Tennessee Valley Authority, 1101 Market Street, Chattanooga, TN 37402

CNL-17-074

June 7, 2017

10 CFR 52, Subpart A

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

Clinch River Nuclear Site
NRC Docket No. 52-047

Subject: Submittal of Supplemental Information Related to the Hydrologic Engineering in Support of the Clinch River Nuclear Site Early Site Permit Application - Groundwater

References:
1. Letter from TVA to NRC, CNL-16-081, "Application for Early Site Permit for Clinch River Nuclear Site," dated May 12, 2016
2. NRC Memorandum, "April 17 - 28, 2017, Audit of Clinch River Nuclear Site Early Permit Application - Hydrology and Health Physics Analyses," dated April 11, 2017

By letter dated May 12, 2016 (Reference 1), Tennessee Valley Authority (TVA) submitted an application for an early site permit for the Clinch River Nuclear (CRN) Site in Oak Ridge, TN. Between April 17, 2017 and April 27, 2017, the NRC conducted an audit of the hydrologic information contained in the CRN Site Early Site Permit Application ESPA), Part 2, "Site Safety Analysis Report (SSAR)," Section 2.4, "Hydrologic Engineering" (Reference 2). During the face-to-face portion of the NRC audit held at the Bechtel Power Corporation (Bechtel) offices in Reston, VA, the NRC requested that by June 5, 2017, TVA provide clarifications and revisions (as appropriate) to SSAR Section 2.4.

The enclosure provides a response and SSAR mark-ups as discussed during the NRC audit. Specifically, the enclosure provides response to information needs 1-f, 24, 26, 28-a, 30, 33-a, 34, 35, 38, 40-a and 40-c. Conforming changes were also made to portions of SSAR Section 2.5, Environmental Report (ER) Section 2.3 and the Administrative Information.

There are no new regulatory commitments associated with this submittal. If any additional information is needed, please contact Dan Stout at (423) 751-7642.

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 7th day of June 2017.

Respectfully,

J. W. Shea
Vice President, Nuclear Licensing

Enclosure:

Supplemental Information Regarding Site Safety Analysis Report Section 2.4, "Hydrologic Engineering"

cc (w/ Enclosure):

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cc (w/o Enclosure):

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ENCLOSURE

Supplemental Information Regarding Site Safety Analysis Report Section 2.4, “Hydrologic Engineering”

By letter dated May 12, 2016 (Reference 1), Tennessee Valley Authority (TVA) submitted an application for an early site permit for the Clinch River Nuclear (CRN) Site in Oak Ridge, TN. Between April 17, 2017 and April 27, 2017, the NRC conducted an audit of the hydrologic information contained in the CRN Site Early Site Permit Application (ESPA) (Reference 2). During the face-to-face portion of the NRC audit held at the TVA offices in Knoxville, TN, the NRC requested that TVA provide supplemental information related to Site Safety Analysis Report (SSAR) Section 2.4, “Hydrologic Engineering,” to reflect the information that TVA provided during the NRC audit.

This enclosure provides the supplemental information as an update of portions of Site Safety Analysis Report Section 2.4 discussed during the audit. Conforming changes were also made to portions of SSAR Section 2.5, Environmental Report (ER) Section 2.3 and the Administrative Information. Specifically, this enclosure provides supplemental information regarding audit information needs 1-f, 24, 26, 28-a, 30, 33-a, 34, 35, 38, 40-a and 40-c. The SSAR markups in this enclosure will be incorporated in a future revision of the early site permit application.

References:

1. Letter from TVA to NRC, CNL-16-081, “Application for Early Site Permit for Clinch River Nuclear Site,” dated May 12, 2016
2. NRC Memorandum, “April 17 - 28, 2017, Audit of Clinch River Nuclear Site Early Permit Application - Hydrology and Health Physics Analyses,” dated April 11, 2017

Supplemental Information to NRC Audit Information Needs:

Following the face-to-face portion of the NRC audit, TVA is providing the following supplemental information related to the referenced audit information need:

Supplemental Information related to NRC Information Need 1-f

As indicated in Section 2 of the 2004 Reservoir Operations Study (ROS), TVA’s operations distinguish between system minimum flows and project specific minimum flows. The objectives for maintaining power reliability, including the consideration of hydrothermal conditions at TVA nuclear plants, is reflected in the minimum flow provided by operation of the entire system, and not by a single dam (e.g., a single project-specific minimum flow). When compared with prior operating policies, the preferred alternative of the 2004 ROS modified project-specific minimum flows as needed for the system minimum flow to collectively meet downstream objectives. As indicated in Appendix B of the 2004 ROS, the preferred alternative makes no changes to prior minimum flow requirements at most tributary dams (including Melton Hill Hydro), though increases in the minimum flows at a number of tributary dams (e.g., Norris Hydro and Apalachia Hydro) were incorporated to accommodate recreation interests, water quality commitments, and process water needs at downstream plants (i.e., non-nuclear plant facilities).

Regarding Melton Hill Hydro, this project has historically been operated as a “run of river” facility, meaning it offers little appreciable storage capacity and is thus operated by creating outflows which are essentially equal to inflows. Because the subbasin of this reservoir offers little ability to appreciably contribute volumes of cooler water to the system, no changes to minimum flow (between the “Base Case” and “Preferred Alternative”) were judged necessary for Melton Hill Hydro.

SSAR Subsection 2.4.1.2.1 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.1.2.1 Surface Water

Reservoir Water Flow

Three dams directly control the water surface elevation at the CRN Site: Norris Dam and Melton Hill Dam, located upstream on the Clinch River; and Watts Bar Dam, located downstream at TRM 529.9.

(SRI/CEII) Norris Dam at CRM 79.8, located about 62 mi upstream from the CRN Site, was completed in March 1936. (Reference 2.4.1-2) Norris Dam is a large structure having a maximum height of approximately 265 ft and an overall length of 1570 ft. There are [redacted]. The remainder of the dam consists of two earthen embankment sections having a combined length of [redacted] ft and [redacted] ft. At a top-of-dam elevation of 1061 ft National Geodetic Vertical Datum of 1929 (NGVD29) Norris Dam is capable of approximately 344,000 cubic feet per second (cfs) of discharge. Norris Dam impounds approximately 2,552,000 acre-feet (ac-ft) of water at the top of gates elevation,1034 ft NGVD29. Norris Dam provides hydro power production, flood control, navigation benefits, improved dissolved oxygen (DO), and low flow regulation to enhance downstream water quality. (Reference 2.4.1-7)

(SRI/CEII) Melton Hill Dam is located 5.2 mi upstream of the CRN Site at CRM 23.1 and was completed in May 1963. It is a run-of-the-river dam and a smaller structure than Norris Dam. It has a maximum height of only about 84 ft and an overall length of 1020 ft. Melton Hill Dam has [redacted] gates with a combined length of [redacted] ft. The remainder of the dam consists of [redacted] having a combined length of [redacted] ft and concrete lock and powerhouse sections with a combined length of [redacted] ft. At an elevation of 802 ft NGVD29 Melton Hill Dam is capable of approximately 146,000 cfs of discharge. Melton Hill Dam impounds approximately 126,000 ac-ft of water at the top of gates elevation, 796 ft NGVD29. The primary functions of Melton Hill Dam are navigation and power production, with some regulation of low water flows. (Reference 2.4.1-8)

(SRI/CEII) Watts Bar Dam located downstream of the CRN Site was completed in 1942. Although Watts Bar Dam is located over 50 mi downstream of the site, the backwater from the reservoir extends upstream to the Melton Hill Dam tailwater (Reference 2.4.1-2). Watts Bar Dam is a large structure having a maximum height of about 112 ft and a length of approximately 2960 ft. Watts Bar Dam has a spillway consisting of [redacted] wide gates for a combined crest length of [redacted] ft. There are [redacted] earthen embankment sections having a combined length of [redacted] ft and concrete powerhouse, lock section and minor ancillary structures with a total length of [redacted] ft. At the Watts Bar screen house over flow elevation of 767 ft NGVD29, the Watts Bar Dam is capable of approximately 1,144,000 cfs of discharge. Watts Bar Dam impounds approximately 1,175,000 ac-ft of water at the top of gates elevation, 745 ft NGVD29. (Reference 2.4.1-9)

TVA operates its dams and associated features as part of an integrated system. Therefore, in addition to the three dams described above which directly control water surface elevation, nine dams upstream in the Tennessee River system have the potential to influence flood levels at Watts Bar Reservoir and, as a result, at the CRN Site. These are Fort Loudoun Dam on the Tennessee River; Watauga, South Holston, Boone, Fort Patrick Henry, Cherokee, and Douglas Dams above Fort Loudoun; and Fontana and Tellico Dams on the Little Tennessee River. The location of TVA dams and reservoirs with respect to the CRN Site are shown in Figure 2.4.1-5. (Reference 2.4.1-5)

TVA developed historical flow information for the Clinch River in the vicinity of the CRN Site from multiple sets of stream gages. Through 1968, the U.S. Geological Survey maintained stream gages on the Clinch River in the vicinity of the CRN Site, as shown in Table 2.4.1-2. In addition, TVA has operated stream gages in the vicinity of the CRN Site as listed in Table 2.4.1-3.

Since the completion of Melton Hill Dam in 1963, the daily average flow rate is about 4800 cfs at the CRN Site. There has been an average of about 13 days per year during which there were no releases from the dam. However, since 1990 there has been an average of only 0.5 days per year during which there were no releases from the dam. The longest period of no release from the dam occurred in February and March 1966 when there was no flow below the dam for 29 consecutive days.

TVA completed a comprehensive Reservoir Operations Study (ROS) in 2004 to determine whether changes in the operation of the Tennessee River system would produce greater overall public value for the people of the Tennessee Valley. The preferred alternative implemented in the spring of 2004 resulted in: (1) changes in minimum flow requirements for ~~each project~~ system operating objectives, (2) establishment of reservoir balancing guides for each tributary storage reservoir to ensure that proportional water releases for downstream system needs are drawn from the tributary reservoirs equitably, (3) scheduled recreational releases at five additional tributary projects, subject to flood control operations or extreme drought conditions (4) establishment of weekly average flow requirements for different periods of the year at Chickamauga and (5) application of other requirements as defined in the Final Programmatic ROS Environmental Impact Statement. As a result of the implementation of the ROS in 2004, historical flow data from Melton Hill Dam are presented for the period 2004 – 2013 only . (Reference 2.4.1-5) Monthly average discharges from Melton Hill Dam for the period 2004 - 2013 are shown in Table 2.4.1-4.

Supplemental Information related to NRC Information Need 24

During the audit, the NRC reviewer noted that different unit nomenclature was used for the various parameters cited in SSAR Section 2.4. TVA informed the NRC reviewer that the unit convention applied to parameters was to retain the units included in the source document for that parameter. A new subsection is being added in Part 1 of the Early Site Permit Application, as described below.

