2 SITE CHARACTERISTICS AND SITE PARAMETERS

This chapter of the safety evaluation report (SER) documents the U.S. Nuclear Regulatory Commission (NRC) staff's review of Chapter 2, "Site Characteristics and Site Parameters," of the Tennessee Valley Authority (TVA's or the applicant's), Construction Permit Application (CPA), Preliminary Safety Analysis Report (PSAR). TVA submitted this CPA for a single unit, small modular reactor (SMR) plant at the Clinch River Nuclear (CRN) Site located in Oak Ridge, Roane County, Tennessee. The PSAR is based on the proposed construction of a one-unit BWRX-300 SMR (hereinafter referred to as CRN-1) designed by GE-Vernova Hitachi Nuclear Energy (GVH) with a nominal electrical output of 300 MWe. The staff's regulatory findings documented in this SER are based on Revision 1 of the TVA CPA PSAR, dated April 9, 2026 (Agencywide Documents Access and Management System [ADAMS] Accession No. ML26119A628). The staff reviewed Chapter 2 of the TVA CPA PSAR, as supplemented, against applicable regulatory requirements using regulatory guidance and standards to evaluate the adequacy of site characteristics and site parameter information with respect to the preliminary design of CRN-1 for the issuance of a construction permit (CP) in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 (TN249), "Domestic Licensing of Production and Utilization Facilities." The NRC staff's reviews and evaluations of subject matter relevant to CRN-1 PSAR Chapter 2, including regulations and guidance used; a summary of the application information reviewed; and evaluation findings and conclusions are discussed in the safety evaluation (SE) sections below.

2.0 Plant Parameter Envelope Evaluation

2.0.1 Introduction

TVA selected the BWRX-300 SMR for deployment at the CRN Site. The suitability of the CRN Site is established in the early site permit application (ESPA). Evaluation of the proposed design parameters as compared to the CRN Site ESPA was provided in Section 2.0 of TVA's PSAR. In support of this safety assessment, Table 2.0-1R in the PSAR provides a comparison of site-related design parameters for which the BRWX-300 SMR is designed to the site characteristics specific to CRN-1. The first four columns of Table 2.0-1R in the PSAR are a compilation of site characteristics for CRN-1. The last two columns of Table 2.0-1R in the PSAR contain information for the corresponding proposed site parameters. Table 2.0-2R in the PSAR provides a comparison of site-related design parameters for which the BRWX-300 SMR is designed to the site-related design specific to CRN-1 in support of TVA's safety assessment. Though the majority of the site characteristics and site-related design parameters in the CRN-1 PSAR are bounded by the ESPA site characteristics and design controlling parameters, those that were not so bounded required requests for variances under 10 CFR 52.39(d) (TN249). TVA identified and requested eleven variances from the ESPA plant parameter envelope (PPE), which are evaluated below.

2.0.2 Technical Evaluation of Requested Variances from the CRN ESPA

As shown in Table 2.0-1R and Table 2.0-2R of the PSAR, the site characteristics and the site-related design parameters for CRN-1 are bounded by those developed for the ESPA PPE, except for the single-unit thermal megawatts value of 800 megawatts thermal (MWt). The proposed design has an 870 MWt nominal output, but the bounding plant megawatts thermal output for the entire CRN Site under the ESPA PPE is 2,420 MWt. As such, the 70 MWt exceedance for a single unit is acceptable for the CRN Site, as it is within the overall bounds of the ESPA PPE. In addition, since the PPE did not consider the proposed design, the radionuclide concentrations released from the facility are different than the assumed releases in the PPE. As a result, the releases of certain radionuclides are higher for the proposed design than were evaluated against the PPE. The staff evaluates the radiological release source terms from the proposed facility in SER Chapters 11 and 15.

The applicant's justifications for the other CRN-1 variances are provided in Enclosure 4 of the CPA and described and evaluated in other chapters of this report. Other release data and exceedances and their justifications are described below:

Loss-of-Coolant Accident : Design-basis accidents (DBAs) for the proposed design are evaluated in Chapter 15 of the PSAR. The feedwater line break (FWLB) accident is the most limiting DBA. Releases for several radionuclides for the FWLB accident exceed the release in the loss-of-coolant accident DBA evaluated in the CRN early site permit (ESP) site safety analysis report (SSAR), as shown in Table 2.0-3R. However, the dose consequence of the postulated FWLB accident (Table 15.7-6) is below applicable acceptance criteria; therefore, the exceedances shown in Table 2.0-3R of the PSAR are acceptable.

Annual Normal Gaseous Radioactive Release: Releases for several radionuclides for Annual Normal Gaseous Radioactive Release exceed the release evaluated in the ESPA SSAR, as shown in Table 2.0-4R in the PSAR. As described in footnotes to Table 2.0-4R, the exceedances have been evaluated and show that CRN-1 calculated site boundary concentration limits and offsite receptor annual average doses are bounded by values presented in ESPA SSAR Table 11.2-7 and Tables 11.3-3 through 11.3-5, and remain within regulatory limits. The staff evaluated the source terms and determined that the overall source term in the ESPA SSAR bounds the source term in the PSAR. As a result, offsite dose receptor annual doses remain within regulatory limits and are therefore acceptable. Additional information regarding the staff's evaluation of this issue can be found in Section 11.3 of this SER.

