and other surface-water bodies. The applicant did not describe how the bounding pathway was identified and did not evaluate alternative pathways.

In response to four staff RAIs, the applicant provided additional details regarding alternative groundwater pathways, the geologic materials along those pathways, the impact of temperature and dissolved solids on flow along groundwater pathways, and hydraulic gradients along those pathways.

The Staff's Technical Evaluation

To ensure that all possible groundwater flow paths are being considered, the staff issued RAI 826, Question 02.04.12-8. In a December 11, 2008, response, the applicant stated that WLS COL FSAR Figure 2.4.12-204, Sheet 8, which shows post-construction water table conditions, was produced from knowledge of 1973 groundwater conditions and the current water table. Using the same figure, the applicant identified five alternative conceptual flow paths from the nuclear island to the accessible environment. Subsequently, after revising the site layout and drainage plan, the applicant reduced the number of pathways to the four shown in WLS COL FSAR Table 2.4.12-1. The applicant identified Pathway 1 as the limiting flow path, meaning the most conservative pathway with respect to predicting the fastest contaminant movement. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.3, "Groundwater Movement." The staff concluded that the applicant's December 11, 2008, response to RAI 826, Question 02.04.12-8, was acceptable and considers the question resolved.

The staff determined that there was uncertainty in the geologic materials that are present along each plausible groundwater pathway. The staff also determined that the major materials, the soil, saprolite, and PWR, were all exposed in the existing excavation and that a postulated leak could enter any of these materials. To address these issues, the staff issued RAI 70, Question 02.04.12-15. In a December 18, 2009, response, the applicant assumed the presence of PWR (the most highly conductive of the three materials) for all pathways. Table 2.4.12-1 of this report shows the corresponding travel-time estimates are shorter and that Pathway 1, from Unit 2 to Hold-Up Pond A, has the shortest travel time and would therefore represent the most conservative pathway to use for the transport analysis in WLS COL FSAR Section 2.4.13. The applicant stated that a storm drain system (DRS) would be designed to route runoff from the nuclear power block area to reduce the potential for flooding. The applicant does not expect the DRS to cause any other groundwater pathway to have a shorter travel time than Pathway 1. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.2, "Sources."

Table 2.4.12-1 Pathway Descriptions and Travel-Time Estimates (for WLS COL FSAR Revision 1, actual geology was used; for WLS COL FSAR Revision 7, the geology for all pathways was assumed to be the PWR material)

Pathway Number	Groundwater Pathway Description	Estimated Travel Time (yr)	
		WLS COL FSAR Revision 1	WLS COL FSAR Revision 7
1	Unit 2 to Hold-Up Pond A	7.2	1.6
2	Unit 2 to the Broad River	2.8	2.7
3	Unit 2 to Make-Up Pond A	23	4.0
4	Unit 1 to Make-Up Pond B	9.8	5.5

The staff evaluated the pathways identified by the applicant and determined that they adequately represent the plausible pathways to each of the major water bodies. The travel paths are conservatively evaluated as straight lines rather than the curved flow paths indicated by the groundwater contour map. Post-construction water table elevations might cause slight differences in groundwater flow and direction, but any change from a straight line would only elongate the travel path and lengthen the travel time. Groundwater gradients would also be affected by post-construction water table elevations. For the travel-time estimates in Table 2.4.12-1 of this report, the applicant used its estimate of the maximum water table elevation of 178 m (584 ft) above MSL to calculate the gradient. The staff considers this choice conservative with respect to calculation of the groundwater gradient. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.3, “Groundwater Movement.” The staff concluded that the applicant’s December 18, 2009, response to RAI 70, Question 02.04.12-15, was acceptable and considers the question resolved.

Liquid released from the liquid waste management system could have a higher temperature and different content of dissolved solids than ambient groundwater. To address the possibility that this might affect groundwater flow paths, the staff issued RAI 826, Question 02.04.12-12. In a December 11, 2008, response, the applicant responded that the leaked fluid would have a total dissolved solids (TDS) content of less than 1 ppm. The applicant stated that any physical properties of the leaked fluid that differed from groundwater conditions would quickly dissipate relative to the travel time. That is, the leaked fluid would quickly take on the physical characteristics of groundwater and, therefore, would neither preferentially rise nor sink as it moved away from the nuclear island.

The staff examined AP1000 DCD Table 5.2-2, which lists the reactor coolant water chemistry specifications. AP1000 DCD Table 5.2-2 suggests the TDS could be as high as 2 parts per million (ppm) if all constituents were at their maximum values. Even if the TDS was 2 ppm, the concentration would still be much lower than the average groundwater TDS of 107 ppm. At the average groundwater temperature of 17ºC (63ºF), the density difference between liquids with 2 and 107 ppm would be less than 0.01 percent. However, the temperature in the effluent holding tank could be much higher than the ambient groundwater temperature. AP1000 DCD Table 11.2-2 lists the design temperature of the effluent hold-up tanks as 65.6ºC (150ºF). The

density of a liquid at that temperature and with a TDS of 2 ppm would be almost 2 percent less than the density of groundwater at the WLS site. Such a density difference could lead to buoyancy and affect hydraulic conductivity until the temperature difference dissipated. During that time, the buoyant leaked fluid could rise into shallower aquifer material and potentially travel via an alternate pathway. The staff considered the finite volume of leaked fluid and believes the temperature difference would dissipate quickly such that the fluid properties would resemble those of the ambient groundwater. Furthermore, if the initial properties of the leaked liquid caused it to flow upward or downward into an alternate flow path, the aquifer materials above and below are less transmissive than the PWR, which is the only material considered in the flow paths analyzed by the applicant. Since the leaked fluid properties exist for a limited time and only in the vicinity of the reactor buildings, and because alternate pathways would have less transmissive properties, the staff concludes that including a separate alternative pathway is not warranted. The staff concluded that the applicant's December 11, 2008, response to RAI 826, Question 02.04.12-12, was acceptable and considers the question resolved.

To clarify what groundwater elevations and travel distances should be used in calculating groundwater gradients, the staff issued RAI 826, Question 02.04.12-13. In a December 11, 2008, response, the applicant revised its estimate of the maximum groundwater elevation upward from 176.5 to 178.0 m (579 to 584 ft) above MSL based on the maximum height of water in the excavation, 176.5 m (579 ft) above MSL, and its expectation that seasonal groundwater variation would be approximately 1.5 m (approximately 5 ft). In subsequent updates to the WLS COL FSAR, the applicant estimated the distance from Unit 2 to the nearest edge of Hold-Up Pond A to be 405 m (1,330 ft). The applicant estimated the groundwater gradient to be 0.0368 between Unit 2 and Hold-Up Pond A and 0.036 between Unit 2 and the Broad River. The staff notes that the applicant updated WLS COL FSAR Figure 2.4.12-208 with the information necessary to calculate groundwater gradients. The staff concluded that the applicant's December 11, 2008, response to RAI 826, Question 02.04.12-13, was acceptable and considers the question resolved.

Maximum Groundwater Elevation

<u>Information Submitted by the Applicant</u>

The maximum allowable groundwater elevation is specified as a site parameter in the AP1000 DCD and is defined in the WLS COL FSAR to be less than plant elevation 29.87 m (98 ft). The initial WLS COL FSAR established the plant elevation to be equivalent to the local elevation of 179.83 m (590 ft) above MSL. Therefore, the maximum allowable groundwater elevation was limited by the AP1000 DCD requirement to be less than 179.22 m (588 ft) above MSL. Throughout most of the staff review period, the maximum allowable groundwater elevation remained unchanged, thus, most of the following discussion refers to maximum groundwater elevation of 179.22 m (588 ft) above MSL.

Due to of changes to the site layout and grading, the current WLS COL FSAR establishes plant elevation to be 180.7 m (593 ft) above MSL. Therefore, the maximum allowable groundwater elevation is limited by the AP1000 DCD requirement to be less than 180.14 m (591 ft) above MSL.

In the earlier versions of the WLS COL FSAR, the applicant stated that the maximum actual groundwater elevation was expected to be 178.00 m (584 ft) above MSL. The applicant based

this maximum actual groundwater elevation on the pre-development groundwater elevations, anticipated land-surface elevations, elevations of surface-water bodies such as the make-up ponds, water elevation in the excavation left after Cherokee plant construction, and seasonal groundwater levels observed in monitoring wells.

In response to five staff RAIs, the applicant provided additional information about establishing the maximum groundwater elevation, characterizing the post-construction groundwater elevations, site grading and drainage. Based on all the information made available, the applicant conducted groundwater modeling to estimate the maximum groundwater elevation. The highest modeled groundwater elevations near the plant were 179.0 and 179.1 m (587.2 and 587.5 AP1000 DCD ft) above MSL.

The Staff's Technical Evaluation

The staff reviewed the applicant's information and analysis related to groundwater levels. The staff paid particular attention to the approach that the applicant used to estimate maximum post-construction groundwater levels. The staff concluded that this approach, while valid in a broad sense, relied too much on generalizations and individual judgment to predict maximum groundwater levels accurately enough to ensure that the AP1000 DCD requirement would be met. To obtain more exact information, the staff issued a series of RAIs to examine the bases of the applicant's groundwater level estimates and to examine the applicability of alternative calculation techniques. Discussion of these RAIs is organized into the four following unnumbered sections corresponding to the principal topics addressed by the RAIs.