Administrative Information (Part 1) is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.3 Unit Convention

During development of the ESPA, the parameter units used were retained from the associated source document. In some cases, units were also converted to facilitate a comparison with other parameters.

Supplemental Information related to NRC Information Need 26

During the audit, the NRC reviewer stated that information describing geologic units was not in SSAR Subsection 2.4.12. A discussion of the geologic units at the CRN Site is contained in SSAR Subsection 2.5.1. SSAR Subsection 2.4.12 is being changed to cite SSAR Subsection 2.5.1, as described below.

SSAR Subsection 2.4.12.1 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12.1 Description and Onsite Use

This subsection contains a description of the regional and local physiography and geomorphology, groundwater aquifers, ~~geologic formations,~~ and groundwater sources and sinks. Onsite uses of groundwater and groundwater requirements are also described. Information regarding geologic formations (e.g., Blackford and Rockdell) is provided in Subsection 2.5.1.

Supplemental Information related to NRC Information Need 28-a

TVA was asked to clarify whether its intention is to initially place two SMR reactors at the Clinch River Nuclear Site. The number of Small Modular Reactor units to be constructed at the CRN Site has not been determined, as a reactor technology has not been selected. The groundwater model addresses two locations on the Clinch River Nuclear Site. SSAR section markups (shown below) have been made to clarify this.

SSAR Subsection 2.4.12.2.2 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12.2.2 Groundwater Flow Directions

Groundwater flow directions in the ORR are generally characterized as from the ridge tops to drainages within the adjacent valley or as a subdued replica of topography. Figure 2.4.12-18 presents conceptual block flow diagrams for Bethel Valley, which has similar geology as the CRN Site (Reference 2.4.12-22). The figure indicates localized influences such as springs, discontinuity orientations (fractures and bedding planes), man-made features (pipelines, tank farms, and building basements), and solution features have an impact on flow directions.

Groundwater flow directions were evaluated during the CRBRP PSAR by preparing two groundwater contour maps, one for December 24, 1973 and one for January 2, 1974 (Reference 2.4.12-1). Both maps indicate a general flow direction toward the southeast or southwest in the area of the proposed nuclear island. An average hydraulic gradient of approximately 0.007 ft/ft is reported for the two maps (Reference 2.4.12-1). It should be noted that these maps were prepared using water level measurements from observation wells with long screened intervals and thus the equipotentials represent a vertically averaged head.

The CRN Site investigation included synoptic measurements of groundwater levels in the site observation wells. These measurements were used to prepare maximum potentiometric surface maps for the site. The maximum potentiometric surface maps used the maximum groundwater level elevation at each well cluster. Figure 2.4.12-19 through 2.4.12-28 present the potentiometric surface maps. The maps indicate a southwest to southeast flow direction in the area of the CRN Site power block area. Hydraulic gradients were measured along selected flow lines on each figure. Table 2.4.12-8 presents the horizontal hydraulic gradients for the ten potentiometric surface maps. The horizontal hydraulic gradients range from 0.03 to 0.12 ft/ft. Horizontal gradients were also evaluated using just the upper site observation wells for the eight quarters of December 2013, March 2014, May 2014, August 2014, November 2014, February 2015, May 2015, and August 2015), resulting in horizontal gradients ranging from 0.05 to 0.17 ft/ft. For comparison the average, hydraulic gradient between the maximum water level at OW-101U and OW-202U ~~(the locations of the two SMR reactors)~~ and the Clinch River arm of the Watts Bar Reservoir is 0.05 ft/ft." This is derived based on a shortest distance of 1400 ft from the reactor locations to the edge of the Clinch River arm of the Watts Bar Reservoir; lowest stage of the reservoir at 735 ft NAVD88 (during the monitoring period); and the maximum water levels at OW-101U and OW-202U of 798.99 and 800.30 ft NAVD88. Due to the complexity of the subsurface hydrogeologic conditions at the CRN Site, the maximum potentiometric groundwater elevation at each well cluster is used, representing a single hydrogeological unit. Given that the U, L, and D wells generally screened within different hydrogeologic units, the maximum potentiometric surface maps do not represent a true potentiometric surface. These maps can, however, be considered bounding in terms of depicting the maximum groundwater elevations at the site.

Vertical hydraulic gradients were determined at each well cluster to evaluate the potential for vertical movement in the subsurface. Table 2.4.12-9 presents the vertical hydraulic gradients for the well clusters. The average vertical hydraulic gradients range from -0.69 to 1.03 ft/ft. A negative vertical hydraulic gradient indicates an upward flow potential and a positive one indicates a downward flow potential. The upward flow potential would suggest groundwater discharge and the downward flow potential would suggest groundwater recharge. A majority of the wells with upward flow potential are located on the western and eastern sides of the site suggesting discharge towards incised site drainage features or to the Clinch River arm of the Watts Bar Reservoir. The exception to this is well cluster OW-409U/L, which is located near the center of the site. This cluster may be indicating groundwater discharge to the adjacent CRBRP excavation. The cluster with the highest downward flow potential is OW-429U/L, suggesting a recharge area. Figure 2.4.12-29 represents the spatial variation of equipotential in the vertical plane in a cross-section along the strike of the bedding plane based on June 13, 2014 observations. Groundwater discharges from the higher equipotential area (at OW-202) to the Clinch River arm of the Watts Bar Reservoir, with OW-202 at the center of the CRS peninsula as a likely location of the groundwater divide.

SSAR Subsection 2.4.12C.5 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12C.5 Numerical Model

Figure 2.4.12C-13 presents a conceptual site layout which is a composite that represents the bounding area for the different potential SMR technologies. Geotechnical borings (referred to as MPs) are concentrated within the power block area and centered near borings MP-101 and MP-202 (Figure 2.4.12C-13)~~, locations where two SMRs were at one time postulated~~. Based on geology observed in the geotechnical borings, most of the power block foot print area lies within the Chickamauga Group of rocks (interbedded siltstone and limestone), whereas the Knox Group (comprised mostly of dolomite) outcrops in the northern extremities of the power block area as indicated on Figure 2.4.12C-13. Within the power block area, the Knox is significantly deeper. For example, at the MP-202 and MP-101 locations, it is encountered at a depth of approximately 450 and 1000 ft bgs, respectively, while at MP-423 and MP-426 the Knox is first encountered at a depth of approximately 30 to 50 ft bgs.

Two, two-dimensional, vertical profile, groundwater models (profile models) were developed along the strike of the bedding planes (approximately N52°E) for the CRN Site. Figure 2.4.12C-13 shows the plan view of the profile models. Profile A intersects and lies close to the MP-202 series of geotechnical borings, representing the northern area of the power block, while Profile C (Profile B is not used) intersects the MP-101 series of geotechnical borings and represents the southern portion of the power block (Figure 2.4.12C-13). Both profiles fall along a three-cluster groundwater monitoring well series (OW-202 U/L/D and OW-101 U/L/D) at the power block area. The geologic formations present along the two profiles are different; Profile A mostly intersects the Fleanor Shale Member of the Lincolnshire Formation, while Profile C mostly intersects the Benbolt Formation. The hydraulic conductivity distribution along these lines, determined from the slug and packer tests, is also different (Table 2.4.12C-6). The combination of a concentration of geotechnical borings in two different clusters (within the foot print of the power block area) and the difference in hydraulic conductivity values led to the need to create two profile models to adequately represent the power block area.

The objective of the groundwater modeling is to determine maximum groundwater heads at and near the power block area under post-construction conditions. The profile models described above are based on the conceptual hydrogeological model for the CRN Site. The intent of the groundwater model is not to exactly duplicate the subsurface geology, but to approximate the site conceptual model, such that the numerical model represents current conditions and conservatively estimates future groundwater flow conditions at the site. It is well understood that there is significant uncertainty in the thickness and hydrogeologic properties of the geologic formations in between the investigation boreholes as a result of subsurface heterogeneity. However, reproduction of this heterogeneity is not an objective of the groundwater model. The groundwater model is intended to be a simplistic representation of the subsurface conditions that is capable of providing credible maximum groundwater heads to reproduce the maximum observed groundwater heads at the CRN Site. The pre-construction or ambient groundwater model can then be modified to represent post-construction conditions and meet the objectives of the groundwater model stated above. The profile models are used to provide conservative estimates of the maximum groundwater heads below safety-related structures. This is achieved through a steady-state groundwater model rather than a transient model to meet the objectives of this modeling task.

The groundwater model was developed using the pre- and post-processor groundwater modeling software, Groundwater Vistas, Version 6.07, Build 10. The numerical code used to simulate the profile models is MODFLOW-SURFACT, Version 3.0, as implemented in Groundwater Vistas (Reference 2.4.12C-11).

SSAR Subsection 2.4.12C.6.1.3 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12C.6.1.3 Calibrated Model Runs

Using the initial hydraulic conductivities as described in Table 2.4.12C-6 and a recharge estimate of 20 percent of the maximum annual precipitation of 76.33 in., the simulated heads were greater than the maximum measured heads in all of the CRN observation wells, except for OW-202U (Table 2.4.12C-8). The rationale for the choice of 20 percent recharge of the maximum recorded annual precipitation is provided in Subsection 2.4.12C.3.7, *Recharge Data – Literature Information*. Decreasing the initial hydraulic conductivities in Layers 5 and 6 by an order of magnitude in the Profile A model results in simulated heads in OW-202U that approximate the measured heads (Run 18 in Table 2.4.12C-8). The hydraulic conductivity values in Profile A of 0.1 ft/day and 0.041 ft/day for Layers 5 and 6, respectively, were within the range of hydraulic conductivity values determined from the slug and the packer tests. It is to be noted that the residuals (i.e., simulated heads minus measured heads) in Run 1 (Profile C) and Run 18 (Profile A) are negative, which means the simulated heads are higher than the measured heads. However, the simulated heads for the shallow U-series observation wells at ~~the two simulated SMR power block areas selected for this (~~OW-202U and OW-101U~~)~~ are comparable to the maximum measured water levels. Although the residuals are high in the observation wells at greater distances from the modeled SMR power ~~blocks~~block area, this has little to no effect on the maximum simulated water levels at the modeled SMR power ~~blocks~~block area; therefore, no attempt is made to decrease the residuals by further improvement of the calibration. The groundwater flow directions in the profile models (Figures 2.4.12C-18 and 2.4.12C-19) show upward flows near the river (depicted by blue arrows) and downward flow at the center of the power block area (depicted by red arrows), which is in general agreement with the vertical hydraulic gradients determined for the site observation wells.