Accidental Liquid Radwaste Release: For the CP application, the applicant considered in PSAR Section 2.4.13 the accidental liquid release of the refueling water storage tank (RWST) inventory. The RWST is liquid tank with the greatest radiological source term in the proposed design. The applicant compared the accidental liquid release from the RWST to the accidental release used in the ESPA in PSAR Table 2.0-5R. Releases for several radionuclides for the Accidental Liquid Radwaste Release from the RWST exceed the release evaluated in the ESPA SSAR, as shown in Table 2.0-5R of the PSAR. However, the radionuclides that exceed the ESPA values are minor dose contributing radionuclides. As a result, the overall source term in the ESPA bounds the source term in the PSAR, and doses to the public from the release are therefore less than the 10 CFR 20.1301 (TN283) limit of 100 millirem (mrem) total effective dose equivalent (TEDE). Therefore, this exceedance remains within regulatory limits and are therefore acceptable. Additional information regarding the staff's evaluation of this issue can be found in Section 11.2 of this SER.

Annual Normal Liquid Radioactive Release: Releases for several radionuclides for Annual Normal Liquid Radioactive Release exceed the release evaluated in the ESPA SSAR, as shown in Table 2.0-6R of the PSAR. The specific radionuclides that exceed ESPA PPE are minor dose contributors with respect to the considered dominant dose contributing radionuclides. The dominant dose contributing radionuclides (e.g., I-131, Cs-137, and H-3) calculated for CRN-1 are exceeded by many orders of magnitude by the corresponding ESPA PPE values. The staff evaluated the source terms and agrees with the above information. As a result, offsite dose receptor annual doses remain within regulatory limits and are therefore acceptable. Additional information regarding the staff's evaluation of this issue can be found in Section 11.2 of this SER.

In the PPE comparison tables provided in Section 2.0 of the PSAR, all other Clinch River ESP-006 PPE performance requirements (structural design, etc.) are met for both the site and a single unit.

2.0.3 Conclusion

The NRC staff reviewed the PSAR and the referenced Clinch River ESP SSAR to ensure that sufficient information was presented to demonstrate that the design of the facility falls within (i.e., is bounded by) the actual site characteristics and postulated design parameters specified in the ESP SSAR PPE and that any variances were justified by the applicant. Accordingly, the staff concludes that the applicant has demonstrated that the design of the facility falls within (i.e., is bounded by) the ESP and CP site characteristics and ESP design parameters needed to meet the requirements of 10 CFR 50.34 and 10 CFR Part 100 (TN282). Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.1 Geography and Demography

2.1.1 Site Location and Description

Section 2.1 of the PSAR addresses site-specific information related to site location and description, exclusion area authority and control, and population distribution. TVA has incorporated site-specific geography and demographic information presented in the ESP by reference and updated any information from the ESP application if new information supersedes the information already reviewed by the staff or if additional information was obtained subsequent to the issuance of the ESP. The staff reviewed the updated information and checked the reference SSAR to ensure that the PSAR represents the complete and current scope of information related to this review topic. The staff also reviewed the staff's ESP final safety evaluation report (FSER) for any gaps of information.

The NRC staff review confirms that the information in the PSAR and incorporated by reference from the ESP addresses the required information related to site-specific geography and demography, except as described below, and updates existing information as applicable.

The CRN Site that will host CRN-1 lies within the U.S. Geological Survey 7.5-minute Elverton and Bethel Valley quadrilaterals and is located on the historical Clinch River Breeder Reactor Project (CRBRP) site. The main site area has been remediated later including partial backfilling of the nuclear island excavation with the finished elevation at approximately 814.5 ft.

Regulatory Evaluation

The acceptance criteria associated with the relevant requirements of NRC regulations for the evaluation of site location and description are given in SRP Section 2.1.1, "Site Location and Description":

- 10 CFR 50.34(a)(1)(ii), as it relates to the inclusion of a detailed description and safety assessment of the site on which the facility is to be located (TN249).
- 10 CFR 100.20(b), as it relates to addressing and evaluating factors that are used in determining the acceptability of the site (TN282).
- 10 CFR 100.21, as it relates to providing information on population density and use characteristics of the site environs.
- 10 CFR 50.35, "Issuance of construction permits."

Population Distribution

TVA has completely updated the information presented in SSAR Section 2.1.3. The staff has reviewed the updated information. The staff's review is described below. It should be noted that the staff uses the term "resident population", consistent with Section 2.1.3 of the SRP, in this section to mean "permanent population," as that term is used in the PSAR.

The staff notes that TVA developed the exclusion area boundary (EAB) encompassing multiple reactor units at the site using an ellipse with the origin at the center point of the proposed site. The major axis of the ellipse is 0.535 mi, and the minor axis is 0.326 mi. However, the demography surrounding the proposed site is described in the PSAR assuming a circle centered at the site center with a radius of 0.535 mi, as stated in PSAR Section 2.1.3.

The staff also notes that TVA has used the recent 2020 U.S. Census Bureau decennial census data to describe the population up to 50 mi surrounding the proposed site into fifteen concentric bands (PSAR figures 2.1-6R and 2,1-7R) at 0 to 0.3 mi, 0.3 to 1 mi, 1 to 2 mi, 2 to 3 mi, 3 to 4 mi, 4 to 5 mi, 5 to 6 mi, 6 to 7 mi, 7 to 8 mi, 8 to 9 mi, 9 to 10 mi, 10 to 20 mi, 20 to 30 mi, 30 to 40 mi, and 40 to 50 mi from the proposed site center point. In addition, these bands are subdivided into 16 directional sectors, each 22.5° wide. The staff notes that 50 mi from the proposed site extends into several counties in three states: Tennessee, North Carolina, and Kentucky. The staff finds that TVA's use of the county-wise demographic information from the official demographers of these states—namely, the University of Tennessee's Boyd Center for Business and Economic Research, the North Carolina Office of State Budget & Management, and the University of Louisville's Kentucky State Data Center, respectively—is appropriate and therefore acceptable.

TVA estimated the growth rate of each county from 2020 to 2025 and used that rate to project the population until 2070. The projected population was divided into concentric bands and sectors, as shown in PSAR Tables 2.1-2R and 2.1-3R. The staff finds the TVA has used an appropriate method to project the future population as they used the population growth rate for each county. In addition, the staff finds that there are some conservatisms in the estimated population; for example, a county with negative population growth rate was assumed to keep the same population, meaning zero growth rate.