Initial Non-Modeling Estimates of Groundwater Elevations

To examine the value of using water marks left by water in the excavation as indicators of groundwater level, and related topics, the staff issued RAI 826, Question 02.04.12-6. In a December 11, 2008, response, the applicant stated it did not have a precise record of the dewatering activities previously carried out during the construction of the Cherokee Nuclear units, and did not know whether there were any dewatering activities during the period after Cherokee construction ceased and before December 2005, when the applicant initiated dewatering of the Cherokee excavation pit. The applicant provided aerial photographs for two dates, February 1994 and February 2005, which show water levels in the excavation pit relative to the Cherokee structures. The applicant used a topographic survey conducted in 2006 to estimate that water-surface elevation in the excavation pit varied between 175.0 and 176.5 m (574 and 579 ft) above MSL from 1994 through 2005. The applicant noted that the average groundwater level fluctuation during the period from April 2006 to April 2007 was 1.4 m (4.5 ft). The applicant estimated, given that the high-water mark in the excavation was determined to be 176.48 m (579 ft) above MSL, the design groundwater elevation to be 176.5±1.5 m (579±5 ft) above MSL, which allows for a 1.5 m (5 ft) seasonal variation over the high-water mark. The current WLS COL FSAR contains this information.

The applicant presented evidence of water levels in the excavation to justify the selection of 178.0 m (584 ft) above MSL as the maximum water table elevation. The staff concluded that the water levels were controlled by the net lateral flux of groundwater and by precipitation and open-water evaporation. Groundwater flow away from the excavation has been facilitated, in part, by the presence of preferential flow paths created by the stormwater drains emplaced

during Cherokee-era construction. The applicant acknowledged such preferential paths exist and committed to removing those drains.

- LWS Proposed License Condition 15: Prior to fuel load, the licensee shall confirm that a single legacy Cherokee project stormwater drain line (designed to transfer stormwater from the Cherokee power block area to Hold-Up Pond A) and any associated bedding material representing a potential preferential groundwater pathway have been removed and the excavation has been backfilled with compacted native soils.

Due to of uncertainty in the water balance of the excavation, the staff does not consider information regarding water levels sufficient to estimate the maximum water table level.

To understand how the applicant had estimated the post-construction configuration of the groundwater surface, and the factors that would control the post-construction groundwater surface at the site, the staff issued RAI 826, Question 02.04.12-14. In a December 11, 2008, response, the applicant reiterated that its estimated post-construction groundwater levels are based on the current water table and pre-construction water table. Water table elevations are expected to conform generally to the surface topography, as modified by WLS construction. The applicant did not recommend modeling of groundwater at the time of the response. The applicant expected to implement a groundwater monitoring program after construction.

To obtain additional information necessary for understanding the data and methods that the applicant used to estimate the post-construction configuration of the groundwater surface, the staff issued RAI 17, Question 02.04.12-19. In a September 30, 2010, response, the applicant provided information about its conceptual model of the post-construction conditions, backfill materials, site grading and drainage, ground cover and stormwater management, and post-construction groundwater flow conditions and maximum groundwater level.

The applicant reiterated that the site conceptual model would be consistent with the Piedmont Master Conceptual Model of LeGrand. In that conceptual model, groundwater is controlled by surface drainages and a two-layer slope-aquifer system in which the aquifer consists of residual soil and saprolite overlying weathered and unweathered bedrock.

The applicant stated that the excavation would be filled with engineered backfill around each of the two nuclear islands and extending outward to form the foundation support of the adjacent buildings. Although the exact properties of the engineered fill are yet to be determined, the applicant stated that the hydraulic conductivity would be 10 to 100 times greater than that of in situ residual soil and saprolite. In WLS COL FSAR Section 2.5.4, the applicant stated that the hydraulic conductivity of the engineered fill would fall between 0.00501 cm/s (14.2 ft/day) and 0.0750 cm/s (212.6 ft/day). This range of values is greater than the conservative value of 0.00140 cm/s (3.97 ft/day) for the hydraulic conductivity of the PWR. The applicant provided WLS COL FSAR Figure 2 to show the area receiving the engineered fill. Backfill in the areas beyond the engineered fill would be compacted residual soil and saprolite material with conductivity slightly lower than undisturbed residual soil and saprolite, so somewhat less than 1.1×10^{-4} cm/s (0.32 ft/day). The staff considers these values sufficiently similar to values for the surrounding material such that groundwater conditions would not be appreciably altered.

The applicant stated that the surface around the WLS site is relatively flat and gently slopes away from the plant. The applicant stated that surface topography would be graded to facilitate stormwater runoff away from safety-related structures.

The applicant stated that the 179.2 m (588 ft) above MSL contour that surrounds the nuclear power block areas would enclose an area of 26.5 ha (65.4 ac). Of that, 15.4 percent (4.1 ha (10.1 ac)) would be impervious surfaces such as roads and parking lots and 20 percent (5.2 ha (12.9 ac)) would be semi-impervious compacted gravel (or similar hardscaped material) that reduces infiltration and promotes runoff. Stormwater runoff from the impervious and semi-impervious areas would be collected in the DRS and routed away from the nuclear power block area to reduce the potential for flooding. About 11.8 percent (3.1 ha (7.7 ac)) of the area would be buildings. Precipitation that falls on those buildings would be collected by a roof drain collection system and routed through downspouts into the DRS piping network. The remaining area, about 53 percent (14 ha (34.7 ac)), would be a grass surface cover. The applicant provided a figure that shows that the grass area would surround, but not occur within, the nuclear power block area.

The applicant considered post-construction groundwater conditions and concluded that the structures would not significantly affect groundwater flow. The applicant stated that the high conductivity of the engineered backfill would help equilibrate any local groundwater perturbation. The applicant reiterated that Cherokee-era drains that could affect groundwater would be removed. The applicant concluded that the post-construction groundwater flow would return to conditions consistent with the Piedmont Master Conceptual Model. The applicant proposed to update the WLS COL FSAR with this information about the data and methods used to estimate the post-construction configuration of the groundwater surface. The staff confirmed that the changes were included in WLS COL FSAR.

The staff reviewed the material provided by the applicant. The key reference, LeGrand, provides a synthesis of knowledge related to natural conditions in the Piedmont and can be used to understand the hydrology of the WLS site prior to Cherokee construction. LeGrand does not provide guidance when a site has been significantly altered. The cut-and-fill operations that occurred during Cherokee construction reworked the topography and hydrogeology so extensively that it no longer resembles a typical Piedmont setting. The buildings and extensive impervious surfaces of the WLS site will further diminish the resemblance to a typical Piedmont setting. Thus, generalizations based on LeGrand are not entirely applicable to the WLS site.

The staff considered the post-construction surface conditions provided by the applicant. Runoff and roof drainage are routed to the DRS network, but the terminus of the network is unknown. The termination of the DRS network in the drainages that surround the plant could lead to increased recharge in these areas. The applicant stated that 20 percent of the nuclear power block area would be semi-impervious and 53 percent of the area around the nuclear power block would be grass, but no estimate of recharge was provided for either area. Given the properties of residual soil and saprolite, an average recharge rate of 5.1 cm/yr (2 in/yr) could be sufficient for groundwater to rise to the surface.

The applicant proposed to update the WLS COL FSAR with respect to water table elevation calculations, backfill properties, qualitative descriptions of surface conditions, and a description of a roof drainage system. The staff reviewed the WLS COL FSAR and confirmed that the

applicant made the proposed changes. However, staff considered the issue of the maximum water table elevation unresolved; with the resolution of this issue is discussed below.

Recharge Rates and Initial Modeling of Groundwater Elevations

The staff requested estimates of the maximum post-construction groundwater level that is based on anticipated post-construction recharge rates associated with the main surface features and potential groundwater mounds beneath the cooling towers and drainage ditches to better understand how the post-construction groundwater surface would respond.

To obtain additional information needed for the staff's review of the maximum groundwater level, the staff issued RAI 94, Question 02.04.12-20. In a May 18, 2011, response, the applicant provided information to support the view that the post-construction groundwater elevation would not exceed 179.2 m (588 ft) above MSL. The new information consisted of (1) estimates of annual average and maximum recharge rates, (2) a one-dimensional (1-D) analytical method to estimate water table fluctuations in response to recharge, and (3) a quasi two-dimensional (2-D) semi-analytical method to estimate water table fluctuations in response to recharge.

The applicant used annual values of precipitation, evaporation, and runoff to estimate an average annual recharge rate of 13 cm/yr (5.1 in/yr) and a maximum post-construction recharge rate of 21 cm/yr (8.2 in/yr). Recharge is a very site-specific process and the rate of recharge must be estimated for specific soil and vegetation conditions. For example, recharge into an unvegetated surface material (e.g., each of the semi-impervious materials described in the WLS COL FSAR) is expected to differ from recharge into grass-covered fill material. Recharge is also dependent on event-specific weather conditions and could be underestimated if processes such as precipitation, evaporation, runoff, and transpiration are represented as annual average values. Given the information presented by the applicant, the staff could not determine whether the proposed values are appropriate to represent the post-construction conditions at the proposed WLS site.

The applicant used a 1-D analytical method based on specific yield to estimate groundwater fluctuation. The applicant noted that the specific yield estimate for well MW-1215 was 0.0041, but claimed that it would underestimate recharge and substituted effective porosity for specific yield in the analysis. For fill, soil/saprolite, and PWR, the effective porosities are 0.09, 0.2, and 0.08, respectively. Using the average effective porosity of 0.145 for fill and soil/saprolite ((0.09+0.20)/2) = 0.145), the COL applicant estimated a 1.43 m (4.7 ft) groundwater rise for the maximum recharge event of 21 cm (8.2 in.) (i.e., the entire annual recharge amount occurred in a single event). Assuming the event occurred when the water table started at 175.7 m (576.5 ft) above MSL (pre-construction elevation in excavation), the final groundwater elevation was estimated by the applicant to be 177.2 m (581.2 ft) above MSL. Had the applicant used the actual specific yield of 0.0041 (from well MW-1215), the estimated rise in groundwater level would have been more than 30 m (100 ft) in excess of the AP1000 DCD level of 179.2 m (588 ft) above MSL. The applicant did not address possible variations in specific yield and did not justify the conservativeness in its estimate of specific yield. The staff identified additional questions relating to specific yield or effective porosity is the appropriate parameter by which to characterize water table fluctuation when groundwater as near the soil surface.