Decreasing the hydraulic conductivity of Layer 2 by an order-of-magnitude from the initial value (Table 2.4.12C-6) in Profile C results in lower RMSE and lower residuals in well OW-101U; however, the residuals in OW-202U increased (indicating a lower simulated head than the measured head) from the initial model Run 1. In order to maintain consistency of hydraulic conductivity in Layer 2 across the two models, the initial hydraulic conductivity as stated in Table 2.4.12C-6 was chosen for the calibrated runs. This resulted in higher negative residuals (simulated heads greater than the measured heads) at the SMR power blocks and provided conservative estimates of maximum simulated heads. The measured heads, simulated heads, and residuals for each of the model runs are provided in Table 2.4.12C-8. Thus, Run 18 for Profile A and Run 1 for Profile C are considered the calibrated model simulations (Table 2.4.12C-8 and Figures 2.4.12C-16 to 2.4.12C-19). A combination of model runs with different recharge and hydraulic conductivities could have produced a lower RMSE and residuals; however, this may not have been a unique set of parameters and thus may not have produced values that are representative of the site conditions.

The profile models were based on the knowledge of the site-specific hydraulic conductivity distribution and recharge values as based on studies in similar hydrogeologic settings close to the CRN Site. The hydraulic conductivity distribution is representative of the geologic formations and does not represent the complex heterogeneity within each formation at the CRN Site. The calibrated groundwater models are thus a simplistic representation of the subsurface and the post-construction simulations should be used with the understanding that the predictions may not precisely mimic future groundwater conditions. However, the groundwater heads obtained from the post-construction simulations are likely to approximate or be higher than the actual

post-construction heads.

ER Subsection 2.3.1.2.2.3 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.3.1.2.2.3 Groundwater Flow Directions

Groundwater flow directions in the ORR are generally characterized as from the ridge tops to drainages within the adjacent valley or as a subdued replica of topography. Figure 2.3.1-32 presents conceptual block flow diagrams for Bethel Valley, which has similar geology as the CRN Site (Reference 2.3.1-35). The figure indicates localized influences such as springs, discontinuity orientations (fractures and bedding planes), man-made features (pipelines, tank farms, and building basements), and solution features have an impact on flow directions. Groundwater flow directions were evaluated during the CRBRP PSAR by preparing two groundwater contour maps, one for December 24, 1973 and one for January 2, 1974 (Reference 2.3.1-20). Both maps indicate a general flow direction toward the southeast or southwest in the area of the proposed nuclear island. An average hydraulic gradient of approximately 0.007 feet per foot (ft/ft) is reported for the two maps (Reference 2.3.1-20). It should be noted that these maps were prepared using water level measurements from observation wells with long screened intervals and thus the equipotentials represent a vertically averaged head.

The CRN Site investigation included synoptic measurements of groundwater levels in the site observation wells. These measurements were used to prepare maximum potentiometric surface maps for the site. The maximum potentiometric surface maps used the maximum groundwater level elevation at each well cluster. Figures 2.3.1-33 through 2.3.1-42 present the potentiometric surface maps. The maps indicate a southwest to southeast flow direction in the area of the proposed CRN Site Powerblock Area. Hydraulic gradients were measured along selected flow lines on each figure. Table 2.4.12-8 in the Site Safety Analysis Report (SSAR) presents the horizontal hydraulic gradients for the ten potentiometric surface maps. The horizontal hydraulic gradients range from 0.03 to 0.12 ft/ft. Horizontal gradients were also evaluated using just the upper site observation wells for the eight quarters (December 2013, March 2014, May 2014, August 2014, November 2014, February 2015, May 2015, and August 2015), resulting in horizontal gradients ranging from 0.05 to 0.17 ft/ft. For comparison the average hydraulic gradient between the maximum water level at OW-101U and OW-202U ~~(the locations of the two SMR reactors)~~ and the Clinch River arm of the Watts Bar Reservoir is 0.05 ft/ft. This is derived based on a shortest distance of 1400 ft from the power block area to the edge of the Clinch River arm of the Watts Bar Reservoir; lowest stage of the reservoir at 735 ft NAVD88 (during the monitoring period); and the maximum water levels at OW-101U and OW-202U of 798.99 and 800.30 ft NAVD88. Due to the complexity of the subsurface hydrogeologic conditions at the CRN Site, the maximum potentiometric groundwater elevation at each well cluster is used, representing a single hydrogeological unit. Given that the “U,” “L,” and “D” wells generally screened within different hydrogeologic units, the “maximum potentiometric surface” maps do not represent a true potentiometric surface. These maps can, however, be considered bounding in terms of depicting the maximum groundwater elevations at the site.

Vertical hydraulic gradients were determined at each well cluster to evaluate the potential for vertical movement in the subsurface. The average vertical hydraulic gradients range from -0.69 to 1.03 ft/ft (Appendix 2.3-C). A negative vertical hydraulic gradient indicates an upward flow potential and a positive one indicates a downward flow potential. The upward flow potential would suggest groundwater discharge and the downward flow potential would suggest groundwater recharge. A majority of the wells with upward flow potential are located on the western and eastern sides of the site suggesting discharge towards incised site drainage

features or to the Clinch River. The exception to this is well cluster OW-409U/L, which is located near the center of the site. This cluster may be indicating groundwater discharge to the adjacent CRBRP excavation. The cluster with the highest downward flow potential is OW-429U/L, suggesting a recharge area. Figure 2.3.1-43 represents the spatial variation of equipotential in the vertical plane in a cross-section along the strike of the bedding plane based on June 13, 2014 observations. Groundwater discharges from the higher equipotential area (at OW-202) to the Clinch River arm of the Watts Bar Reservoir, with OW-202 at the center of the CRS peninsula as a likely location of the groundwater divide.

Supplemental Information related to NRC Information Need 30

The NRC reviewer requested that TVA provide the document number for the Nuclear Energy Institute (NEI) groundwater initiatives discussed in SSAR Subsection 2.4.12.4. The document is NEI 07-07. The reference is being added as described below.

SSAR Subsection 2.4.12.4 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12.4 Monitoring or Safeguard Requirements

Groundwater levels at the CRN Site were determined through the use of groundwater observation wells installed in 2013 as part of the site subsurface investigation. Consistent with Regulatory Guide 4.21, *Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning*, and the Nuclear Energy Institute (NEI) groundwater initiatives (Reference 2.4.12-50), the existing groundwater observation well network is evaluated and an environmental monitoring program developed as part of detailed design activities for the CRN Site. The groundwater monitoring program considers the following components:

- Periodic water level measurements in observation wells and geochemical sampling and analysis are made to detect changes in the bedrock aquifer and backfill that may impact groundwater levels or the accidental release analysis.

- Operational accident monitoring—the effluent and process monitoring program is addressed in the combined license application.

Groundwater level measurements in bedrock aquifer and backfill observation wells (existing or future) are made during construction and operation. Selection of observation wells included in the program is made before the start of operation based on well condition, position relative to plant site and other observation wells (provide optimal spatial distribution for potentiometric map preparation and vertical hydraulic gradient assessment), and long-term viability of the observation well (likelihood that the well will not be damaged or destroyed).

Geochemical sampling and analysis of the bedrock aquifer and backfill wells are performed during construction and operation. Analysis includes field parameters (pH, temperature, specific conductance, oxidation-reduction potential, and dissolved oxygen), major cations, major anions, total dissolved solids, silica, and any additional water quality parameters as needed.

Operational accident monitoring is initiated in the unlikely event of a release of liquid effluent from the plant. Quarterly groundwater samples are collected from downgradient bedrock aquifer and backfill observation wells as needed to identify impact. Selection of downgradient observation wells is based on flow directions determined from the most recent groundwater level measurements.

Safeguards are used to minimize the potential for adverse impacts to the groundwater caused by construction and operation of the CRN Site. These safeguards include the use of emergency cleanup procedures to capture and remove surface contaminants, and other measures deemed necessary to prevent or minimize adverse impacts to the groundwater beneath the site.

SSAR Subsection 2.4.12.6 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12.6 References

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2.4.12-50 NEI 07-07, "Industry Ground Water Protection Initiative – Final Guidance Document," Rev. 0, August 2007.

Supplemental Information related to NRC Information Need 33-a/40-c

The terminology used to refer to the fill was not consistent throughout the SSAR. SSAR markups are provided below to consistently refer to the fill throughout the SSAR. Note that the SSAR markup for 2.4.12C.7.1, also includes the correction of a typographical error in the elevation of the SMR with shallowest foundation.

SSAR Subsection 2.4.12.4 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12.4 Monitoring or Safeguard Requirements

Groundwater levels at the CRN Site were determined through the use of groundwater observation wells installed in 2013 as part of the site subsurface investigation. Consistent with Regulatory Guide 4.21, *Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning*, and the Nuclear Energy Institute (NEI) groundwater initiatives (Reference 2.4.12-50), the existing groundwater observation well network is evaluated and an environmental monitoring program developed as part of detailed design activities for the CRN Site. The groundwater monitoring program considers the following components:

- Periodic water level measurements in observation wells and geochemical sampling and analysis are made to detect changes in the bedrock aquifer and granular backfill that may impact groundwater levels or the accidental release analysis.
- Operational accident monitoring—the effluent and process monitoring program is addressed in the combined license application.

Groundwater level measurements in bedrock aquifer and granular backfill observation wells (existing or future) are made during construction and operation. Selection of observation wells included in the program is made before the start of operation based on well condition, position relative to plant site and other observation wells (provide optimal spatial distribution for potentiometric map preparation and vertical hydraulic gradient assessment), and long-term viability of the observation well (likelihood that the well will not be damaged or destroyed).

Geochemical sampling and analysis of the bedrock aquifer and granular backfill wells are performed during construction and operation. Analysis includes field parameters (pH, temperature, specific conductance, oxidation-reduction potential, and dissolved oxygen), major cations, major anions, total dissolved solids, silica, and any additional water quality parameters as needed.

Operational accident monitoring is initiated in the unlikely event of a release of liquid effluent from the plant. Quarterly groundwater samples are collected from downgradient bedrock aquifer and granular backfill observation wells as needed to identify impact. Selection of downgradient observation wells is based on flow directions determined from the most recent groundwater level measurements.

Safeguards are used to minimize the potential for adverse impacts to the groundwater caused by construction and operation of the CRN Site. These safeguards include the use of emergency cleanup procedures to capture and remove surface contaminants, and other measures deemed necessary to prevent or minimize adverse impacts to the groundwater beneath the site.

SSAR Subsection 2.4.12.5.1 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12.5.1 Groundwater Flow Model

Two-dimensional, vertical profile, groundwater models (profile models) were developed along the geologic strike of the bedding planes (principal flow direction) at the CRN Site. The purpose of the profile models is to evaluate maximum groundwater level as a result of construction and operation of the units at the CRN Site.

Two profile models were developed – one within the northern sector and the other along the southern sector of the power block area, both oriented along a strike of the bedding planes. Both profile models encompass the Chickamauga Group of interbedded siltstone and limestone, which includes the Fleanor Shale member (in the northern profile model – Profile A) and the Benbolt Formation (in the southern profile model- Profile C), Figure 2.4.12-40. A detailed discussion of the groundwater flow modeling is presented in Appendix 2.4.12C and summarized as follows.