PSAR Figure 2.1-6R, based on 2020 population data, shows the distribution of both resident and transient populations surrounding the proposed site. The staff notes that both Oak Ridge National Laboratory (ORNL) and the Y-12 National Securities Complex are within 10 mi from the proposed site. These facilities employ 5,772 and 7,241 staff, respectively, as stated in PSAR Section 2.1.3.1. PSAR Section 2.1.3.1 states that although U.S. Census Bureau counted them as residents at their residences, a portion of the workforce may be transient within a 10 mi radius from the proposed site. The staff finds this a potential conservatism in the estimated population.

Several cities and towns are within 10 to 50 mi of the proposed site. The largest city, Knoxville, had a population of 599,356 in 2020. PSAR Section 2.1.3.2 gives the population in some of the larger cities and towns within this 50 mi zone. The resident population for each sector within this zone was projected to the years 2030, 2040, 2050, 2060, and 2070. The year 2070 is taken as the anticipated end of normal facility licensed life.

Although the surroundings of the proposed site are relatively rural, there are numerous facilities and recreational areas that draw a transient population. The staff finds that TVA assessed the major transient population generators such as employers, tourists and recreational areas, educational facilities, national and state parks, and hospitals. To avoid double counting, people attending public venues were not counted as transient population. PSAR Section 2.1.3.3 lists a few of the major resources used for gathering transient population. PSAR Table 2.1-4R identifies major facilities contributing to the transient population within 10 mi of the proposed site. Several national and state parks within 10 to 50 mi of the proposed site, as listed in PSAR Table 2.1-6R, contribute to the regional transient population.

PSAR Section 2.1.3.3.3 describes the major sources of transient population within 10 to 50 mi of the proposed site. In addition to the City of Knoxville, the Knoxville Metro Area is within this zone. In addition, the economic center of Knoxville, TN, which includes counties of Morgan, Roane, Loudon, Blount, Knox, Anderson, Campbell, Union, and Grainger, is also within this zone. PSAR Table 2.1-6R lists the national and state parks within this zone that attract substantial number of visitors annually (transient population). For example, the Great Smokey Mountains National Park with recorded annual visitors of 14,161,548 has the largest transient population.

The staff finds that TVA has appropriately weighted the transient population in a distance band, based on the ratio of hours spent in a sector on a 24-hour day. TVA lists the total resident and transient population within 0 to 10 mi of the proposed site by the sector and the year of interest in PSAR Table 2.1-2R. The total population within this region is expected to grow from 98,127 in 2020 to 119,055 in 2070, as shown in PSAR Table 2.1-2R.

The staff finds that TVA has defined the low-population zone (LPZ) to be a circular region with 1 mi long radius from the site center point, as stated in PSAR Section 2.1.3.4. PSAR Figure 2.1-8R shows the resident and transient population within this zone, divided in 16 equal sectors. Based on 2020 census, 112 residents live within the LPZ. There are no facilities within the LPZ for transient population; however, such facilities are within 5 mi of the center point of the proposed site, as identified in PSAR Figure 2.1-9R.

Population Center

TVA identified only three urban areas within 50 mi of the proposed site that qualify as a population center with at least 25,000 residents: (1) Knoxville, (2) Cleveland, and (3) Morristown. In addition, the proposed site is within the city limit of the City of Oak Ridge, which had a population of 31,402 in 2020. The proposed site is at the southern end of the city, while the densely populated portions of the City of Oak Ridge are in the northeast side. Therefore, the staff finds that the City of Oak Ridge is the nearest population center, as discussed in PSAR Section 2.1.3.5, with more than 25,000 residents, as the definition of population center is based on population distribution rather than on political boundaries. In addition, the staff finds that the densely populated portions of the City of Oak Ridge are beyond the distance of one and one-third times the distance from the reactor to the outer boundary of the LPZ. Therefore, the staff concludes that the City of Oak Ridge is the nearest population center satisfying the requirements of the nearest population center given in 10 CFR 100.11.

Population Density

TVA assessed the population density around proposed CRN-1 in PSAR Section 2.1.3.6. PSAR Figure 2.1-11, Sheets 1-3, show the cumulative total population, comprising both resident and transient populations, for the years 2030 (assumed start of the proposed operating license [OL]), 2035, and 2070 (proposed end of the operating life of the facility), and compared with the NRC siting criteria given in Regulatory Guide (RG) 4.7, Revision 4 (NRC 2024-TN12833), "General Site Suitability Criteria for Nuclear Power Stations" and RG 1.70, Revision 3 (NRC 1978-TN12879), "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition." These figures show that the population density up to 30 mi from the proposed facility remains below 500 persons/square mile through the proposed end of CRN-1's operating life in 2070, consistent with guidance in RG 1.70 and RG 4.7. Therefore, the staff finds that the projected cumulative population is consistent with guidance on site suitability in RG 1.70 and RG 4.7.

2.1.1.1 Conclusion

The staff concludes that the information provided by the applicant in the PSAR and the referenced Clinch River Nuclear Site ESP SSAR is sufficient to evaluate compliance with the siting evaluation factors in 10 CFR 100.3, as well as with the radiological consequence evaluation factors in 10 CFR 50.34(a)(1)(ii) for the site. The staff further concludes that the applicant provided sufficient details about the site location and site description to allow the staff to evaluate, as documented in Sections 2.1.2, 2.1.3, and 13.3 and Chapters 11 and 15 of this report, whether the applicant has met the relevant requirements of 10 CFR Part 100 with respect to determining the acceptability of the site. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii),10 CFR 100.3, 100.20(a), and 100.21(a) and (b) and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.1.2 Exclusion Area Authority and Control

Regulatory Evaluation

The acceptance criteria associated with the relevant requirements of NRC regulations for the evaluation of exclusion area authority and control are given in SRP Section 2.1.2, "Exclusion Area Authority and Control":

- 10 CFR 50.34(a)(1)(ii), as it relates to a detailed description and safety assessment of the site on which the facility is to be located (TN249).
- 10 CFR 100.3, as it relates to defining an exclusion area and setting forth requirements regarding activities in that area (TN282).
- 10 CFR 100.20(b), as it relates to addressing evaluating factors that are used in determining the acceptability of the site.