The applicant also used a 2-D semi-analytical method described by Park and Parker to estimate groundwater fluctuations in response to precipitation that varies over time. The applicant applied the method by representing the maximum recharge event (21 cm/yr (8.2 in/yr)) with four 5.21 cm (2.05 in.) events on four separate days distributed somewhat evenly throughout the year. The applicant estimated the model parameters but did not calibrate the model to the actual WLS site. The applicant estimated the maximum water table rise to be 0.37 m (1.2 ft). The applicant's analysis appeared to assume that temporary mounding above the AP1000 DCD value for maximum groundwater level was not a problem, whereas the regulatory requirement is that the maximum groundwater elevation must be less than AP1000 DCD value at all times.

Groundwater Modeling Using MODFLOW: Model Conditions

After the initial estimation of maximum groundwater elevations as described above, the applicant estimated post-construction groundwater elevations by conducting computer modeling using the MODFLOW program.

Additional information relevant to groundwater modeling was provided in the applicant's November 22, 2011, response to RAI 484, Question 10.04.05-2. Although this RAI requested information about Standard Review Plan (SRP) Section 10.04.05, Circulating Water System, the response also contained information about changes to site surface grading and drainage. This information is relevant because the configuration of the land surface is one of the inputs for groundwater modeling. In this response, the applicant stated that the ridge to the northwest of Unit 1 and the two cooling-tower berms would be removed. Site grading in the area of the nuclear power block would be reshaped to promote drainage away from the nuclear island. The surface would grade down to the 178.8 m (586.5 ft) elevation of the vehicle barrier system that would surround the two units. Beyond the vehicle barrier system, the surface would grade down 0.3 to 0.5 m (1 to 1.5 ft) before it engages steeper slopes to the adjacent water bodies.

The applicant provided a second response to RAI 94, Question 02.04.12-20, on November 22, 2011, in which the applicant used groundwater simulations to demonstrate that the AP1000 DCD requirement regarding the maximum groundwater level would be met. The applicant conducted seven groundwater simulations using MODFLOW 2000, Version 1.19.01, embedded in the pre- and post-processing package called Groundwater Vistas.

For the simulations, the applicant established an initial potentiometric surface, an extreme precipitation event, model domain, material properties, boundary conditions, a base case and set of sensitivity cases, and six observation points around the perimeter of both units.

Based on the new site grading and drainage plan, the placement of impervious surfaces, and knowledge of groundwater hydrology in the Piedmont and at the WLS site, the applicant updated the post-construction potentiometric surface map. The new map shows groundwater levels grading from 176.8 m (580 ft) above MSL along the south end of the reactor area to 173.7 m (570 ft) above MSL along the north end.

For the extreme event, the applicant chose Tropical Storm Jerry, which occurred in August 1995. The total precipitation received at the Greenville-Spartanburg Airport during the 47-hour storm was 36.75 cm (14.47 in.). During a single day of that storm, 31.29 cm (12.32 in.) of rain was received, which is the highest 24-hour total in the 45-year record and far exceeds the next highest 24-hour amount of 15.77 cm (6.21 in.) received in September 1972.

The applicant set up the model domain as a square, 914 m (3,000 ft) on each side, centered on the two units and encompassing the vehicle barrier system. Table 2.4.12-2 of this report shows the hydraulic parameters were assigned according to the geologic descriptions in the WLS COL FSAR. For each material, the applicant used the median values for hydraulic conductivity and specific yield. For building foundations and vehicle barrier system, the applicant assumed values that were much lower than those for the geologic materials.

Table 2.4.12-2 Hydraulic Parameters Used in the MODFLOW Simulations

Material	Hydraulic Conductivity (cm/s [ft/day])	Specific Yield (-)
Building Foundations	3.53×10^{-8} (0.0001)	0.001
Granular Backfill	0.011 (31.18)	0.20
Soil Backfill	5.39×10^{-5} (0.1528)	0.09
Soil/Saprolite	1.14×10^{-4} (0.3232)	0.20
Partially Weathered Rock	1.53×10^{-4} (0.4337)	0.08

The boundary conditions were defined for the base of the domain, the sides (groundwater inflow and outflow), and the top in the form of recharge. The base of the model domain was assumed to be no flow. The sides of the model domains were represented with a constant head boundary on the south side of the domain and general head boundaries along the remainder of the domain.

Water input at the top of the model domain was defined by the precipitation event and the runoff-recharge relationship for each surface condition. The precipitation event was modeled as three events. First, a 47-hour storm was applied at rates equivalent to 40 percent of those for Tropical Storm Jerry. Second, a period of 72 hours with no precipitation was imposed to allow the groundwater to equilibrate to the precipitation just received. Finally, the hourly precipitation record of Tropical Storm Jerry was applied.

Precipitation received at the surface was partitioned into runoff according to methodology described by the USDA. The USDA method relies on knowledge of the surface condition, soil type, and vegetation. For each of the 22,576 model cells, the applicant assigned one of the following surface types: buildings; roads; vehicle barrier system; hardscape; grass; and brush. For each surface type, the applicant selected a runoff curve number from the tables provided by USDA and used it to represent the percentage precipitation that would run off. In the case of the grass cover, the applicant added the runoff from buildings, roads, and vehicle barrier system to the amount of precipitation before calculating runoff from grass.

The applicant assumed no interim water storage on the surface such that water that did not run off infiltrated the surface. The applicant assumed no evapotranspiration and no time delay as water moved through the vadose zone to the groundwater. Thus, the applicant used the infiltration rate to define the upper recharge boundary condition.

Groundwater Modeling Using MODFLOW: Results of Simulations

The applicant conducted seven simulations. For the base case (Run 1), it used the projected post-construction potentiometric surface, median hydraulic parameters, and Type B soils (per USDA). The six sensitivity cases examined the impact of a higher initial potentiometric surface (Run 2), lower conductivity values (Run 3), minimum specific yield values (Run 4), maximum specific yield values (Run 5), Type A (instead of Type B) soils (Run 6), and a combination that included lower conductivities and specific yields and Type A soils (Run 7).

The base case results showed that the highest groundwater elevations occurred at the two observation points on the south side of the units. The highest elevation, 177.4 m (582.2 ft) above MSL, occurred just to the southwest of Unit 1. Just to the north of the units, the groundwater elevations are around 175.3 m (575 ft) above MSL. For the sensitivity cases, the highest groundwater elevations always occurred at the two southern observation points. Runs 2 and 7 yielded the highest overall elevations, 179.0 and 179.1 m (587.2 and 587.5 ft) above MSL, respectively. The applicant stated that its analysis demonstrated compliance with the AP1000 DCD site parameter criteria for maximum groundwater level of 149 m (588 ft) above MSL. The applicant provided a copy of all MODFLOW input files to the staff.

The staff examined the proposed site grading and drainage plans and believes it would significantly enhance the ability of the site to increase runoff, reduce recharge, and reduce the potential for groundwater to rise above the AP1000 DCD limit of 179.2 m (588 ft) above MSL. High elevations to the northwest, west, and east that could have increased groundwater levels have been removed. Surface topography slopes down from the units in all four directions, thus facilitating runoff removal in all directions. The maximum elevation of the surface drainage to the southwest is 178.8 m (586.5 ft) above MSL; this ensures that higher groundwater levels further south would not propagate northward to the nuclear islands.

The staff examined the proposed post-construction potentiometric surface. In contrast to the previous map, the new map does not show two groundwater divides on either side of the reactor area. Consistent with that change, the new groundwater levels are about 1.5 m (5 ft) lower than previous estimates. The staff notes that the proposed map appears to be reasonable and consistent with knowledge of the area.

The staff examined the MODFLOW analysis. The use of the precipitation record from Tropical Storm Jerry to evaluate maximum water table rise is appropriate. The event far exceeds the 100-year storm of 18 cm (7.2 in.) predicted for the Cherokee County. Including a pre-storm that adds 40 percent of tropical storm Jerry precipitation adds conservatism. In fact, the total precipitation added (51.46 cm (20.26 in.)) in the 7-day simulation far exceeds all monthly precipitation records.

The staff examined the model domain. Cell sizes are smaller in the reactor areas and larger away from the reactors. The extent of the domain does not extend to natural boundaries such as Make-Up Pond B and the Broad River. Instead, the applicant chose to focus the analysis on a smaller domain. Doing so required establishing head boundary conditions at interim locations. The analysis only addresses a short period of 7 days. In that time, any effects from lateral boundary conditions would not be discernible. As a result, the staff performed confirmatory analyses as described below.

The staff examined the material properties and confirmed they are reasonable to somewhat conservative with respect to hydraulic conductivity. The applicant's groundwater modeling was based on the median hydraulic conductivity for the well-graded gravel granular material ($1.1\text{x}10^{2}$ cm/sec (11,381 ft/year)). In WLS COL FSAR Table 2.5.4-211, the minimum value of hydraulic conductivity reported for the poorly graded gravel granular fill materials is stated as "<~5.0E-03" cm/sec ("<~5,173" ft/year). The MODFLOW sensitivity case Run 3 examined the impact of using minimum conductivity values. The result was an increase in the maximum groundwater elevation to 177.2 m (581.47 ft), which is only 0.02 m (0.08 ft) above the base case (Run 1) and far below the assumed maximum groundwater elevation of 178.0 m (584 ft).

The staff examined the boundary conditions. Using a no-flow bottom boundary is consistent with data from the site. Even if there was a small amount of flow, up or down, the fluxes would be too small to affect a 7-day simulation. Therefore, the lateral boundary conditions are not ideal, so the staff ran the base case with different lateral boundary conditions and confirmed that these boundaries do not measurably affect the results of the short 7-day simulations.