The profile models were developed based on the conceptual understanding of the hydrogeologic features of the site. This included interpretation of the hydrogeologic subsurface investigations at the CRN Site; modeling studies conducted at the ORR area; and an understanding that the site has undergone significant disturbance as a result of CRBRP site preparation activities. A total of six active layers were simulated: Layer 1 was simulated as a fill layer based on CRBRP land disturbance; Layer 2 was simulated as a soil layer representing the vadose zone; Layer 3 represents the highly fractured bedrock encompassing the interface between soil and competent bedrock; and Layers 4 to 6 represent the competent bedrock with fracture density deceasing with depth.

The profile models were calibrated by matching the simulated heads against the maximum observed heads within the power block area measured during the subsurface investigations at the CRN Site. Sensitivity of model parameters (hydraulic conductivity and recharge) to simulated heads was evaluated during the calibration phase of the model. Alternate conceptual models were also simulated: 1) a preferential flow zone in Layer 3 was simulated by assuming a very high hydraulic conductivity for this layer; 2) the impact of spatially variable recharge rates was assessed; and 3) the impact of using a uniform recharge rate was assessed. A uniform recharge rate of 8.76 in./yr provided the most conservative estimate for the maximum groundwater heads at the power block area. This pre-construction model with a uniform recharge of 8.76 in./yr served as the base for the post-construction model simulations. The hydraulic conductivity values assigned in the model layers were within the range of values obtained from the packer, slug, and aquifer performance tests at the CRN Site and from literature studies at ORR.

The post-construction model included a surface elevation of approximately 821 ft NAVD88 and is based on the CRN Plant Parameter Envelope (PPE) conceptual design grade in the power block area. The post-construction models included two embedment depths: a shallow reactor building embedment depth of about 50 ft below grade, and a deep reactor building embedment depth of about 140 ft below grade. The grade elevation at the power block at the reactor building was assigned a value of 821 ft NAVD88. A uniform recharge of 8.76 in./yr was assigned in the post-construction models except at the power block area and part of the turbine area (which are comprised of paved areas and buildings). Model sensitivity to variation of granular backfill hydraulic conductivity with regard to simulated groundwater heads was evaluated. Higher granular backfill hydraulic conductivity resulted in lower groundwater heads at the power block area. The model simulated groundwater heads underneath the foundation embedment structure ranging from 802.3 to 810.9 ft NAVD88 for Profile A and from 807.3 to 816.1 ft NAVD88 for Profile C.

SSAR Subsection 2.4.12C.7.1 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12C.7.1 Modifications to Pre-Construction Models

The general structure of the profile models along with hydraulic conductivity distributions for subsurface layers remained the same as the pre-construction model; however, some nominal changes were made to include representative structures (Figures 2.4.12C-23 and 2.4.12C-24). The following describes the changes to the pre-construction models to develop the post-construction profile models:

- An extra subsurface model layer was added below the bottom of the conceptualized SMR nuclear reactor (Layer 7) to determine the maximum head imposed at the base of the reactor foundation embedment depth and SMR structure. The hydraulic conductivity for this layer remained the same as in the pre-construction model for the same depth. Figures 2.4.12C-23 and 2.4.12C-24 shows the hydraulic conductivity distributions for the layers in the post-construction models for Profiles A and C.
- Surface grade elevations across the two profile models were based on the PPE with maximum foundation embedment depth of approximately 140 ft below grade. Additionally, a shallow SMR foundation embedment depth was also included (in a separate model configuration) at approximately 50 ft below grade (top of the competent rock) in order to represent a technology requiring a shallow foundation embedment depth. These two different excavation depths provide the bounding foundation embedment depths for the different SMR technologies. The width of the power block in the profile models approximates the width of the power block area in the site layout drawing. The grade elevations are approximate and may change when a specific technology is selected for the Combined License Application (COLA).
- ~~Construction fill~~ Granular backfill material was included in areas where the surface elevation of the pre-construction model was raised to accommodate the post-construction model grade. The grade elevation of the power block area corresponds to an elevation of 821 ft NAVD88. The power block is assumed to include: a) radwaste building with foundation embedment elevation selected at 818 ft NAVD88; b) reactor building foundation embedment elevation selected at approximately 681 ft NAVD88 for the deepest SMR technology and at approximately ~~707~~770 ft NAVD88 for the shallowest SMR technology; and c) auxiliary building elevation selected at 748 ft NAVD88 for the deepest SMR technology and at about 770 ft NAVD88 for the shallowest SMR technology. The embedment depth of the turbine building was assumed to be at an elevation of 814 ft NAVD88, which is 6 ft below grade. The assumption of the embedment depth of the turbine building is based on the approximation of a shallow

depth of embedment. The turbine building depth is independent of the different SMR technologies. The inclusion of the radwaste, turbine, and auxiliary buildings, which are not part of the PPE, provides a representation of the type of buildings that are likely to be constructed for a nuclear power plant; these buildings do not have any appreciable impact on the outcome of the hydraulic heads. Embedded structures in the profile models are represented by no-flow cells.

In summary:

1. The hydraulic conductivity of the ~~construction fill~~granular backfill material is assumed to be representative of clean sand with a value of 10^{-2} cm/s (28.35 ft/day) (Reference 2.4.12C-8). This value corresponds to the mid-range of clean sand and is equivalent to a hydraulic conductivity value of ~~a fill~~granular backfill material that has undergone some compaction, which is typically within the range used in construction sites for a nuclear power plant. The value of hydraulic conductivity is assumed to be uniform (i.e., homogeneous) and represents fill adjacent in and outside of the power block area.
2. Recharge is assumed to be 8.76 in./yr, based on an alternative conceptual model for the preconstruction model runs, except in the power block area and part of the turbine area, which are assumed to be impervious.

SSAR Subsection 2.4.12C.7.2 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12C.7.2 Results

The objective of the groundwater modeling as outlined in Subsection 2.4.12C.1 is to determine post-construction maximum groundwater head in the power block area. The maximum allowable head at the foundation embedment depth of the reactor building is based on the requirements of a specific nuclear technology. However, as the present groundwater modeling post-construction analysis is independent of any technology, and site-specific grade elevations (i.e., beyond the immediate vicinity of the power block) are not finalized, the groundwater heads reported here are preliminary until a technology is selected and site-specific grade elevations are established in the COLA.

The hydraulic conductivity of the site granular backfill as well as amount of post-construction recharge to the subsurface are the dominant factors controlling the hydraulic heads in the power block area. Two sensitivity runs were conducted by varying the hydraulic conductivity of the ~~construction~~granular backfill by an order of magnitude larger and smaller than the base value of 10^{-2} cm/s (28.35 ft/day). A value of ~~construction~~granular backfill of 10^{-3} cm/s (2.835 ft/day) typically represents a highly compacted backfill; whereas, a value of 10^{-1} cm/s (283.5 ft/day) represents an uncompacted granular backfill material.

Tables 2.4.12C-11 and 2.4.12C-12 depict the simulated groundwater heads beneath the reactor and the auxiliary building as well as adjacent to the reactor building. Figures 2.4.12C-25 and 2.4.12C-26 show the locations of the simulated groundwater heads in the profile section with deep and shallow foundation embedment, as presented in Tables 2.4.12C-11 and 2.4.12C-12. Figures 2.4.12C-27 to 2.4.12C-29 show hydraulic head distribution in the Profile A model for the deep and shallow foundation embedment, with hydraulic conductivity of the ~~fill~~granular backfill materials of 10^{-2} cm/s (28.35 ft/day), 10^{-3} cm/s (2.835 ft/day), and 10^{-1} cm/s (283.5 ft/day), respectively. Similarly, Figures 2.4.12C-30 to 2.4.12C-32 show hydraulic head distribution in the Profile C model for the deep and shallow foundation embedment, with hydraulic conductivity of the ~~fill~~granular backfill material of 10^{-2} cm/s (28.35 ft/day), 10^{-3} cm/s (2.835 ft/day), and 10^{-1} cm/s (283.5 ft/day), respectively.

Simulated groundwater heads are typically lower in Profile A than compared to Profile C. This is a result of a combination of more ~~construction fill~~granular backfill in the area of the previous CRBRP excavation area and higher hydraulic conductivity values in the Fleanor Shale Member of the Lincolnshire Formation (Profile A) than in the Benbolt Formation (Profile C). The variability of the depth and location of the ~~fill~~granular backfill also results in variable groundwater heads underneath the structures. Variation of granular backfill hydraulic conductivity values by an order of magnitude did not result in a significant change in groundwater head elevations underneath the structures, although there was slight difference in the groundwater head elevations. Lower groundwater heads were observed underneath the structures with higher granular backfill hydraulic conductivity. A higher granular backfill hydraulic conductivity value of 10^{-1} cm/s (283.5 ft/day) results in lower groundwater heads below the shallow SMR foundation embedment than deep SMR foundation embedment depth. The difference is more apparent in Profile C than Profile A (Tables 2.4.12C-11 and 2.4.12C-12).