Technical Evaluation

The CRN Site for CRN-1 is approximately 935 ac and is owned by the United States of America and managed by TVA. As shown in PSAR Figure 2.1-3, no public transportation routes cross the proposed site. PSAR Section 2.1.2 states that the only known mineral resource within the property boundary is limestone. The United States of America owns all of the mineral rights.

PSAR Section 2.1.2 also states that the EAB is delineated by the property boundary, also referred to as the owner-controlled boundary, as shown in PSAR Figure 2.1-5. TVA will have control over all activities with the EAB, including exclusion and removal of personnel and property. The staff notes two existing electric transmission lines traversing the proposed site: (1) Bull Run FP–Watts Bar NP 500 kV and (2) Kingston FP–Ft Loudoun HP 161 kV No. 1. TVA owns and controls both of these transmission lines. The staff notes that, in PSAR Section 2.1.2.1, TVA has committed to relocate the Kingston FP–Ft Loudoun HP 161 kV No. 1 transmission line to the east prior to construction of the proposed facility.

The staff also finds that no residents live within the EAB. In addition, no commercial activities take place within the EAB. TVA prohibits any recreational or hunting activities within the EAB. Barge traffic occurs on the Clinch River arm of the Watts Bar Reservoir; however, the river flows close to the site boundary and is outside the EAB. Hazards associated with the barge traffic are reviewed in SER Section 2.2.4.3. In addition, PSAR Section 2.1.2.2 states that there is one small family cemetery within the EAB. Additionally, one Native American mound has been located within the EAB. The staff finds that TVA security personnel control access to the cemetery and the burial mound.

In summary, the NRC staff finds that TVA has authority within the EAB and possesses absolute ownership of land with mineral rights. Although no abandonment of any public roads is needed, TVA has committed to relocate one electric transmission line before construction of the proposed facility starts. In addition, the staff finds that TVA has legal authority for exclusion or removal of personnel or property from the EAB. All nearby roadways, railways, or waterways are outside the EAB. Therefore, based on the above discussion, the NRC staff concludes that TVA will have control over all activities within the EAB during the operating life of the proposed facility.

The staff concludes that the applicant's exclusion area described in the PSAR and the referenced Clinch River Nuclear Site ESP SSAR is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1), 10 CFR 100.3, and 10 CFR 100.20(b), with respect to determining the acceptability of the site and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.2 Nearby Industrial, Transportation, and Military Facilities

PSAR Section 2.2 provides a description of potential hazards associated with nearby transportation routes, industrial and military facilities, and civilian and military airports located near the site to establish whether the effects of potential hazards onsite or in the vicinity of the site should be considered as design-basis hazards in accordance with 10 CFR 100.20(b). TVA evaluated each of the identified hazards following RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release," Rev. 2 (NRC 2021-TN13248), and RG 1.91, "Evaluations of Explosions Postulated to Occur at Nearby Facilities and on Transportation Routes near Nuclear Power Plants," Rev. 3 (NRC 2021-TN12834). The applicant must evaluate potential hazards associated with nearby transportation routes, industrial and military facilities, and civilian and military airports. The applicant should also determine whether bulk storage or transportation of hazardous materials might occur at or near the site and should assess the impact of potential explosions. If applicable, the applicant should assess aircraft hazards associated with nearby airports, Federal airways, holding and approach patterns, military airports, training routes, and training areas in accordance with NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*, Section 3.5.1.6 (NRC 2010-TN13245).

2.2.1 Locations and Routes

2.2.1.1 Introduction

Regulatory Evaluation

The acceptance criteria associated with the relevant requirements of NRC regulations for the evaluation of the identification of potential hazards in the site vicinity is given in SRP Section 2.2.1-2.2.2, "Identification of Potential Hazards in Site Vicinity":

- 10 CFR 50.34(a)(1)(ii), as it relates to a description and safety assessment of the site, including site evaluation factors identified in 10 CFR Part 100 (TN249).
- 10 CFR 100.20(b), as it relates to the nature and proximity of human-related hazards (e.g., airports, dams, transportation routes, and military and chemical facilities) that must be evaluated to establish site parameters for use in determining whether a plant design can accommodate commonly occurring hazards and whether the risk of other hazards is very low (TN282).

2.2.1.1.1 Technical Evaluation

TVA provided detailed descriptions of the industrial and military facilities and transportation routes near the proposed site in PSAR Section 2.2.1, in accordance with NUREG-0800 (NRC 2021-TN8013). The staff notes that, within 5 mi of the proposed site, there is one navigable waterway, the Clinch River arm of Watts Bar Reservoir; one major highway, I-40; four major roads, TN-1/US 11-70, TN-58, TN-95, and TN-327; one minor rail line operated by Heritage Railroad Construction; and two active natural gas pipelines, East Tennessee Natural Gas Pipeline 1 (East) and Pipeline 2 (North). In addition, the staff notes that there are five private airports/airfields and three Federal airways within 10 miles of the proposed site.

The staff's review is limited to only those facilities and transportation routes that are new (i.e., not reviewed in the ESP SSAR) or for which recent information supersedes the information and analysis presented in the ESP SSAR. Consistent with guidance in RG 1.78, hazardous chemicals stored at distances larger than 5 mi from the proposed site were excluded from further assessment unless the chemicals were identified to cause potentially significant impact on the proposed facility.