The staff examined the methodology used to calculate runoff and establish recharge rates. It appears to the staff that the applicant treated the runoff curve numbers as runoff coefficients (i.e., percentages) rather than as parameters in the USDA's Equation 2.3. The staff used Equation 2.3 to calculate the true runoff percentage, which yielded a runoff fraction that was slightly higher than the value determined by the applicant. The applicant's calculation resulted in slightly higher recharge rates, which its analysis revealed would not cause the site to exceed the AP1000 DCD requirement. Repeating the applicant's analysis with the slightly lower but correct recharge rates would yield the same result.

Table 2.4.12-3 of this report lists the runoff coefficients used to establish recharges rates for the MODFLOW simulations. The staff examined the applicant's choices of runoff curve numbers to represent surface conditions at the site and identified some differences from how the staff would parameterize the site. The practice is to route the runoff from buildings and roads to hardscape, and runoff from hardscape to grass.

Using the runoff curve numbers and runoff routing method described above, the staff repeated the base-case simulation. The results at the observation points showed very little difference from the applicant's results. This lack of sensitivity is due in part to the relatively low recharge rates in the hardscape and to the high conductivity of the engineered fill, which quickly dissipates local groundwater mounds caused by variations in recharge rates.

The staff's review confirmed that groundwater would not exceed an elevation of 179.2 m (588 ft) MSL. As noted above, because recent changes to the site grading yielded a higher plant elevation, the current WLS COL FSAR requires the maximum groundwater elevation to be less than 180.1 m (591 ft). Since all other conditions remain the same, the staff affirms that the site groundwater would not exceed an elevation of 180.1 m (591 ft) MSL.

In summary, the applicant described changes to the site grading and drainage plan and provided groundwater modeling results to support its assessment that the site meets the AP1000 DCD requirement relative to the maximum groundwater elevation. The staff evaluated the site grading changes and the modeling analysis and conducted confirmatory modeling analyses. Since the applicant used a very extreme storm event, did not account for evaporation or transpiration, and did not account for runoff that would be routed well away from the site

before it could infiltrate, the staff concluded that the site would be able to meet the AP1000 DCD requirement. The staff notes that the applicant included a description of the latest site grading and drainage plan, the vehicle barrier system, and the groundwater modeling analysis in WLS COL FSAR Section 2.4.12.2, "Sources." The staff concluded that the applicant's responses to RAI 826, Questions 02.04.12-6, and 02.04.12-14; RAI 17, Question 02.04.12-19; RAI 94, Question 02.04.12-20; and RAI 484, Question 10.04.05-2, were acceptable. Accordingly, the staff considers these questions resolved.

Table 2.4.12-3 Runoff Curve Numbers Used to Estimate Recharge

Surface Condition	Runoff Curve Numbers				Comments
	Applicant		NRC Staff		
	Type B Soils	Type A Soils	Type B Soils	Type A Soils	
Buildings	100	100	100	100	A value of 100 is not provided in USDA (1986), but staff judged it to be sufficient given the stated intent of the applicant to manage all precipitation that falls on buildings. The applicant routed runoff to grass, the staff routed runoff to hardscape
Roads	100	98	89	83	The applicant used USDA (1986) values associated with curbed roads; the staff used values associated with uncurbed roads. The applicant routed runoff to grass; the staff routed runoff to hardscape
Hardscape	85	76	85	76	Both the applicant and the staff routed runoff to grass
VBS	100	98	98	98	The applicant used value of 100 for Type B soil; the staff used value of 98. Both the applicant and the staff routed runoff to grass
Brush	82	72	48	30	The applicant used values for dirt (Table 2-2a, USDA 1986); the staff used values for brush (Table 2-2c, USDA 1986)
Grass	61	61	61	39	Applicant used value for Type A soil that is not consistent with USDA (1986)

Monitoring

Information Submitted by the Applicant

The applicant stated that a groundwater monitoring program would be developed. The applicant provided a list of three areas within the site to be considered for monitoring and a list of generalized considerations for implementation of the program. In response to a staff RAI requesting details, the applicant provided additional information about post-construction monitoring plans to reduce uncertainties in groundwater flow paths used for WLS COL FSAR Section 2.4.13.

The Staff's Technical Evaluation

In the December 11, 2008, response to RAI 826, Question 02.04.12-11, the applicant described post-operational monitoring activities that address traditional monitoring goals as well as goals related to reducing uncertainties about the plausible groundwater pathways. The activities include placement of near-field and far-field wells to detect early releases and to verify that there is no offsite migration, and placement of both shallow and deep wells to monitor plausible flow paths close to the facilities. The applicant stated that the post-construction groundwater monitoring program would be consistent with the guidance provided by the Nuclear Energy Institute (NEI 2009), which references NEI and EPRI. The staff reviewed those references and confirmed they would form the basis for an adequate monitoring program. The staff notes that the applicant included this monitoring information in WLS COL FSAR Section 2.4.12.4, "Monitoring or Safeguard Requirements." The staff concluded that the applicant's December 11, 2008, response to RAI 826, Question 02.04.12-11, was acceptable and considers the question resolved.

2.4.12.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.12.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant addressed the information relevant to groundwater, and that there is no outstanding information required to be addressed in the WLS COL FSAR related to this section. As set forth above, the applicant presented and substantiated information to establish the site description. The staff reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.12, herein, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This applicant addressed groundwater in COL Information Item 2.4-4. The staff concludes that the applicant provided sufficient information on groundwater characteristics to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

2.4.13 Accidental Release of Radioactive Liquid Effluent in Ground and Surface Waters

2.4.13.1 *Introduction*

This section of the WLS COL FSAR provides a characterization of the attenuation, retardation, dilution, and concentrating properties governing transport processes in the surface-water and groundwater environment at the site. The goal of this section is not to provide an assessment of the effects of a specific release scenario but to provide a suitable conceptual model of the hydrological environment for other assessments. Since it would be impractical to characterize all the physical and chemical properties (e.g., hydraulic conductivities, porosity, and mineralogy) of a time-varying and heterogeneous environment, the section characterizes the environment in terms of the projected transport of a postulated release of radioactive waste. The accidental release of radioactive liquid effluents in ground and surface waters is evaluated using information about existing uses of groundwater and surface water and their known and likely future uses as the basis for selecting a location to summarize the results of the transport calculation. The source term from a postulated accidental release is reviewed under NUREG-0800, Section 11.2, following the guidance in Branch Technical Position (BTP) 11-6, “Postulated Radioactive Releases Due to Liquid-containing Tank Failures.”

The source term is determined from a postulated release from a single tank outside of the containment. The results of a radionuclide transport analysis are evaluated against SRP Section 11.2 and BTP 11-6 guidance and effluent concentration limits (ECLs) as acceptance criteria to meet the requirements of 10 CFR Part 20, Appendix B, as SRP acceptance criteria. Under SRP guidance, the effluent concentration limits of 10 CFR Part 20, Appendix B, are applied as acceptance criteria only for the purpose of assessing the acceptability of the results of the consequence analysis and are not intended for demonstrating compliance with ECLs.

The following specific areas are reviewed by the staff: (1) alternative conceptual models of the hydrology at the site that reasonably bound the site’s hydrogeological conditions to the degree that these conditions affect the transport of radioactive liquid effluent in the groundwater and surface-water environment; (2) a bounding set of plausible surface and subsurface pathways from potential points of an accidental release to determine the critical pathways that may result in the most severe effect on existing uses and known and likely future uses of groundwater and surface-water resources in the vicinity of the site; (3) the ability of the groundwater and surface-water environments to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluents during transport; and (4) the assessment of scenarios wherein an accidental release of radioactive effluents is combined with potential effects of seismic and non-seismic events.

2.4.13.2 *Summary of Application*

This section of the WLS COL FSAR addresses the accidental release of radioactive liquid effluents in groundwater and surface waters. The applicant addressed information related to accidental release of radioactive liquid effluents as follows:

AP1000 COL Information Item

- COL Information Item 2.4-5

In addition, this section addresses the following COL-specific information identified in AP1000 DCD Section 2.4.1.5, Revision 19.

> Combined License applicants referencing the AP1000 certified design will address site-specific information on the ability of the ground and surface water to disperse, dilute, or concentrate accidental releases of liquid effluents. Effects of these releases on existing and known future use of surface water resources will also be addressed.

2.4.13.3 *Regulatory Basis*

The relevant requirements of NRC regulations for the pathways of liquid effluents in ground and surface waters, and the associated acceptance criteria, are specified in NUREG-0800, Section 2.4.13.

The applicable regulatory requirements for evaluating accidental release of radioactive liquid effluents in ground and surface waters are set forth in the following:

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

The staff also used the acceptance criteria identified in NUREG-0800, Section 2.4.13:

- Alternate Conceptual Models: Alternate conceptual models of hydrology in the vicinity of the site are reviewed.

- Pathways: The bounding set of plausible surface and subsurface pathways from the points of release are reviewed.

- Characteristics that Affect Transport: Radionuclide transport characteristics of the groundwater environment with respect to existing and known and likely future users should be described.

- Consideration of Other Site-Related Evaluation Criteria: The COL applicant's assessment of the potential effects of site-proximity hazards, seismic, and non-seismic events on the radioactive concentration from the postulated tank failure related to

accidental release of radioactive liquid effluents to ground and surface waters for the proposed plant site is needed.

- BTP 11-6 provides guidance in assessing a potential release of radioactive liquids after the postulated failure of a tank and its components, located outside of containment, and effects of the release of radioactive materials at the nearest potable water supply, located in an unrestricted area, for direct human consumption or indirectly through animals, crops, and food processing.