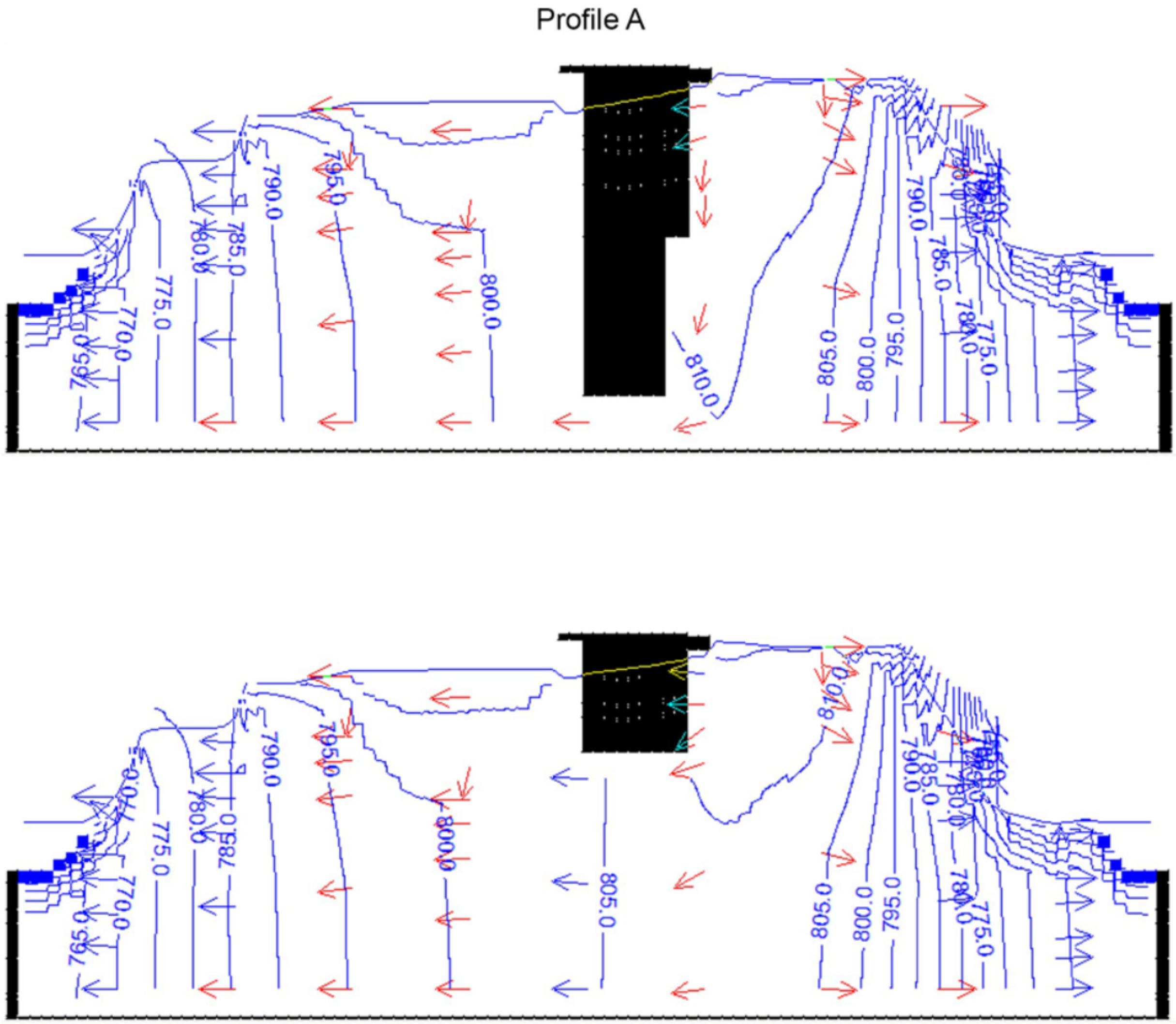
SSAR Subsection 2.4.12C.8 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12C.8 Conclusions

The following are concluded from the groundwater modeling results:

- Pre-construction groundwater model simulated heads closely matched the observed maximum groundwater heads at observation wells near the proposed location of the SMRs for this modeling exercise.
- Groundwater heads are sensitive to recharge in the groundwater model, similar to observed water level response due to precipitation during the subsurface investigations at the CRN Site. Higher recharge translates to higher water levels. A uniform recharge of 8.76 in./yr in the two profile models results in water levels close to the land surface at the power block area. This provides a conservative estimate with respect to the maximum water levels under predictive model simulations.
- Higher hydraulic conductivity of the ~~construction~~ granular backfill results in decreases in the simulated groundwater heads surrounding the shallow and deep structures.
- Maximum simulated groundwater heads surrounding the shallow and deep structures varies between the profile models (Profiles A and C). The simulated groundwater heads were slightly lower in Profile A than in Profile C. This is due to the presence of more granular backfill and a higher hydraulic conductivity of the geologic formation in Profile A than in Profile C.
- Simulated groundwater heads underneath the structures in deep foundations varied between 802.3 to 810.9 ft NAVD88 for Profile A and 807.3 to 816.1 ft NAVD88 for Profile C using the highest hydraulic conductivity granular backfill.

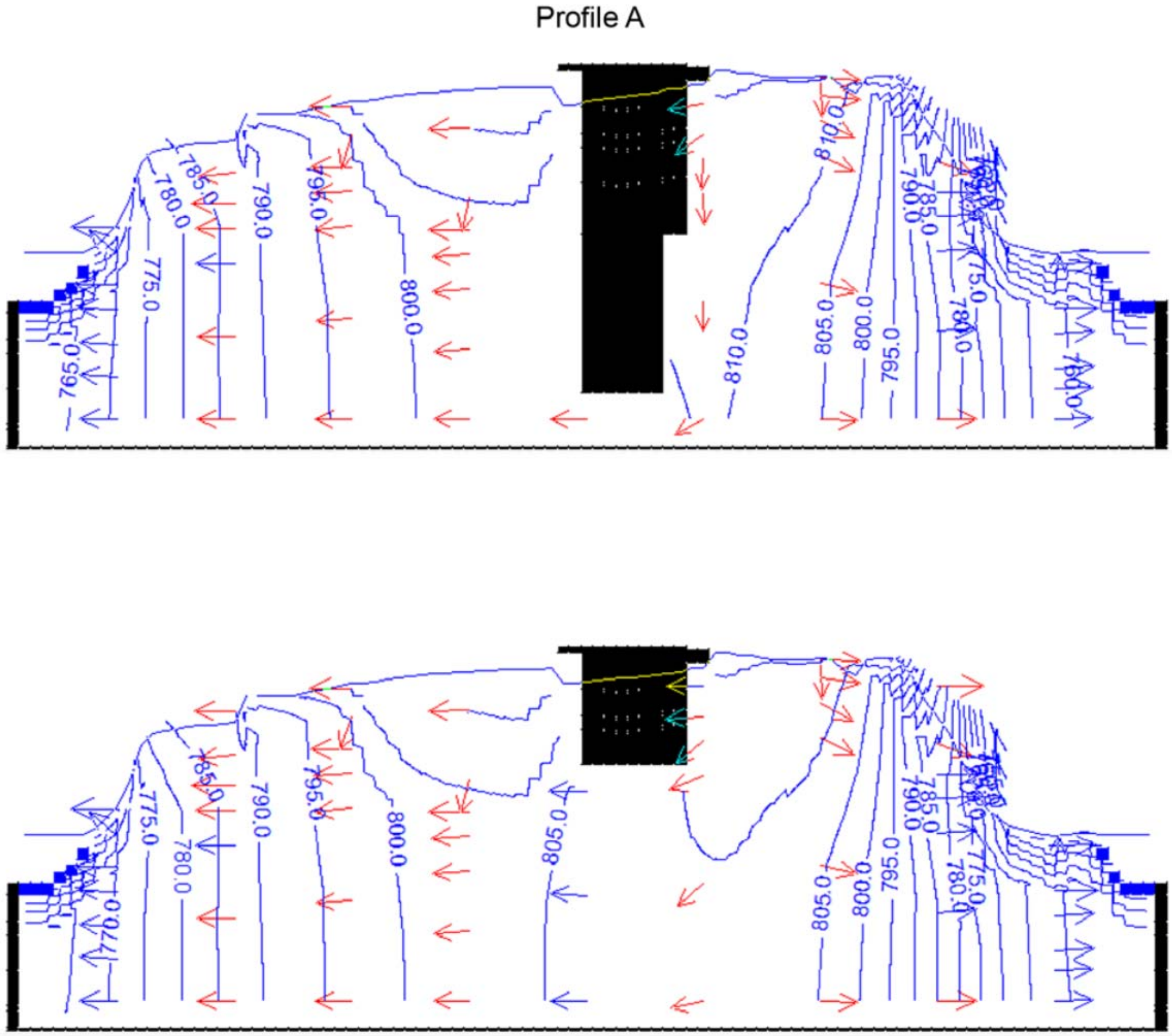
SSAR Figure 2.4.12C-27 is being revised as indicated (no revisions to the image have been made). Strikethroughs indicate text to be deleted. Underlines indicate text to be added.



Note: Red arrow indicates downward flow and blue arrow indicates upward flow; blue lines with numbers indicates groundwater contours; deep blue blocks represent constant head of Clinch River; and black blocks represents no flow cells.

Figure 2.4.12C-27. Groundwater Heads—~~Fill~~Granular Backfill Hydraulic Conductivity of 10^{-2} cm/s in Profile A Model: a) Deep Foundation Embedment and b) Shallow Foundation Embedment

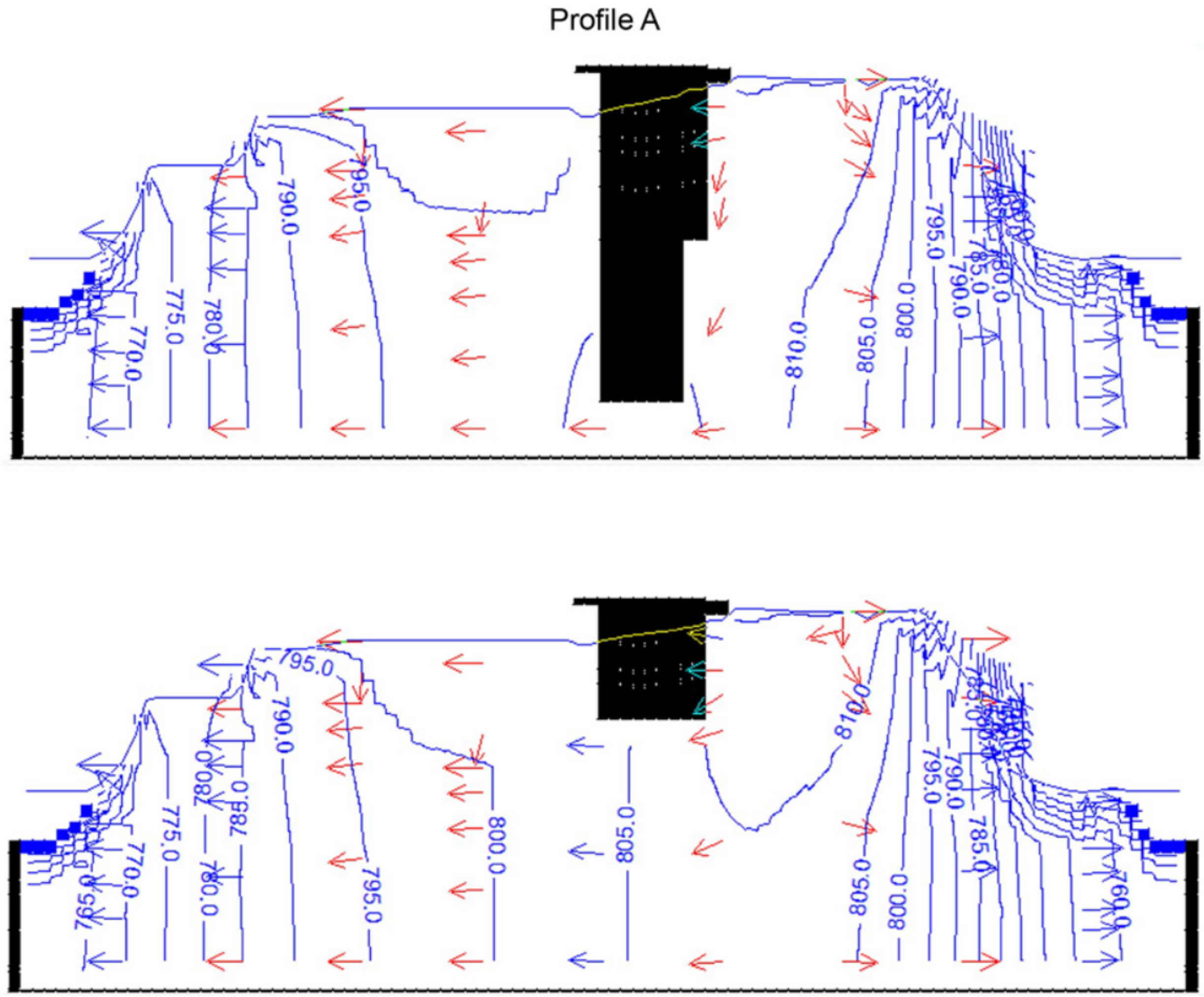
SSAR Figure 2.4.12C-28 is being revised as indicated (no revisions to the image have been made). Strikethroughs indicate text to be deleted. Underlines indicate text to be added.