2.2.1.1.2 Aircraft Crash Hazards

The applicant has revised the original assessment of potential aircraft crash hazard given in the ESP SSAR, as TVA has selected the proposed design for the facility and incorporated the possibility of construction of the Oak Ridge General Aviation Airport, a general aviation airport originally proposed to be located at the East Tennessee Technology Park (ETTP). The staff learned that the proposed Oak Ridge General Aviation Airport will not be constructed at the ETTP as originally proposed, owing to the Orano uranium enrichment facility being in the airport's flight path. The City of Oak Ridge will be relocating the proposed airport to a new location, and a new site selection process will be conducted when appropriate. The staff, therefore, concludes that any aircraft crash hazard from aircraft operations at the proposed Oak Ridge General Aviation Airport at the ETTP would be negligible.

The staff has reviewed the discussion given in PSAR Section 2.2.2.7 regarding aircraft crash hazard at the proposed facility. In addition, as part of the regulatory audit, the staff reviewed documentation supporting the PSAR's aircraft crash hazard assessment. As PSAR Section 2.2.2.7 documents significant changes to the aircraft hazard assessment compared to that given in ESP SSAR Section 2.2.2.7. The staff reviewed the new analysis provided in the PSAR. The staff's review of that analysis is documented below.

<u>Airports</u>

In PSAR Section 2.2.2.7, TVA described airports and airways near proposed CRN-1 and updated the assessment of aircraft crash hazard to the proposed facility using NUREG-0800, Section 3.5.1.6.

TVA identified five small privately owned airports/airfields within 5 to 10 mi of the proposed site: (1) Big T (80TN), (2) Wolf Creek (2TN7), (3) COX Farm (TN71), (4) Will A Hildreth Farm (TN74), and (5) Meadowlake (12TN), and described the annual number of operations (landing and takeoff) at these airports/airfields in PSAR Table 2.2-7R. As shown in PSAR Table 2.2-7R, the annual number of operations at each of these airports is too small, per NUREG-0800, Section 3.5.1.6, proximity criterion 1.A, to pose a credible aircraft crash hazard from taking off or landing an aircraft from these airports/airfields. There are two other privately owned airports, Oliver Springs (TN08) and Fergusons Flying Circus (TN09), within 10 to 15 mi from the proposed site. Based on information given in PSAR Table 2.2-7R, the annual number of operations at these two airports is also too small to pose a credible aircraft crash hazard to the proposed facility following proximity criterion 1.A of NUREG-0800, Section 3.5.1.6. The staff also finds that the annual number operations at the two prominent airports closest to the proposed site, Knoxville McGhee Tyson Airport (TYS) and Knoxville Downtown Island Airport (DKX), are also not large enough to be a significant contributor to the aircraft crash hazard because of the large distances at which they are located relative to the CRN Site. In addition, the staff has eliminated any contribution to the total crash hazard by aircraft using the proposed Oak Ridge General Aviation Airport at the ETTP as the airport is no longer being proposed to be located at the ETTP. Therefore, based on the above discussion, the staff finds TVA's assessment that air traffic at the nearby airports does not contribute significantly to the aircraft crash hazard at the proposed facility is acceptable.

<u>Airways</u>

PSAR Section 2.2.2.7.2 identifies the nearest military training route as IR2, which is located at a distance of 19.2 mi from proposed CRN-1. Based on criterion 1.B of Section 3.5.1.6 of NUREG-0800, flights on IR2 would not have significant effects on safe operation of the proposed facility because of the large intervening distance. Similarly, the nearest military operating area (MOA), Snowbird MOA, is at a distance of 36 mi from the proposed facility. The staff finds that such a significantly large separation distance would preclude the hazardous activities conducted by military aircraft in the MOA from being a credible hazard to the proposed facility.

PSAR Section 2.2.2.7.3 and Figure 2.2-3R show the victor airway V16, jet route J46, and high altitude route Q65 near the proposed site. The staff notes that the nearest edges of airways V16 and J46 are within 2 mi of the proposed site. Consequently, proximity criterion 1.C of Section 3.5.1.6 of NUREG-0800 is not satisfied, and a detailed assessment of aircraft crash hazard, as summarized in PSAR Section 2.2.2.7, at the proposed facility is needed. Although the centerline of airway Q65 is approximately 9 mi away from site, TVA included this airway in assessing the aircraft crash hazards as a conservative approach to the evolving National Airspace Redesign.

2.2.1.1.3 Annual Crash Frequency Assessment

TVA described its assessment of potential aircraft crash hazard at the proposed facility in PSAR Section 2.2.2.7.4. The staff has reviewed the detailed assessment of aircraft hazards. In addition, the staff audited a document describing assessments of potential aircraft hazards at the proposed facility, “Aircraft Hazard Analysis Calculation,” Black & Veatch report to the TVA, dated 2023, in the electronic reading room.

TVA used the formulas given in DOE standard DOE–STD–3014 (DOE 2006) to estimate the effective area of the safety-related structures at the proposed facility for each aircraft type flying in airways V16, J46, and Q65. TVA estimated the effective area of the reactor building (RB) to assess the aircraft crash hazard. In addition, TVA estimated the combined effective area of the RB, radwaste building (RWB), and control building (CB) to ensure availability of the control room operators in an aircraft crash onto the proposed facility. In addition, failure of the RWB in an aircraft crash event may result in potential offsite exposures. In accordance with Table 2 in RG 1.143, “Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants,” Revision 2 (NRC 2001-TN1134), the RWB is classified as an RW-IIA (high hazard) building and, therefore, needs to be designed against small aircraft crashes.