In addition, the hydrologic characteristics should conform to appropriate sections from RG 1.113, "Estimating Aquatic Dispersions of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I."

The staff used best current practices to analyze groundwater transport of radioactive liquid effluents. The regulatory basis of the information incorporated by reference is addressed in the staff's FSER for the AP1000 certified design, NUREG-1793.

2.4.13.4 *Technical Evaluation*

The staff reviewed WLS COL FSAR Section 2.4.13 Revisions 0 to 7; corrections and additions to the WLS COL FSAR submitted by the applicant as letters; and associated applicant responses to RAIs issued by the staff. The staff also checked the referenced AP1000 DCD and departures and supplements specified in the WLS COL FSAR.

The staff reviewed COL Information Item 2.4-5 related to the provision of site-specific information about accidental release of liquid effluents into ground and surface water at the plant site included under WLS COL FSAR Section 2.4. Additional aspects of this information item are addressed in Section 2.4.12 of this report.

The staff reviewed the specific items related to the assessment of an accidental release of radioactive liquid effluents in groundwater and surface water included in the WLS COL FSAR and associated RAI responses. To improve readability, the staff's discussion of these items is organized into the following sections, which correspond to the sections of WLS COL FSAR Section 2.4.13, Version 7.

Groundwater

Information Submitted by the Applicant

In WLS COL FSAR Section 2.4.13, the applicant provided information that described movement of accidentally released effluents from the nuclear island area to the nearest potable water supply in an unrestricted area. The applicant identified the groundwater pathway from Unit 2 to Hold-Up Pond A (Pathway 1) as the bounding pathway because of its higher groundwater velocity and shorter travel time. The failure of a Unit 2 effluent hold-up tank, located below ground level in the auxiliary building, was identified as the appropriate scenario for analysis of a postulated accidental release of radioactive liquid effluent. The radioactive source term for this release was described based on AP1000 DCD, Tables 11.1-2 and 11.1-8. The conceptual model of the release is that one of the effluent hold-up tanks, having a capacity of 106,000 L (28,000 gal), ruptures and releases 80 percent of the volume, which equates to 84,800 L

(22,400 gal) of liquid effluent. Radionuclides in the effluent travel with groundwater to Hold-Up Pond A where they enter Hold-Up Pond A and flow directly into the Broad River. The applicant used RESRAD-OFFSITE Version 2.0 to calculate the transport rates and determine the radionuclide concentrations in the Broad River.

The applicant stated that three soil samples were collected from a depth range of 13.7 to 22.3 m (45 to 73 ft) below ground in two wells. The samples were analyzed for soil distribution coefficients (i.e., K_d values) for colbalt (Co)-60, cesium (Cs)-137, iron (Fe)-55, iodine (I)-129, nickel (Ni)-63, plutonium (Pu)-242, strontium (Sr)-90, technetium (Tc)-99, and uranium (U)-235.

In response to three staff RAIs, the applicant provided additional information and clarification related to the K_d values for the three main geologic materials.

The Staff's Technical Evaluation

The staff reviewed the applicant's information about accidental releases. Because of the subsurface location of the release, transport by surface water away from the release location was not considered feasible, and was not considered further. The staff reviewed the applicant's information regarding the groundwater pathway, and concluded that additional information was required to complete its evaluation of the risks from radionuclide transport by this pathway.

To clarify the suitability of the onsite K_d measurements for the evaluation of accidental releases, the staff issued RAI 828, Question 02.04.13-10. In the November 25, 2008, response, the applicant described the soil K_d values with respect to the effluent chemistry, site geochemistry, and the relationship to radionuclide migration. The applicant stated that the water in the effluent hold-up tanks is slightly acidic, has a TDS content of less than 1 ppm, and would not vary significantly from the ambient groundwater conditions in pH, salts, metals, or organics. Given those conditions, the applicant stated that the effluent would not alter the groundwater chemistry outside the range under which the K_d values were determined. The applicant stated that the K_d values determined for three samples at the WLS site are sufficient to represent the range of values within each of the alternative flow pathways. The applicant bounded its calculations by using the lowest measured K_d value regardless of media. The applicant used a K_d value of 0 for tritium and stated that tritium contributes 99 percent of the dose. The applicant also analyzed the sensitivity of the RESRAD-OFFSITE results to variations in K_d values. The staff evaluated the RESRAD-OFFSITE analyses and confirmed the results. The applicant updated the WLS COL FSAR to explain in more detail the nature of the K_d values and to describe the results of the sensitivity tests. The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-10, was acceptable and considers the question resolved.

The staff noted that the three samples tested included one from fill material and two from soil/saprolite. There were no measurements of K_d in the PWR, which is the material considered in the most conservative pathway. To evaluate the significance of this data gap, the staff issued RAI 828, Question 02.04.13-12. In a November 25, 2008, response, the applicant stated that PWR samples were not analyzed because of the difficulty of working with a representative sample. Therefore, the applicant assumed that K_d values for fill and soil/saprolite were reasonable alternatives for PWR. Partly because of this assumption, the applicant evaluated the sensitivity of its analysis to variations in the distribution coefficients (see Section 2.4.13.4.5 herein). The staff considered this to be a reasonable approach. The staff notes that the

applicant included this information in WLS COL FSAR Section 2.4.13.1, "Groundwater." The staff concluded that the applicant's November 12, 2009, response to RAI 828, Question 02.04.13-12, was acceptable and considers the question resolved.

The staff noted that, in the proposed revision to Section 2.4.13.4, the applicant referred to the "lowest uncertainty corrected K_d values." In a broad sense, the term "uncertainty" was intended to capture all aspects that contribute to uncertainty, many of which would never be known. The applicant defined the conservative K_d value as the lowest of three (3) measured K_d values minus one standard deviation. Calling any value the "lowest uncertainty corrected value" implies that all uncertainty has been removed and that the value is known with certainty. That is not the case for K_d values. To clarify the description of K_d, the staff issued RAI 73, Question 02.04.13-23. In a November 12, 2009, response, the applicant stated that the K_d values are indeed the mean values minus one standard deviation and concurred that the phrase "uncertainty corrected" could be misinterpreted. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.13.1, "Groundwater." The staff concluded that the applicant's November 12, 2009, response to RAI 73, Question 02.04.13-23, was acceptable and considers the question resolved.

Accident Scenario

<u>Information Submitted by the Applicant</u>

The applicant described the limiting accident scenario as the failure of a Unit 2 effluent hold-up tank, located in the Unit 2 auxiliary building, and resulting transport of radioactive contaminants to the Broad River. The applicant chose this scenario because the hold-up tank of Unit 2 was closest to the closest point of exposure: Hold-Up Pond A and the Broad River. The applicant ruled out other tanks because they had lower volumes and lower isotope inventories relative to the effluent hold-up tanks. Following BTP 11-6, March 2007, the applicant assumed that 80 percent of the effluent tank capacity (a release volume of 84,800 L (22,400 gal)) was immediately released through cracks in the auxiliary building walls and floor into the surrounding subsurface soil.

In response to three staff RAIs, the applicant provided additional information and clarification related to the identification of plausible alternative conceptual models.

<u>The Staff's Technical Evaluation</u>

The staff reviewed the applicant's information about the accidental release scenario. This information identified the assumed source of the release and the groundwater pathway that the applicant believed would be most probable. The staff identified certain missing or incomplete information needed for evaluation of the applicant's analysis of the accident scenario.

To understand the process used to identify subsurface pathways that affect the transport of radioactive liquid effluents so as to ensure that the most conservative of plausible conceptual models has been identified, the staff issued RAI 828, Question 02.04.13-3. In a November 25, 2008, response, the applicant increased the number of plausible flow paths from two to five (in subsequent WLS COL FSAR updates, the applicant reduced the number of flow paths from five to four). Despite the greater number of plausible pathways, the applicant stated that Pathway 1, the pathway that had been chosen previously for the RESRAD-OFFSITE modeling analysis,

remained the most conservative pathway. Therefore, the applicant determined that a RESRAD-OFFSITE analysis of another pathway was not necessary. The staff concluded that this explanation was reasonable. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.13.3, "Groundwater Movement." The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-3, was acceptable and considers this question resolved.

To understand the impact of the post-construction water table (which may differ from the pre-construction water table) on the selection of alternative pathways, the staff issued RAI 828, Question 02.04.13-18. The staff examined the November 25, 2008, response and concluded that the process and the methods used by the applicant to determine the bounding set of plausible surface and subsurface pathways were reasonable. As discussed in WLS COL FSAR Section 2.4.12, the applicant has generated a post-construction water table that is consistent with the recharge-affecting surface conditions. The new estimate of the post-construction water table does not alter the potential pathways and thus does not change the selection of the primary pathway for the transport analysis, which is from Unit 2 to the Broad River. The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-18, was acceptable and considers the question resolved.

The staff examined the responses to these RAIs and determined that the process and the methods used by the applicant to determine alternate conceptual models of the site hydrology are reasonable but potentially incomplete. The applicant did not evaluate the impact of a failure of the dams associated with Make-Up Ponds A and B. Such an event could increase the hydraulic gradient substantially and shorten travel times. The applicant did not evaluate alternative geohydrologic features such as continuous PWR along all pathways. The applicant did not evaluate the potential for preferential flow paths (e.g., buried pipes, or coarse bedding material beneath them) created by Cherokee construction activities. To address these issues, the staff issued RAI 73, Question 02.04.13-19.