Note: Red arrow indicates downward flow and blue arrow indicates upward flow; blue lines with numbers indicates groundwater contours; deep blue blocks represent constant head of Clinch River; and black blocks represents no flow cells.

Figure 2.4.12C-28. Groundwater Heads—~~Fill~~Granular Backfill Hydraulic Conductivity of 10^{-3} cm/s in Profile A Model: a) Deep Foundation Embedment and b) Shallow Foundation Embedment

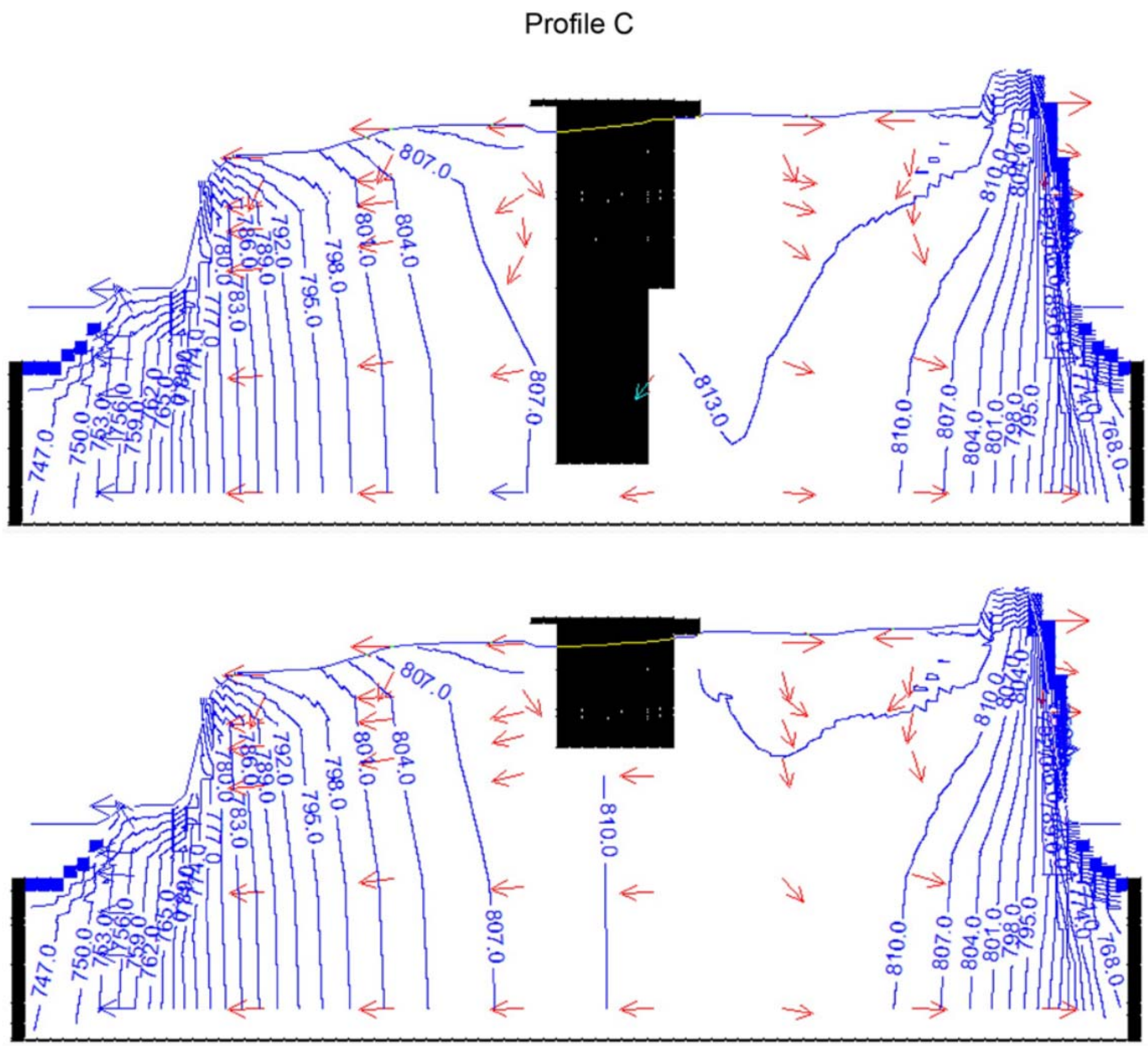
SSAR Figure 2.4.12C-29 is being revised as indicated (no revisions to the image have been made). Strikethroughs indicate text to be deleted. Underlines indicate text to be added.



Note: Red arrow indicates downward flow and blue arrow indicates upward flow; blue lines with numbers indicates groundwater contours; deep blue blocks represent constant head of Clinch River; and black blocks represents no flow cells.

Figure 2.4.12C-29. Groundwater Heads~~—Fill~~Granular Backfill Hydraulic Conductivity of 10^{-1} cm/s in Profile A Model: a) Deep Foundation Embedment and b) Shallow Foundation Embedment

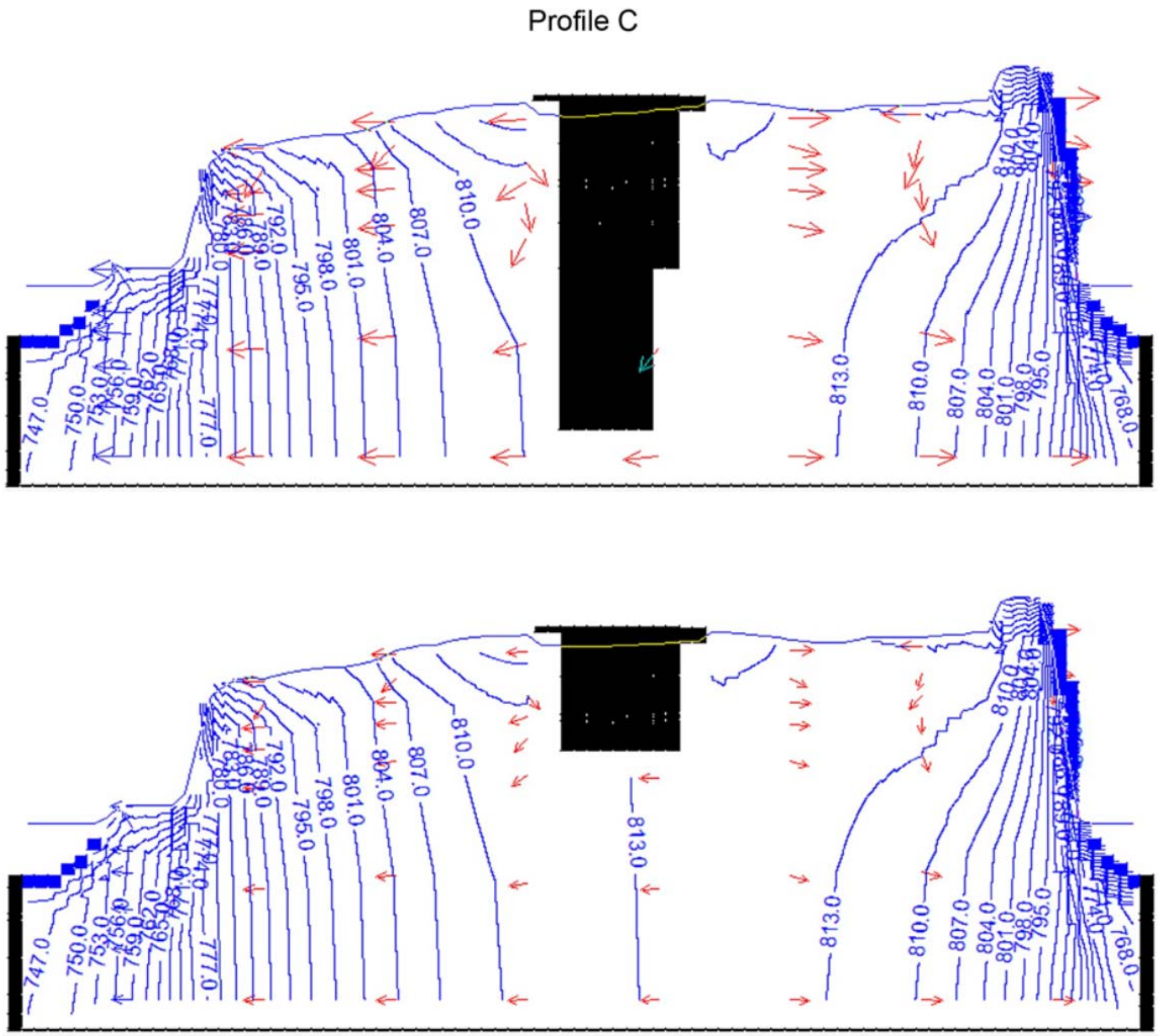
SSAR Figure 2.4.12C-30 is being revised as indicated (no revisions to the image have been made). Strikethroughs indicate text to be deleted. Underlines indicate text to be added.



Note: Red arrow indicates downward flow and blue arrow indicates upward flow; blue lines with numbers indicates groundwater contours; deep blue blocks represent constant head of Clinch River; and black blocks represents no flow cells.

Figure 2.4.12C-30. Groundwater Heads—~~Fill~~Granular Backfill Hydraulic Conductivity of 10^{-2} cm/s in Profile C Model: a) Deep Foundation Embedment and b) Shallow Foundation Embedment

SSAR Figure 2.4.12C-31 is being revised as indicated (no revisions to the image have been made). Strikethroughs indicate text to be deleted. Underlines indicate text to be added.



Note: Red arrow indicates downward flow and blue arrow indicates upward flow; blue lines with numbers indicates groundwater contours; deep blue blocks represent constant head of Clinch River; and black blocks represents no flow cells.