Information on the annual number of flights using airways V16, J46, and Q65 is not available. TVA found that airways V16, J46, and Q65 terminate at or originate from Knoxville McGhee Tyson Airport (TYS), Knoxville Downtown Island Airport (DKX), and James M. Cox Dayton International Airport (DAY), respectively. Consequently, TVA used annual operation (takeoffs and landings) information at these airports to estimate the annual number of flights using these airways. The staff finds this approach to be reasonable to estimate the annual number of flights using these airways.

Excluding any contribution from Oak Ridge General Aviation Airport, which, as explained above, is no longer being proposed to be located at the ETTP, TVA estimated the total frequency of crashes if an aircraft transiting nearby airways crashes into (1) the RB of the proposed facility, and (2) the RB, RWB, or CB of the proposed facility, to be 2.21×10^{-5} per year and 3.83×10^{-5} per year, respectively, as given in PSAR Section 2.2.2.7.

The staff finds that the estimated effective area of the proposed facility has significant conservatisms, as elaborated below:

1. The turbine building (TB), as shown in PSAR Figures 1.2-2 and 1.2-3, significantly reduces the potential for a crashing aircraft, especially general aviation aircraft, to reach the RB and RWB as the TB is taller than both the RB and RWB. This reduces the fly-in component of the effective area estimated and thereby reduces the estimated crash frequency. In addition, the service building (SB), with non-nuclear construction practices,

provides some protection from a direct strike by a crashing aircraft because the SB provides an obstruction against a skidding aircraft that reduces its impact on the RB.
2. The DOE "Effective Area" formula inherently assumes that a crashing aircraft strikes the structure in a direction perpendicular to its diagonal. Based on PSAR Figures 1.2-2 and 1.2-3, a crashing aircraft can strike the RB unopposed by other buildings from only one side; from all other sides, other buildings surrounding the RB obstruct a crashing aircraft from direct fly-in to the RB. The presence of an obstruction seriously reduces the speed of the crashing aircraft and the potential for the crashing aircraft to cause damage to the RB.
3. As shown in PSAR Figure 1.2-3, only the top of the RB can be hit by a crashing aircraft from at least three sides. The lower part of the RB is protected by surrounding buildings and can be hit on only one side.
4. As can be seen in PSAR Figure 1.2-3, the reactor will be deeply embedded in the ground. Only a small fraction of the reactor will be above ground and vulnerable to damage from a strike by a crashing aircraft.

As the annual aircraft crash frequency onto a facility is directly related to its effective area, the staff finds that the estimated crash frequency of the proposed facility is conservative.

However, the annual crash frequency at the RB and combined RB, CB, and TB of the proposed facility exceeds the annual frequency to be considered a beyond design basis event, as given in Section 2.2.3 of NUREG-0800. The staff finds that the analysis provided by TVA does not support the finding that the risk from aircraft flying in the vicinity of the proposed site is acceptably low, and therefore, the design-basis acceptance criteria in 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 3 and GDC 4, are applicable to the proposed facility design, in conformance with Section 3.5.1.6 of NUREG–0800. TVA must either submit a new analysis or additional information demonstrating compliance with the threshold annual frequency, or demonstrate at the OL stage that the proposed facility is appropriately protected against design-basis aircraft impact (GDC 4) and ensuing fires (GDC 3). Important to safety structures, systems, and components (SSCs) shall be shown to be capable of withstanding the effects of the postulated aircraft impact, and associated fires from spill of aviation fuel, that causes the release of radioactivity that could exceed Part 100 dose guidelines, without a loss of safe shutdown capability.

2.2.1.1.4 SSAR Permit Condition 2.2-1 (ESP Permit Condition 1)

Permit Condition 2.2-1 (Permit Condition 1) in ESP FSER states that:

> Based on the regional government projections of industrial growth, the Metropolitan Knoxville Airport Authority has selected the Heritage Center Industrial Park, approximately 6 mi from the CRN Site, as the potential site for a general aviation airport. Current site plans indicate that construction may be completed by the year 2022. Therefore, the applicant shall evaluate this airport for potential aircraft crash impact probability in the COLA and address it in FSAR Section 3.5.1.6.

This permit condition deals with potential aircraft crash hazards to the proposed facility from aircraft using the proposed Oak Ridge Airport near the ETTP to land or take off. As previously discussed, the Oak Ridge Airport is no longer proposed to be located at the ETTP, and a new site has not been announced. Therefore, the staff finds that this permit condition is no longer necessary for the safety of the proposed facility and this permit condition can be considered closed. However, as previously discussed, the total frequency of aircraft crashing annually onto the proposed facility, as discussed in PSAR Section 2.2.1.1.4, exceeds the annual frequency to be considered a beyond design basis event, as specified in Section 2.2.3 of NUREG-0800. Therefore, in the OL application TVA must submit a new analysis or additional information demonstrating compliance with the threshold annual frequency, or that the proposed facility has been designed to meet the relevant requirements of 10 CFR Part 50, Appendix A, GDC 3 and GDC 4, so that it is protected against design-basis aircraft impact and associated fires.

2.2.1.1.5 Conclusion

Based on the above discussion, the staff concludes that the “true” effective area of the proposed facility would be much smaller than what has been estimated by TVA. As the aircraft crash frequency of a facility is directly related to its effective area, the staff finds that the estimated crash frequency is conservative. However, the annual crash frequency exceeds the annual frequency to be considered a beyond design basis event, as given in Section 2.2.3 of NUREG-0800. Therefore, aircraft crash hazard becomes a design-basis event (DBE) unless TVA can show calculations at the OL stage that the annual frequency of aircraft crashes at CRN-1 are below the frequency stipulated in Section 2.2.3 of NUREG-0800, or that the final design of the proposed facility has features installed that reduce the potential for radioactive dose below the exposure guidelines in 10 CFR Part 100. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.2.1.2 *Nearby Facilities*

TVA updated the list of facilities within 5 mi of the proposed site and listed the updated facilities in PSAR Figure 2.2-1R. The staff has reviewed the information in the PSAR on nearby industrial, transportation, and military facilities of the proposed site area using the review procedures described in NUREG-0800, Sections 2.2.1 and 2.2.2, and identified facilities and transportation routes that may affect safe operation at the proposed facility.