In a November 12, 2009, response, the applicant stated that the transport calculation was changed to assume PWR occurred along all potential transport pathways. This change eliminated any concern that the occurrence of PWR would be underestimated. The changed calculation also led the applicant to confirm the Pathway 1 (from Unit 2 to Hold-Up Pond A) as the limiting pathway. The applicant considered the impact of dam failure and demonstrated that, because of distance, Pathway 1 would remain the limiting pathway. The applicant acknowledged the potential for Cherokee-era drainage piping to be a preferential flow pathway in the event of an effluent tank release. The applicant reviewed the Cherokee piping system and identified the piping corridor from the nuclear power block area north to Hold-Up Pond A as the only one having the potential to affect flow and transport. The applicant committed to removing this piping system and associated bedding materials. The staff notes that the applicant included this information in WLS COL FSAR Section 2.4.12.2, "Sources." The staff concluded that the applicant's November 12, 2009, response to RAI 73, Question 02.04.13-19, was acceptable and considers the question resolved.

Source Term

Information Supplied by the Applicant

The applicant identified the source-term concentrations per the information in the AP1000 DCD Tables 11.1-8 (H-3), 11.1-2 (corrosion products chromium (Cr)-51, manganese (Mn)-54, manganese (Mn)-56, Fe-55, Fe-59, Co-58, and Co-60), and 11.1-2 for the other isotope concentrations after adjusting them by the factor 0.12/0.25 in accordance with BTP 11-6, March 2007. The applicant described the two pathways that were considered in WLS COL FSAR Revision 0. Travel time to the Broad River was shorter (because of hydrogeology) than to Hold-Up Pond A. Unit 2 was closer to the Broad River than Unit 1. Thus, transport of the Unit 2 effluent tank contents directly to the Broad River was identified as the limiting scenario because it minimized the transport distance and time. The applicant assumed the contents of the failed effluent tank entered the subsurface environment at a depth of 10.2 m (33.5 ft) and completely filled the soil pore space in an area large enough to contain 84,791 L (22,400 gal) of effluent.

In response to four staff RAIs, the applicant provided additional information and clarification related to the use of RESRAD-OFFSITE to calculate contaminant transport.

The Staff's Technical Evaluation

In RAI 828, Question 02.04.13-14, the staff requested that the applicant provide the calculation package used to convert source concentration values in AP1000 DCD Tables 11.1-2 and 11-1-8 to RESRAD-OFFSITE input values (with units of pCi/g water). In a November 25, 2008, response, the applicant summarized the steps used to convert source concentrations to RESRAD-OFFSITE input values. The activities listed in AP1000 DCD Table 11.1-2 for non-corrosion products were stated to be corrected by 0.12/0.25 as recommended by AP1000 DCD Section 2.1 (the staff noted that the WLS COL FSAR incorrectly cites NRC BTP 11-6 as the source for this correction). The activities for the corrosion products were taken directly from AP1000 DCD Table 11.1-2. The resulting activities for all constituents were adjusted by a factor of 1.01 and then converted from microcuries to picocuries by multiplying by 1×10^6. The applicant proposed no changes to the WLS COL FSAR.

The staff's review of the calculation package showed that the applicant used the uncorrected values, i.e., the applicant did not modify the values in DCD Table 11.1-2 by the factor 0.12/0.25. The applicant did not explain the reason for adjusting concentrations by a factor of 1.01, but such an adjustment increases concentrations slightly and therefore could be viewed as being conservative. The staff noted that the table of concentrations in the RAI response from the applicant contained a xenon (Xe)-133 concentration of 1.2×10^{-2} µCi/g. The AP1000 DCD value is 1.2×10^{2} µCi/g. The applicant did not include Xe-133 in its RESRAD-OFFSITE groundwater analysis. The staff issued two more RAIs related to the source term, as discussed below.

In RAI 828, Question 02.04.13-16, the staff requested that the applicant explain more fully the conceptual model of the accidental release with respect to soil volume occupied, duration of leak, and impact on surrounding groundwater. In a November 25, 2008, response, the applicant stated that the release to groundwater was assumed to be instantaneous and that the leaked fluid immediately occupied a rectangular plume volume that was 2.0 m (6.6 ft) high and 6.5 m (21.4 ft) wide on each side. Although the leak was considered to be instantaneous, the

applicant assumed that the release mechanism was sufficiently gradual that there was no perturbation to the groundwater surface, flow rate, and flow direction. The applicant assumed that aspects of a real leak event, such as potential groundwater flow into the auxiliary building and the time delay for contaminants to exit the building, were inconsequential; this assumption makes the release analysis more conservative. The applicant proposed no changes to the WLS COL FSAR. The staff considered the assumptions and agreed with the applicant's assessment. The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-16, was acceptable and considers the question resolved.

To address questions raised by the staff's review of the applicant's response to RAI 828, Question 02.04.13-14, as described above, the staff issued RAI 73, Question 02.04.13-26. In the November 12, 2009, response to RAI 73, Question 02.04.13-26, the applicant stated that it would apply the 0.12/0.25 factor correctly and repeat the RESRAD-OFFSITE analysis. The applicant stated that the modification by a factor of 1.01 is just a conservative adjustment. The staff noted that the table of concentrations in the RAI response from the applicant contained a Xe-133 concentration of 1.2 $x10^{-2}$ µCi/g, whereas the correct value from the AP1000 DCD is 1.2 x 10^{2} µCi/g. The applicant indicated that the $1.2x10^{-2}$ value was only a typographical error. The applicant did not include Xe-133 in its RESRAD-OFFSITE groundwater analysis because it is a gas and because it has a short half-life of 0.014 years. The staff noted that the other source-term gases listed in WLS COL FSAR Section 2.4.13.3 also have short half-lives (much less than 0.1 years) except for krypton (Kr)-85, which has a half-life of 10.8 years. However, Kr-85 is a noble gas and would partition rapidly into the atmosphere, both at the time of the release and if it reaches the Broad River. Therefore, significant exposure by way of groundwater and surface water appears unlikely. The staff notes that the applicant updated WLS COL FSAR Section 2.4.13.3, "Source Term." The staff concluded that the applicant's November 12, 2009, response to RAI 73, Question 02.04.13-26, was acceptable and considers the question resolved.

To clarify the handling of tritium in the applicant's evaluation of accidental releases, the staff issued RAI 73, Question 02.04.13-27. In a November 12, 2009, response the applicant stated that the AP1000 vendor (Westinghouse) recognized that tritium was not in AP1000 DCD Table 11.1-2 and indicated that the best available value for tritium was in AP1000 DCD Table 11.1-8, Realistic Source Terms. The staff notes that the applicant updated WLS COL FSAR Section 2.4.13.3, "Source Term." The staff concluded that the applicant's November 12, 2009, response to RAI 73, Question 02.04.13-27, was acceptable and considers the question resolved. The staff also concluded that that the applicant's November 12, 2009, response to RAI 73, Questions 02.04.13-26 and 02.04.13-27, provides information to find the applicant response to RAI 828, Question 02.04.13-14, acceptable and considers the question resolved.

Conceptual Model

Information Submitted by the Applicant

The applicant stated in WLS COL FSAR Revision 0 that the conceptual model was conservative because it used the shortest travel time, did not credit dilution in the Broad River, assumed a straight travel path, and assumed the entire domain had the properties of PWR (which has a high permeability). The applicant used RESRAD-OFFSITE to determine radionuclide concentrations in the Broad River for an evaluation period of 50 years. The applicant provided a list of parameters used in its analysis. The applicant calculated the maximum radionuclide

concentration for each isotope in the Broad River during the evaluation period and compared it to the limiting concentrations defined in 10 CFR Part 20, Appendix B, Table 2, Column 2. The applicant reported that all concentrations were below the limits. In addition, the applicant calculated the sum of fractions of effluent concentrations using all maximum radionuclide concentrations and showed it to be well below a value of 1.0. The applicant stated that this result was conservative because the maximum concentration of each radionuclide occurred at a different time due to variations in transport time to the Broad River.

In response to 12 staff RAIs, the applicant provided additional information and clarification related to the conceptual model and parameter choices affecting the RESRAD-OFFSITE calculation of contaminant transport.

The Staff's Technical Evaluation

The staff reviewed the applicant's conceptual model for groundwater transport of radionuclide contaminants from a release. The staff determined the applicant's conceptual model generally reasonable, but required much additional information and analysis from the applicant to support the staff's review. Therefore, in RAI 828, Question 02.04.13-5, the staff requested that the applicant clarify why different values of porosity were used in each section. If this was done for conservatism, the staff requested that the applicant explain why each is conservative. In a November 25, 2008, response, the applicant set the total porosity of the PWR equal to its estimate of 0.08 for the effective porosity. The applicant stated that the lowest porosity values are the most conservative values because they result in the shortest travel time and, thus, the highest concentration of radionuclides in the receptor water body. The staff notes that the applicant updated WLS COL FSAR Table 2.4.13-203. The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-5, was acceptable and considers the question resolved.

To clarify the conservatism of the hydraulic conductivity value used for the PWR, the staff issued RAI 828, Question 02.04.13-6. In a November 25, 2008, response, the applicant changed the statement from "highest measured" to "conservative" hydraulic conductivity. The staff notes that the applicant updated WLS COL FSAR Section 2.4.12.2, "Sources." The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-6, was acceptable and considers the question resolved.

In RAI 828, Question 02.04.13-7, the staff requested that the applicant define the nature of the contaminated zone; namely, describe the materials that make up the contaminated zone. In a November 25, 2008, response the applicant stated that the contaminated zone consists of PWR with some portions of residual soils and fill. The applicant considers use of PWR to represent the most conservative approach for estimating transport. The applicant set both total and effective porosity of PWR to the value of 0.08. This value is much lower than the WLS COL FSAR Revision 0 value of 0.44 and the applicant considers it much more conservative. The staff notes that the applicant updated WLS COL FSAR Table 2.4.13-203 to the revised porosity values for the partially weathered zone. The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-7, was acceptable and considers the question resolved.