Figure 2.4.12C-31. Groundwater Heads—~~Fill~~Granular Backfill Hydraulic Conductivity of 10^{-3} cm/s in Profile C Model: a) Deep Foundation Embedment and b) Shallow Foundation Embedment

SSAR Subsection 2.5.1.2.6.8 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.5.1.2.6.8 Effects of Human Activities

Fossil fuels such as oil and natural gas, coal, oil shales and radioactive minerals are found in Tennessee. Only oil and natural gas and coal are currently being recovered (Reference 2.5.1-271). The Tennessee Department of Environment and Conservation (TDEC) (Reference 2.5.1-272) allows access to its databases through Dataviewer, which reflects overnight updates to the agency's consolidated state databases. Accessing the Water Resources Permits Dataviewer for oil and gas wells reveals four permit applications for Roane County, TN, dating from June, 1981 to July, 2006, as listed in Table 2.5.1-18. None of these wells for which a permit application was submitted are within 5 mi of the CRN Site. The closest permit-application well to the site is the Edwards-Fowler Unit #1 well (Permit No. 10766) located approximately 5.5 mi to the northwest. According to information obtained from the TDEC (Reference 2.5.1-272) this well currently produces gas. The other three wells listed in Table 2.5.1-18 either produced gas for a period of time (Eula Butler Etal #1 well; Permit No. 10574) or were never permitted for gas production.

Areas of Tennessee mined for coal, past and present, and with potential reserves of coal are located along the Roane-Morgan and Roane-Cumberland county lines. There are no coal mines within 5 miles of the CRN Site. Accessing the TDEC Water Resources Permits Mapviewer (Reference 2.5.1-273) indicates that the closest coal mines to the CRN Site are in Morgan County, owned and operated by Clear Energy Corporation (formerly Dalco of Tennessee, LLC.) and are producers of bituminous coal and lignite (Figure 2.5.1-61).

Construction materials mined or quarried in Tennessee include dimension stone (sandstone and marble), crushed stone, limestone and clay and sand and gravel (Reference 2.5.1-271). Accessing the TDEC Water Resources Permits Mapviewer (Reference 2.5.1-273) Figure 2.5.1-61 shows the water resource permit applications that currently exist within approximately 10 miles of the CRN Site. As shown on this figure several of these water permits are for mining purposes, however, none of these are within 5 mi of the CRN Site. The two mines closest to the site are quarries and are located approximately 8 mi northwest and east of the site and are Roane County Quarry and Dixie Lee Quarry, respectively. Both of these quarries produce crushed and broken limestone.

Injection of radioactive waste at the ORNL, located about 4 mi east of the CRN Site, is well documented (References 2.5.1-100 and 2.5.1-238). All experimental and operational injections are reported to have been made within the Conasauga shale which underlies the Rome Formation at the CRN Site (See Figure 2.5.1-37). The radioactive waste was mixed with a cement grout slurry and injected into the shale. Hydrofracturing techniques were used to create cracks in the rock to accommodate the radioactive waste solutions. Several experimental well injection sites and an operational well injection site were established between 1959 and 1972 and during this time, periodic injections of radioactive waste solutions were made between depths of approximately 300 and 1000 ft below the ground surface. Ground behavior monitoring techniques implemented within the vicinity of the operation well site indicated minimal uplift of the ground surface, approximately 0.06 ft within a 1700-ft (0.3-mi) radius. A fourth operational injection well site was planned for future injections at the site (References 2.5.1-100 and 2.5.1-238).

Anthropogenic activities at the CRN Site included large-scale grading and excavation for the CRBRP. These graded areas contain ~~unengineered~~ fill (see Subsection 2.5.4).

SSAR Subsection 2.5.3.8.2.3 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.5.3.8.2.3 Anthropogenic Features

The CRN Site has never been commercially mined; there is no potential hazard from mine collapse (see Subsection 2.5.1.2.6.8). The previous ~~grading/excavation~~grading and excavation of the CRBRP ~~may~~ contains ~~unengineered~~ fill and will be evaluated for any future development.

SSAR Subsection 2.5.4.2.4 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.5.4.2.4 Engineering Properties

The engineering properties for the existing fill/residual soil, ~~structural~~ granular backfill, weathered rock and the bedrock within the footprint of the power block area are derived from the recent subsurface investigation and laboratory testing programs and are provided in Table 2.5.4-20.

The engineering properties for the bedrock are developed for each of the stratigraphic units, independent of depth. Field and laboratory test results indicated no appreciable variation in the intact rock and rock mass properties with depth. Engineering properties are developed for the Benbolt and Rockdell Formations, the Eidson and Fleanor Members of the Lincolnshire Formation and the Blackford and Newala Formations. The engineering properties are developed to evaluate the stability of the foundation materials.

The following subsections briefly describe the sources and/or methods used to develop the selected properties shown in Table 2.5.4-21.

SSAR Subsection 2.5.5.2 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.5.5.2 Design Criteria and Analyses

Since site grading has not been established, the presence of permanent safety-related slopes cannot be determined. This determination will be made during the combined operating license stage. If permanent safety-related slopes are identified, these slopes will be analyzed to ensure adequate margin against the potential failure of these slopes impacting safety-related structures.

Construction excavation cut slopes will be required in the PBA for construction of the foundations. Soil and rock will be removed and replaced with compacted ~~structural fill~~ granular backfill and lean concrete, respectively. The conceptual design of the excavation, including excavation support and slope stabilization details, is developed in the COLA. The construction excavation cut slopes will be temporary since they are for the construction period only. The excavation will be backfilled and none of these slopes will remain after construction in the PBA.

Supplemental Information related to NRC Information Need 34

A clarification of a footnote for SSAR Table 2.4.13-5 was requested during the audit. SSAR Table 2.4.13-5 was change as shown below.

SSAR Table 2.4.13-5 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

Table 2.4.13-5 (Sheet 3 of 3)
Transport/Dilution Analysis Parameters and Results

Source Term Characteristics						Dilution – No Sorption				Sorption Parameters		Dilution – With Sorption			
Radionuclide	Half-life[a] (days)	Decay Constant[b] ($days^{-1}$)	Initial Activity[c] (Ci)	Initial Concentration[d] ($\mu Ci/cm^3$)	ECL[e] ($\mu Ci/cm^3$)	Minimum Dilution Factor[f]	Minimum Dilution Time (years)	River Concentration[g] ($\mu Ci/cm^3$)	C/ECL[h]	K_d[i] (cm^3/g)	R[j]	Minimum Dilution Factor[f]	Minimum Dilution Time (years)	River Concentration[g] ($\mu Ci/cm^3$)	C/ECL[h]
Ce-144	2.84×10^{2}	2.44×10^{-3}	2.02×10^{5}	5.34×10^{3}	3.00×10^{-6}	1.31×10^{7}	0.91	4.09×10^{-4}	1.36×10^{2}	54	1619.8	7.24×10^{113}	147.71	7.37×10^{-111}	0
Pr-143	1.36×10^{1}	5.097×10^{-2}	2.15×10^{5}	5.68×10^{3}	2.00×10^{-5}	5.39×10^{12}	0.61	1.05×10^{-9}	5.27×10^{-5}	0	1.0	5.39×10^{12}	0.61	1.05×10^{-9}	5.27×10^{-5}
Pr-144m	5.00×10^{-3}	1.39×10^{2}	3.02×10^{3}	7.98×10^{1}	N/A	*	*	*	N/A	0	1.0	*	*	*	N/A
Pr-144	1.20×10^{-2}	5.78×10^{1}	2.02×10^{5}	5.34×10^{3}	6.00×10^{-4}	*	*	*	*	0	1.0	*	*	*	0
Nd-144	8.36×10^{17}	8.29×10^{-19}	7.50×10^{-11}	1.98×10^{-12}	2.00×10^{-9}	5.71×10^{6}	0.94	3.47×10^{-19}	0	0	1.0	5.71×10^{6}	0.94	3.47×10^{-19}	0
U-235m	1.81×10^{-2}	3.84×10^{1}	3.28×10^{0}	8.67×10^{-2}	N/A	*	*	*	N/A	0	1.0	*	*	*	N/A
U-235	2.57×10^{11}	2.70×10^{-12}	3.56×10^{-8}	9.41×10^{-10}	3.00×10^{-7}	5.71×10^{6}	0.94	1.65×10^{-16}	0	0	1.0	5.71×10^{6}	0.94	1.65×10^{-16}	0
Np-239	2.36×10^{0}	2.94×10^{-1}	2.72×10^{6}	7.19×10^{4}	2.00×10^{-5}	4.74×10^{28}	0.31	1.52×10^{-24}	0	0	1.0	4.74×10^{28}	0.31	1.52×10^{-24}	0
Pu-239	8.79×10^{6}	7.89×10^{-8}	7.25×10^{-1}	1.92×10^{-2}	2.00×10^{-8}	5.71×10^{6}	0.94	3.35×10^{-9}	1.68×10^{-1}	16.7	501.6	2.90×10^{9}	473.18	6.60×10^{-12}	3.30×10^{-4}

(a) Values from References 2.4.13-8, 2.4.13-9, and 2.4.13-10 highlighted in yellow, green, and blue, respectively.
(b) Calculated as ln(2)/half-life.
(c) Initial activity is the peak activity value from Table 2.4.13-1.
(d) Calculated as initial activity divided by source term volume.
(e) Values from 10 CFR 20, Appendix B, Table 2, Column 2.
(f) Calculated using Equation 2.4.13-1 (Equation 4.41 of Reference 2.4.13-3).
(g) Calculated as Initial Concentration/Dilution Factor.
(h) Ratio of River Concentration to the effluent concentration limit (ECL). Values less than 10^{-6} are reported as zero.
(i) K_d = distribution coefficient; Based upon laboratory testing.
(j) R = retardation coefficient; Calculated using Equation 2.4.13-4.

Notes:

Ci = Curies

N/A: Not applicable; no ECL available.

* ~~Indicates values beyond Microsoft Excel's computational range associated with short-lived radionuclides, indicated~~ Indicates negligible concentrations in the Reservoir ~~will be negligible~~.

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Supplemental Information related to NRC Information Need 35

The discussion for the 7 day required minimum flow value of 400 cfs average daily flow from Melton Hill Dam was revised for consistency with the discussion contained in the ER, as shown below.

SSAR Subsection 2.4.13.5.3.3 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.13.5.3.3 River Flow Rate (Q)

Outflow data for the Melton Hill Reservoir were used to assess the volumetric flow rate of the Reservoir near the CRN Site. Melton Hill Dam is located approximately five river miles upstream of the CRN Site. Daily average flow data were available from August 1962 to October 2013. This time range includes additional zero flow data associated with the early period of record before Melton Hill Dam was closed and filling of the reservoir was underway. The following statistics were calculated for this time period:

1. Daily average outflow rates range from 0 to nearly 35,000 cubic feet per second (cfs).

2. Zero flow was recorded for about 3.7 percent of the days in the period of record.

3. Daily average flow rate over the entire period of record is 4876 cfs.

4. Annual averages (based on calendar year) range from 2005 to 8071 cfs.

5. Lowest average flow rate over a continuous 365-day period was about 1760 cfs, which occurred from December 12, 2007 to December 10, 2008.