In PSAR Table 2.2-3R, TVA identified the potential hazardous facility transportation routes within 5 mi of the proposed site. Chemicals stored at these offsite locations are listed in PSAR Table 2.2-2R to identify the design-basis hazards. The staff notes that the following facilities require further assessment of whether the chemicals stored at or transported to or from these facilities can be a design-basis hazard to the proposed facility, as they are either new facilities (i.e., not considered in the ESP SSAR) or there is new information about stored chemicals at the facilities that was not considered in the ESP SSAR. The facilities are:

1. Diversified Scientific Devices
2. East Tennessee Technology Park (ETTP)
3. Energy Solutions Services–Bear Creek Facility
4. Knoxville PDC–Volkswagen Group of America
5. NAC Philotechnics–Horizon Center
6. Oak Ridge National Laboratory–Battelle
7. Oak Ridge National Laboratory–United Cleanup Oak Ridge (UCOR)
8. TVA–Melton Hill Hydro Plant
9. Weigel’s #58

Hazardous chemicals stored at these facilities are identified in PSAR Table 2.2-5R and were evaluated by TVA for potential to explode, form flammable vapor clouds, or pose toxicity hazards to the operators of the control room of the proposed facility. These facilities and chemicals are described below. The staff's review of TVA's assessments of these hazards is described in SER Sections 2.2.2.4.1 through 2.2.2.4.3.

Diversified Scientific Services is located approximately 3.4 mi west of the proposed site and provides radioactive waste treatment services. It uses sodium hydroxide as part of the process and stores maximum 10,000 lb of sodium hydroxide in containers with maximum capacity of 3,350 lb.

ETTP is the home of several facilities. The staff notes that UCOR LLC, located in the ETTP, manages hazardous waste and remediates sites for eventual site transition to public use. It stores 49,999 lb of chemical Ultrapoles. In addition, 4,999 lb of sulfuric acid and 24,999 lb of gasoline are also stored in this facility.

Energy Solutions–Bear Creek Facility processes radioactive waste approximately 1.6 mi north of the proposed site. It uses nitric acid and propane as part of the process. As per PSAR Table 2.2-2R, 645 lb of nitric acid and 25,000 lb of propane are stored at this facility.

Knoxville PDC–Volkswagen Distributor is a car distribution service approximately 1 mi away from the proposed site and uses a maximum of 4,999 lb of sulfuric acid stored in containers. The largest container at this facility holds 200 lb of sulfuric acid.

NAC Philotechnics is located approximately 4.9 mi away from the proposed site at the Horizon Center and processes radioactive and mixed waste.

ORNL–Battelle is a Federally sponsored research and development facility and uses nitric acid among other hazardous materials.

ORNL–UCOR conducts site remediation by deactivating and demolishing old facilities. Both nitric acid and sulfuric acid are used in the process.

TVA–Melton Hill is located approximately 4.7 mi from the proposed site and is a hydroelectric power generation facility. It uses chlorine as a part of the process.

Weigle's #58 is a convenience store that dispenses gasoline, propane, and diesel fuel. It is approximately 3.7 mi from the proposed site.

2.2.1.3 Nearby Waterway

PSAR Section 2.2.2.4 states that significant waterborne commerce is only possible near the proposed site on the Clinch River arm of the Watts Bar Reservoir. The staff finds that TVA reviewed the annual waterborne commerce data for the period of 2015 through 2021, compiled by the U.S. Army Corps of Engineers' Waterborne Commerce Statistics Center. The staff concludes that TVA used the appropriate database maintained by the U.S. Army Corps of Engineers for assessing hazards posed by commerce on the waterway near the proposed site and that there is inconsequential shipping on the river. As no hazardous materials are transported on the nearby waterway, the staff considers it reasonable to exclude waterborne traffic from the design-basis hazard assessment for the proposed facility.

2.2.1.4 *Pipelines*

Two natural gas pipelines, Pipeline 1 and Pipeline 2, operated by the East Tennessee Gas Company, are near the proposed site. Currently, Enbridge Inc. owns and operates these pipelines. Potential hazards posed by these pipelines were evaluated by the staff during its review of the ESP SSAR. No new or additional information was provided by TVA in the PSAR that alters the staff's conclusion in the ESP FSER that these pipelines do not pose a design-basis hazard.

2.2.1.5 *Railroads*

The major rail line near the proposed site is operated by Norfolk Southern and is approximately 7 mi from the site. The staff previously reviewed the potential hazards from cargo transported on this line in its review of the ESP SSAR and found them to have negligible effects on the proposed facility. The staff did not review the potential hazards from this rail line as no new information has been presented by TVA that may invalidate the staff findings in ESP FSER.

TVA also reported in PSAR Section 2.2.2.6 that the EnergySolutions Heritage Railway Corporation operates a minor rail line for recreational and industrial uses. Wind turbine blades are transported on this line. Wind turbine blades are not a type of cargo that would pose a threat to the proposed facility because they do not explode or produce toxic fumes that may affect safe operation of the proposed facility. Therefore, the staff concludes that cargo traffic on this minor line does not pose a design-basis hazard to the proposed facility.