To gain a clearer understanding of the significance of precipitation, runoff, evapotranspiration, and recharge with respect to radionuclide transport, the staff issued RAI 828,

Question 02.04.13-11. In a November 25, 2008, response, the applicant revised its estimate of average annual precipitation from 1.01 to 1.23 m/yr (39.8 to 48.4 in/yr) based on precipitation data from Gaffney, SC, for the years from 1944 to 2007. The applicant described the calculation process in which it used the SCS curve number method to estimate the runoff coefficient. For the watershed containing Make-Up Pond A and Hold-Up Pond A, the applicant calculated annual runoff to be 53 percent of precipitation. For the watershed containing Make-Up Pond B, it calculated annual runoff to be 39 percent of precipitation. For the RESRAD-OFFSITE analysis, the applicant used the value of 39 percent for both watersheds, which is realistic for the Make-Up Pond B watershed and conservative for the watershed containing Make-Up Pond A and Hold-Up Pond A. Using this analysis, the applicant revised its runoff coefficient from 0.36 to 0.39.

Given that the average annual precipitation is 123.0 cm (48.41 in.), runoff amounts to 48.0 cm (18.88 in.). The applicant calculated evaporation using regional pan evaporation data, which showed an annual pan evaporation rate of 132 cm (51.8 in.). Pan evaporation data tend to overestimate actual evaporation, so the applicant used a correction factor of 0.7 to adjust the pan data, yielding an estimate of annual evaporation of 91 cm (36 in.). In the RESRAD-OFFSITE analysis, the applicant specified an evaporation factor of 0.74. RESRAD-OFFSITE uses the evaporation factor to estimate how much of the infiltration water (i.e., precipitation - runoff, or P-R) is lost to evaporation (which includes transpiration from vegetation). In this case, annual evapotranspiration (E) is estimated to be 55.5 cm (21.85 in.). Annual net infiltration, also called groundwater recharge, is thus 19.5 cm (7.68 in.) (i.e., (P-R)-E). The staff notes that the applicant updated WLS COL FSAR Table 2.4.13-203 to include the above runoff coefficient and evaporation factor. The staff concluded that the COL applicant's November 25, 2008, response to RAI 828, Question 02.04.13-11, was acceptable and considers the question resolved.

To review the appropriateness of contaminant transport modeling methods used by the applicant, the staff issued RAI 828, Question 02.04.13-13. In a November 25, 2008, response, the applicant sent the input and output files. The staff reviewed the RESRAD-OFFSITE input file and noted that the dry bulk density of the saturated zone material is 1.51 g/cm^3 (94.3 pcf). The applicant stated that this value should be 1.59 g/cm^3 (99.3 pcf). The RESRAD-OFFSITE model requires the user to specify the initial radionuclide concentration on a picocurie per gram of soil basis. Instead of providing the appropriate soil-based concentrations, the applicant used the liquid-based concentrations that are identified in AP1000 DCD, Table 11.1-2. Since RESRAD-OFFSITE assumes the input concentrations are soil based, RESRAD-OFFSITE multiplies the input concentrations by a factor equal to the bulk density divided by the porosity to yield the initial groundwater concentration. The net effect is that the RESRAD-OFFSITE groundwater concentrations are much higher (by the factor bulk density divided by porosity) than the liquid concentrations specified in the AP1000 DCD. The staff notes that the applicant updated the RESRAD-OFFSITE analysis to use the correct porosity and appropriate method for initializing the contaminant concentration. The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-13, was acceptable and considers the question resolved.

In RAI 828, Question 02.04.13-15, the staff requested that the applicant explain how contaminant concentrations were affected by mixing in the Broad River as part of the RESRAD-OFFSITE analyses. In a November 25, 2008, response, the applicant stated that it

used a mixing volume of 150,000 m^3 (5,297,200 ft^3) in the Broad River. That volume is the default volume used by RESRAD-OFFSITE to represent a lake. The volume represents 17.5 percent of the static pool that would reside behind the Ninety-Nine Islands Dam if there were no flow. The volume does not take into account the daily flow of water past the site. That flow is on the order of 6.2 x 10^6 m^3/day (2.2x10^8 ft^3/day), which, on a daily basis, is equivalent to 41 mixing volumes. The applicant stated that a residence time of 1 year was chosen to standardize the exposure duration to the accumulation duration. Actual residence time would be less than 1 day. The applicant stated that groundwater concentrations were not evaluated at the river edge because no regulatory basis exists for an intermediate release point. The applicant described the rationale for the mixing volume in the Broad River in WLS COL FSAR Section 2.4.13.4, "Conceptual Model." The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-15, was acceptable and considers the question resolved.

To explain the period used for evaluating radionuclide concentrations, the staff issued RAI 828, Question 02.04.13-17. In a November 25, 2008, response, the applicant expanded the evaluation period from 50 to 1,000 years. The applicant stated that this time period was sufficient for all radionuclides to either appear in the receptor body or disappear through radioactive decay. The staff notes that the applicant updated WLS COL FSAR Section 2.4.13.4, "Conceptual Model," to reflect the change in the length of the evaluation period. The staff concluded that the applicant's November 25, 2008, response to RAI 828, Question 02.04.13-17, was acceptable and considers the question resolved.

To clarify the initial dimensions assumed for the contaminant plume, the staff issued RAI 73, Question 02.04.13-20. In a November 12, 2009, response, the applicant stated that it would use the effective porosity to define the plume size and would update the WLS COL FSAR accordingly. The applicant approximated the plume as a cube with dimensions of 10.2 m (33.5 ft) on each side. The staff confirmed this dimension was consistent with the effective porosity. The staff notes that the applicant updated WLS COL FSAR Section 2.4.13.4, "Conceptual Model," and WLS COL FSAR Table 2.4.13-203 to reflect the change in the plume size. The staff concluded that the applicant's November 12, 2009, response to RAI 73, Question 02.04.13-20, was acceptable and considers the question resolved.

The staff agreed that travel times decrease as the effective porosity is reduced. However, the staff noted that as the total porosity is decreased, the retardation factor is increased, which means that travel times are increased. Bulk density (p_b), water density (p_w), total porosity (n), and soil distribution coefficient (K_d) affect the retardation of contaminants in the following manner.

$$\text{Retardation (R)} = 1+((p_b/p_w)/n)K_d$$

Therefore, it is imperative that appropriate values of total and effective porosity be used for any contaminant that has the potential to be sorbed. Therefore, in RAI 73, Question 02.04.13-21, the staff requested that the applicant justify why a total porosity value of 0.08 is conservative for contaminants that sorb to the sediments. In a November 12, 2009, response, the applicant identified appropriate site-specific values for total porosity and effective porosity for PWR of 27 percent and 8 percent, respectively. The applicant used these values in revised RESRAD-OFFSITE transport analyses. Additional discussion is included below in the applicant's response to RAI 73, Question 02.04.13-29. The staff concluded that the applicant's

November 12, 2009, response to RAI 73, Question 02.04.13-21, was acceptable and considers the question resolved.

The staff noted that the applicant's proposed revision to WLS COL FSAR Section 2.4.13 described the annual precipitation used in the RESRAD-OFFSITE analysis as being the highest annual precipitation rate. Since average annual precipitation is used, the description is incorrect in both the proposed text and in WLS COL FSAR Table 2.4.13-203 and needs to be corrected in both locations. The staff also noted that the recharge rate of 19.5 cm/yr (7.68 in/yr) is lower than expected. In WLS COL FSAR Section 2.4.1.2.4, the applicant stated that, because surface materials in many areas are relatively impermeable, recharge is only 25 to 38 cm/yr (10 to 15 in/yr). In Environmental Report Section 2.3.1.1.5, the applicant stated that the recharge rate ranges from 22 to 33 percent of annual precipitation, which translates to 27.2 to 40.6 cm/yr (10.7 to 16.0 in./yr). Since recharge is used in RESRAD-OFFSITE to leach contaminants from the contaminated zone into the groundwater, the staff issued RAI 73, Question 02.04.13-24.

In a November 12, 2009, response to RAI 73, Question 02.04.13-24, the applicant stated that the value of 19.5 cm/yr (7.68 in/yr) is conservative. However, the applicant provided a more conservative value for the RESRAD-OFFSITE analyses. The input value for annual precipitation was updated to 1.27 m (i.e., approximately 50 in. as stated in WLS COL FSAR Section 2.3.1.1) and the evapotranspiration coefficient was revised to a value of 0.64, based on regional information. The runoff coefficient was assigned a value of zero to maximize the recharge rate. These three changes increased the effective recharge rate for the RESRAD-OFFSITE analyses to approximately 46 cm/yr (18 in./yr). The staff notes that the applicant updated WLS COL FSAR, Table 2.4.13-203, to reflect the changes. The staff concluded that the applicant's November 12, 2009, response to RAI 73, Question 02.04.13-24, was acceptable and considers the question resolved.

To understand the rationale for using the default mixing volume in RESRAD-OFFSITE, the staff issued RAI 73, Question 02.04.13-28. In a November 12, 2009, response, the applicant defined the mixing volume as 856,036 m^3 (30,230,600 ft^3), which it determined to be the volume of the Broad River reservoir from the postulated release point downstream to the Ninety-Nine Islands Dam. The applicant determined the residence time of radionuclides in the reservoir to be 0.00397 years (1.5 days) by assuming only 50 percent of the FERC license requirement for minimum flow (13.7 m^3/s [483 cfs]) passing the Ninety-Nine Islands Dam. The staff notes that the applicant updated WLS COL FSAR Table 2.4.13-203 to reflect the changes. The staff concluded that the applicant's November 12, 2009, response to RAI 73, Question 02.04.13-28, was acceptable and considers the question resolved.