Additionally, TVA conducted its own analysis and determined the average weekly discharge from Melton Hill Dam over its lifetime to be approximately 4800 cfs with a maximum weekly discharge of approximately 25,450 cfs. TVA also analyzed expected flow frequency from Melton Hill Dam based on 100 years of reservoir and system simulation conducted for the development of reservoir operating policy and determined a minimum flow requirement from Melton Hill Dam to be 400 cfs average daily flow. ~~This minimum flow of 400 cfs average daily flow continuing for seven days has a probability of occurrence of less than 0.1 percent.~~ This minimum daily average release can be met, and has in the past been met, by operating the hydropower generating units for a period of only one hour per day. This can result in periods, potentially lasting up to 46 hr, where there are no releases from Melton Hill Dam. However, events during which there is no release from Melton Hill Dam for periods in excess of 36 hr are extremely rare. A bypass, which can produce a continuous flow rate of 400 cfs even when the hydropower generating units are not operating, will be installed at the dam.

Based on Equation 2.4.13-1, increase in flow (Q) in the Reservoir results in increase of dilution factor (DL), which in turn results in decrease in radionuclide concentrations in the Reservoir (C). Taking a conservative approach (i.e., least dilution and maximum radionuclide concentration in the Reservoir), the minimum flow of 400 cfs average daily flow was used as input for Q in Equation 2.4.13-1. As noted in Reference 2.4.13-3, contaminated groundwater “would enter the surface water as a diffuse patch” as a result of source geometry (e.g., a pool of liquid on the ground surface) and dispersion processes which tend to spread the plume in all directions during transport, promoting mixing of contaminated groundwater seepage with the flow in the Reservoir. The dilution flow rate of 400 cfs is selected to represent the near-field dilution

(i.e., dilution at the interface of groundwater and surface water interaction) which results as groundwater enters the Reservoir via seepage through the riverbed prior to being available to a receptor.

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A portion of the last sentence of item 9 in SSAR Subsection 2.4.12C.4 was inadvertently omitted. Item 9 in SSAR Subsection 2.4.12C.4 is being corrected as shown below.

SSAR Subsection 2.4.12C.4 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12C.4 Conceptual Site Model and Assumptions

Two major hydrostratigraphic units are identified at the CRN Site: the Chickamauga Group and the Knox Group. The Chickamauga Group is in most part identified as an aquitard and the Knox Group is identified as an aquifer (Reference 2.4.12C-33). The Chickamauga Group of rocks outcrops along the southern part of the Clinch River peninsula at the CRN Site (most of the power block foot print area lies within the Chickamauga Group of rocks). The Knox Group lies below the Chickamauga Group and outcrops at the northern extremity of the power block area at the CRN Site. The Chickamauga Group and the Knox Group are separated by an unconformity and the various geologic bedding units within the two groups strike approximately at N52°E and dip at 33°SE. The Chickamauga Group at the CRN Site is comprised of interbedded siltstone and limestone and is comprised of the following geologic formations, from older to younger: Blackford, Eidson, Fleanor, Rockdell, Benbolt, Bowen, Witten, and Moccasin (Reference 2.4.12C-10). The Knox Group is primarily composed of dolomite where groundwater flow occurs through solution conduits. The Knox Group at the CRN Site consists of the Newala Formation.

The Clinch River arm of the Watts Bar Reservoir surrounding the CRN peninsula (east, west, and south) is the main discharge point for the active groundwater flow system and is considered to be the hydrologic boundary (Reference 2.4.12C-24). The higher portion of Chestnut Ridge (which is nearly one mile north of the power block area) is a major topographic divide between Bear Creek Valley to the northwest and the peninsula formed by the Clinch River arm of the Watts Bar Reservoir (Reference 2.4.12C-24). The summit of the Chestnut Ridge has an elevation greater than 1100 ft above sea level and is more than 300 ft above the elevation of the plant grade. Because of this difference in elevation and because the upper portion of the ridge is nearly one mile from the power block area, it is unlikely that changes in groundwater levels at or near the Chestnut Ridge could affect groundwater levels at the CRN Site.

Groundwater recharge is derived primarily from precipitation, although periodic recharge from the Clinch River arm of the Watts Bar Reservoir during high stages of the Reservoir may also be occurring, but this is not considered to represent a significant part of the recharge to the aquifer. Recharge is most effective in those areas where the overburden soils are thin and permeable. Recharge may also occur through sinkholes (if present) that penetrate relatively thick and impervious formations (Reference 2.4.12C-24).

Based on evaluation of the site geologic cores, geophysical logs, and the geotechnical and hydrogeologic investigations, the following can be concluded with regards to the site hydrogeologic conceptual model:

1. Man-made fill materials are ubiquitous and more prominent in the proposed power block area and also west of the proposed power block area. The fill materials identified from the CRN Site subsurface investigations (Reference 2.4.12C-1) are likely to be from the excavation work undertaken for the defunct CRBRP (Reference 2.4.12C-24). Site conditions reflect the state of excavation and partial backfilling when the CRBRP was discontinued in the 1980s. Thickness of the fill materials range from non-existent to approximately 51 ft (Reference 2.4.12C-1).

2. The fill materials are underlain by unconsolidated residual soil materials of silt and clay, which vary in thickness from non-existent to approximately 50 ft (Reference 2.4.12C-1).

3. The residual soil materials are underlain by weathered and heavily fractured bedrock, which varies in thickness from non-existent to approximately 21 ft. The weathered bedrock unit acts as a transmissive unit with dominant groundwater flow along the strike of the bedding planes. The water table is typically in the interface of the weathered bedrock unit and in the residual soil (Reference 2.4.12C-1).

4. Below the weathered zone is the competent bedrock unit with the frequency of fractures and joints progressively decreasing with depth (Figure 2.4.12C-3). The bedrock units have a bedding plane strike of approximately N52°E and dip to the southeast at an average angle of approximately 33 degrees. The recent CRN Site subsurface investigation indicates a primary discontinuity set oriented at a strike of N60°E and dip of 59°NW and a secondary set oriented N60°E and dip of 38°SE. The strike and dip of the rocks underlying the site is approximately N51° to N53°E and 32° to 36°SE, respectively, as calculated using the top of the Fleanor Member and the top of the Rockdell Formation. This may vary slightly across the site as a result of localized deformation.

5. The fill, residual soil, and weathered bedrock units (regolith) along with the shallower depths of the competent bedrock units act as a porous medium (Figures 2.4.12C-12, Sheets 1–11). The shear zone depicted on Figures 2.4.12C-12, Sheets 6 to 10, represents a laterally continuous interval of calcite-filled and cemented fractures in the lower Eidson. As these fractures are completely healed, they do not represent a zone of secondary porosity that would be conducive to preferential groundwater flow. Webster and Bradley (Reference 2.4.12C-37) state that groundwater flow in the regolith is characteristic of both porous media as well as fracture controlled flow at the nearby ORNL Site.

6. The groundwater flow at the CRN Site can be characterized as fractured porous media within the shallower regions (less than 100 ft bgs) of the competent bedrock due to the dominance of fractures. This results in a porous media flow; however, flow in the deeper regions of the competent bedrock units are purely fracture flow as groundwater flow occurs only through some of the fractures and negligible flow through the rock matrix. As the groundwater flow through the fractured porous media is mainly through fractures, it is conceptually understood that most of the water contained within this domain is stored in the rock matrix. Although deeper regions in the bedrock might contain higher hydraulic conductivity zones at a particular location, on a regional scale these zones are only connected through the shallow zones. As a result, when the water table drops these fractures remain saturated but are no longer connected regionally, and flow through these fractures decreases significantly (References 2.4.12C-17 and 2.4.12C-18).

7. The hydraulic properties at the site are spatially variable as is the groundwater flow rate. The hydraulic properties are also anisotropic with groundwater flow dominating along the strike of the bedding planes (References 2.4.12C-17, 2.4.12C-18, 2.4.12C-19, and 2.4.12C-35). The groundwater flow velocity is highly transmissive through the fractures; however, the number of fractures in comparison to the total volume of the aquifer is small; therefore, the average volumetric flow rate through the aquifer is low. Weathering of the bedrock unit can increase the porosity, hydraulic conductivity, and matrix diffusion coefficient.

8. Groundwater heads from the majority of the onsite well clusters show significant vertical variation, and this implies poor vertical connection of fractures. Conversely, in some of the well clusters the vertical variations of the hydraulic heads are minimal, which is attributed to a localized strong vertical interconnection of fractures.

9. Moore (Reference 2.4.12C-20) stated…and the locations of the most permeable flow paths are unknown. ~~Tucci~~ As indicated in ~~(~~Reference 2.4.12C-35~~)~~, ~~estimated~~ only about 1 percent of the total groundwater flow occurs below 200 ft of ground surface at the nearby ORNL.

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Supplemental Information related to NRC Information Need 40-a

The site layout drawing referred to in the second bullet of SSAR Subsection 2.4.12C.7.1 is SSAR Figure 1.2-2. For clarity, a citation to Figure 1.2-2 is being added to SSAR Subsection 2.4.12C.7.1 as shown below.

SSAR Subsection 2.4.12C.7.1 is being revised as indicated. Strikethroughs indicate text to be deleted. Underlines indicate text to be added.

2.4.12C.7.1 Modifications to Pre-Construction Models

The general structure of the profile models along with hydraulic conductivity distributions for subsurface layers remained the same as the pre-construction model; however, some nominal changes were made to include representative structures (Figures 2.4.12C-23 and 2.4.12C-24). The following describes the changes to the pre-construction models to develop the post-construction profile models:

- An extra subsurface model layer was added below the bottom of the conceptualized SMR nuclear reactor (Layer 7) to determine the maximum head imposed at the base of the reactor foundation embedment depth and SMR structure. The hydraulic conductivity for this layer remained the same as in the pre-construction model for the same depth. Figures 2.4.12C-23 and 2.4.12C-24 shows the hydraulic conductivity distributions for the layers in the post-construction models for Profiles A and C.

- Surface grade elevations across the two profile models were based on the PPE with maximum foundation embedment depth of approximately 140 ft below grade. Additionally, a shallow SMR foundation embedment depth was also included (in a separate model configuration) at approximately 50 ft below grade (top of the competent rock) in order to represent a technology requiring a shallow foundation embedment depth. These two different excavation depths provide the bounding foundation embedment depths for the different SMR technologies. The width of the power block in the profile models approximates the width of the power block area in the site layout drawing (shown in Figure 1.2-2). The grade elevations are approximate and may change