In RAI 73, Question 02.04.13-29, the staff requested that the COL applicant clarify the choice of parameters used to initialize the RESRAD-OFFSITE analyses and explain how leaked fluid concentrations were transformed into initial radionuclide concentration on a picocurie per gram of soil basis. In a November 12, 2009, response, the applicant provided a revised RESRAD-OFFSITE analysis. The contaminated zone was assumed by the applicant to be a cube composed of PWR having an effective porosity of 0.08 and a dry bulk density of 1.98 g/cm^3 (124 pcf). The initial source-term concentrations were converted to a soil mass basis by using the dry bulk density; this method yielded the final concentration input to RESRAD-OFFSITE in picocuries per gram. Although the WLS site geology is variable, all five pathways (subsequently reduced to the current four pathways) were conservatively

evaluated by the applicant by assuming the pathway was composed entirely of PWR, which has the highest conductivity and yields the shortest travel time.

The limiting pathway was from Unit 2 to Hold-Up Pond A. Contaminant transport to Hold-Up Pond A was via groundwater. Once at the Hold-Up Pond A, the applicant assumed all groundwater entered the surface water in the pond, travel over the spillway, and enter the Broad River. Dilution in the Broad River was described previously in this report in the response to RAI 73, Question 02.04.13-28. The applicant reported that the radionuclide concentrations were below the limits in 10 CFR Part 20, Appendix B, Table 2, Column 2. In addition, the total sum of fractions was also less than 1.0 for both the hypothetical well (approximately 0.8) and the surface-water analyses (approximately 4×10^{-5}). The nearest potable water supply is located approximately 34 km (21 mi) downstream of the outfall from Hold-Up Pond A. The staff expects that the Broad River concentrations and sum of fractions would be even lower at that location. The staff notes that the applicant updated WLS COL FSAR Section 2.4.13, Table 2.4.13-203, and WLS COL FSAR Table 2.4.13-204 to reflect the changes. The staff concluded that the applicant's November 12, 2009, response to RAI 73, Question 02.04.13-29, was acceptable and considers the question resolved.

Sensitive Parameters

Information Submitted by the Applicant

The applicant did not provide any sensitivity analyses in WLS COL FSAR Revision 0. Partly because of the RAI process, the applicant included sensitivity analyses in WLS COL FSAR Revision 1 and all subsequent revisions. The applicant examined the RESRAD-OFFSITE sensitivities for selected parameters, including total porosity, effective porosity, hydraulic conductivity, hydraulic gradient, and K_d values for those radionuclides that were evaluated for site soils. The applicant stated that no variation in any single parameter had sufficient impact to cause the concentrations to exceed 10 CFR Part 20, Appendix B, Table 2, Column 2 limits or for the sum of fractions calculation to exceed 1.0.

In response to one staff RAI, the applicant provided additional clarification related to the nature of the K_d values used for the PWR.

The Staff's Technical Evaluation

The staff examined the sensitivity cases and determined they covered a sufficient range of parameter variation to conclude that reducing parameter uncertainty would not alter the results.

With respect to the sensitivity analysis of the K_d values, the lower values affected the results for two radionuclides, namely, I-129 and Tc-99. Predicted concentrations were 10 and 5.8 percent higher, respectively. The applicant stated that, in both cases, the higher concentrations were still well below limits listed in 10 CFR Part 20, Appendix B, Table 2, Column 2.

The staff determined that the K_d value for PWR had the potential to be less than that for the soil/saprolite zone, which was the only material tested. Therefore, the staff issued RAI 73, Question 02.04.13-25. In a November 12, 2009, response, the applicant stated that the PWR material is a transition material between the saprolite above and the underlying bedrock and that the measurements on samples from the soil/saprolite are representative and appropriate for

the accidental release analysis. The staff recognizes the difficulty of measuring K_d values directly on PWR and agrees that, as an alternative, using the lowest K_d values of all three samples and the results of the sensitivity tests (i.e., no impact) provides sufficient information to conclude that the WLS site meets the 10 CFR Part 20 concentration and sum of fractions requirements. The staff concluded that the applicant's November 23, 2009, response to RAI 70, Question 02.04.13-25, was acceptable and considers the question resolved.

Regulatory Compliance

Information Submitted by the Applicant

The applicant stated that meeting the concentration limits of 10 CFR Part 20 Appendix B, Table 2, Column 2 results in a dose of less than 0.05 Roentgen equivalent man (REM) and, therefore, demonstrates that the requirements of 10 CFR 20.1301 and 10 CFR 20.1302 are met.

The Staff's Technical Evaluation

The staff evaluated and confirmed the applicant's demonstration that radionuclide concentrations and sum of fractions in the Broad River would be well below the requirements of 10 CFR Part 20.

2.4.13.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.13.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant addressed the relevant information and there is no outstanding information expected to be addressed in the WLS COL FSAR related to this section. As set forth above, the applicant presented and substantiated information to establish the potential effects of accidental releases from the liquid waste management system. The staff reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description, and about the design of the liquid waste management system, to allow the staff to evaluate, as documented in this section, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site, and with respect to 10 CFR 20 as it relates to ECLs. This addresses, and closes, COL information item 2.4-5. The staff concluded that the applicant provided sufficient information to satisfy the applicable requirements of 10 CFR Part 20, 10 CFR Part 52, and 10 CFR Part 100.

2.4.14 Technical Specifications and Emergency Operation Requirements

2.4.14.1 *Introduction*

WLS COL FSAR Section 2.4.14 describes technical specifications and emergency operation requirements as necessary. The requirements described implement protection against floods for safety-related facilities to ensure that an adequate supply of water for shutdown and cool-down purposes is available.

Section 2.4.14 of this report presents the staff's evaluation of required technical specifications and emergency operations for the proposed plant site.

2.4.14.2 *Summary of Application*

This section of the WLS COL FSAR addresses technical specifications and emergency operation requirements. The applicant addressed information related to technical specifications and emergency operation requirements as follows:

<u>AP1000 COL Information Item</u>

- COL Information Item 2.4-6

In addition, this section addresses the following COL-specific information identified in AP1000 Tier 2, Section 2.4.1.6, Revision 19.

> Combined License applicants referencing the AP1000 certified design will address any flood protection emergency procedures required to meet the site parameter for flood level.

2.4.14.3 *Regulatory Basis*

The relevant requirements of NRC regulations for consideration of emergency protective measures, and the associated acceptance criteria, are described in NREG-0800, Section 2.4.14.

The applicable regulatory requirements for technical specifications and emergency operation requirements are set forth in the following:

- 10 CFR 50.36, "Technical Specifications," as it relates to identifying technical specifications related to all emergency procedures required to ensure adequate plant safety from controlling hydrological events by the organization responsible for the review of issues related to technical specifications.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

2.4.14.4 *Technical Evaluation*

Information Submitted by the Applicant

The applicant stated that the maximum flood water-surface elevation at the WLS site is 178.3 m (584.8 ft) above MSL, resulting from a PMF event in the watershed of Make-Up Pond B. The applicant noted that the safety-related plant grade at the WLS site is 179.8 m (590 ft) above MSL. Therefore, the applicant concluded that a freeboard of over 1.5 m (5 ft) is available under the worst flooding scenario. The applicant stated that based on the description provided in WLS COL FSAR Section 2.4.12.5, the maximum expected groundwater elevation would not exceed the design criteria for the chosen reactor design. The applicant stated that no safety-related facilities would be affected by low flow or drought conditions in the Broad River. The applicant concluded that, based on site-specific conditions at the WLS site, no emergency protective measures designed to minimize the impact of hydrologic events on safety-related facilities are needed.

As described in Section 2.4.2.4 of this report, the applicant revised the analysis for site flooding under local intense precipitation in response to the staff's RAI 484, Question 10.04.05-2. The applicant's revised analysis established a slightly higher maximum water-surface elevation of 179.72 m (589.62 ft) above MSL caused by the effects of the local intense precipitation.

The Staff's Technical Evaluation

The staff reviewed COL Information Item 2.4-6 related to the provision of site-specific information about flood protection emergency operation procedures at the plant site included under WLS COL FSAR Section 2.4.

As stated in Section 2.4.10 of this report, the staff concluded that the site characteristic maximum flood water-surface elevation near the WLS site from several flooding mechanisms described in earlier sections herein remains below the site grade and meets the AP1000 DCD site parameter. As stated in Section 2.4.11 of this report, the staff concluded that there are no safety-related systems that can be affected by low water at the WLS site. Therefore, the staff concluded that no emergency operation requirements for flooding and water availability are needed for the WLS site.

2.4.14.5 *Post Combined License Activities*

There are no post COL activities related to this section

2.4.14.6 *Conclusion*

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to technical specification and emergency operations requirements, and there is no outstanding information required to be addressed in the WLS COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the

staff to evaluate, as documented in Section 2.4.14 of this report, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. The WLS COL FSAR addressed flood protection emergency operation procedures in COL Information Item 2.4-6. The staff concluded that the applicant provided sufficient information to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100..

2.4.15 Combined License Information

The applicant also identified the following AP1000 DCD Tier 2 departure:

> STD DEP 1.1-1 within FSAR Section 2.4.1, "Hydrologic Description," identifies instances where the FSAR sections are renumbered to include content consistent with Regulatory Guide 1.206, as well as NUREG-0800. Here, Subsections in Section 2.4.15 of the DCD are renumbered as Section 2.4.1, 2.4.2, 2.4.3, 2.4,4, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.9, 2.4.10, 2.4.11, 2.4.12, 2.4.13, and 2.4.14.

The applicant's evaluation, in accordance with 10 CFR Part 52, Appendix D, Section VIII.B.5, determined that this departure did not require prior NRC approval. The staff concluded that it is reasonable that the departure does not require prior NRC approval. The applicant's process for evaluating departures and other changes to the AP1000 DCD are subject to NRC inspections. The NRC evaluated the AP1000 DCD Tier 2 departure in the aforementioned renumbered sections.