2.2.1.6 *Highways*

TVA reported in PSAR Section 2.2.2.5 that daily traffic on I-40 near the proposed site was 52,212 vehicles in 2022. The staff notes that I-40 at its closest point is approximately 1 mi from the proposed site. PSAR Section 2.2.2.5 also states that the other nearby major highways (i.e., TN 1/US 11-70, TN 58, TN 95, and TN 327), are further away from the proposed site with significantly less daily traffic. Additionally, hazardous chemicals may be transported on I-40, while no other roads close to the proposed site have been identified as carrying hazardous chemicals. Therefore, the staff agrees that potential hazards posed to the proposed facility from traffic on I-40 would bound hazards from other nearby highways, as stated in PSAR Section 2.2.2.5.

2.2.1.7 *Projected Industrial Growth*

The U.S. Department of Energy is conducting a major cleanup of the ETTP to convert it into a private industrial park, called Heritage Center Industrial Park. Other nearby facilities under planning or construction that may pose a hazard to the proposed facility include the Kairos Power Hermes Facility, the X-energy TRISO-X Fuel Fabrication Facility, the Kairos Power Atlas Fuel Fabrication Facility, and Coqui Pharmaceutical, as stated in PSAR Section 2.2.2.8. The NRC staff is also aware of a nuclear fuel enrichment facility proposed to be constructed by Orano Enrichment USA at the nearby Horizon Center. TVA, in PSAR Section 2.2.2.8, commits to analyzing potential explosions, flammable vapor cloud formation, and release of toxic chemicals at these facilities in the application for an OL for CRN-1. The NRC staff finds this acceptable as such an analysis is not required for issuance of a CP. The NRC staff will evaluate the analysis TVA commits to providing in PSAR Section 2.2.2.8 as part of its review of the CRN-1 OLA, if submitted.

As information sufficient to assess the potential radiological effects of the proposed Coqui Pharmaceutical facility is not currently available, TVA did not assess the potential radiological effects of this facility. However, TVA anticipated, in PSAR Section 2.2.2.8, that any offsite radiological hazards would be similar to the SHINE medical isotope facility and chemicals stored on site would be found not to pose a hazard to the control room personnel at the proposed facility if released. Given the lack of currently available information, the NRC staff finds it acceptable that TVA did not assess the potential radiological effects of the proposed Coqui Pharmaceutical facility in the PSAR but expects an assessment of the potential hazards of the proposed Coqui Pharmaceutical facility on the operation of CRN-1 in the OLA, if information on the Coqui Pharmaceutical facility is available at the time the OLA is submitted.

2.2.2 Evaluation of Potential Accidents

2.2.2.1 *Introduction*

The staff's evaluation of potential accidents considers the applicant's analyses of potential accidents involving hazardous materials either stored at nearby facilities or on site or transported along roadways in the vicinity of the proposed facility to confirm that appropriate data and analytical models have been used. The staff's review covers the following specific areas: (1) hazards associated with nearby industrial facilities, such as manufacturing, processing, or storage facilities, and (2) hazards associated with nearby transportation routes (highway I-40, navigable waterway, and pipelines). Each hazard review area includes consideration of the following principal types of hazards:

- Overpressure resulting from explosions involving flammable materials including vapor clouds resulting from the atmospheric release of gases (such as propane and natural gas) with a potential for ignition and explosion.

- Thermal effects attributable to fires.

- Toxic vapors or gases and their potential for incapacitating nuclear plant control room operators.

2.2.2.2 *Summary of Application*

The applicant evaluated potential accidents based on information compiled for the identified facilities in PSAR Sections 2.2.1 and 2.2.2 in accordance with regulatory requirements in 10 CFR 100.20 and 10 CFR 100.21 using the guidance in RG 1.78, Revision 2, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release;" RG 1.91, Revision 3, "Evaluations of Explosions Postulated to Occur at Nearby Facilities and on Transportation Routes Near Nuclear Power Plants;" RG 4.7, Revision 4, "General Site Suitability Criteria for Nuclear Power Stations;" and RG 1.206, Revision 1 (NRC 2018-TN6192), "Applications for Nuclear Power Plants." The applicant performed an analysis of these accidents to determine whether any of them should be considered a DBE. The DBEs are defined as those accidents that have a probability of occurrence on the order of 10^{-7} per year or greater with potential consequences serious enough to affect the safety of the plant to the extent that the guidelines specified in 10 CFR Part 100 could be exceeded. The following accident categories are considered in selecting DBEs: explosions, flammable vapor clouds (delayed ignition), toxic chemicals, fires, collisions with intake structures, and liquid spills.

2.2.2.3 Regulatory Basis

The acceptance criteria associated with the relevant requirements of NRC regulations for the evaluation of potential accidents are given in SRP Section 2.2.3, “Evaluation of Potential Accidents” (NRC 2007/2018-DOE 2017-TN5828).

The staff considered the following regulatory requirements when evaluating the potentiality and consequences of accident sequences:

- 10 CFR 50.34(a)(1)(ii), as it relates to a description and safety assessment of the site, including site evaluation factors identified in 10 CFR Part 100 (TN249).
- 10 CFR 100.20(b) (TN282), as it relates to the nature and proximity of human-related hazards (e.g., airports, dams, transportation routes, and military and chemical facilities) that must be evaluated to establish site parameters for use in determining whether a plant design can accommodate commonly occurring hazards and whether the risk of other hazards is very low; and
- 10 CFR 100.21(e), as it relates to the requirement that the potential hazards associated with nearby transportation routes, industrial, and military facilities be evaluated and site parameters be established such that potential hazards from such routes and facilities will not pose undue risk to the type of facility proposed to be located at that site.
- 10 CFR 50.35, “Issuance of construction permits.”

2.2.2.4 *Technical Evaluation*

In PSAR Section 2.2.2.2, TVA has provided information on potential hazardous chemicals at nearby facilities using the U.S. Environmental Protection Agency’s (EPA’s) Envirofacts/Enviromapper database and information obtained from the Military Department of Tennessee. The staff finds that TVA has used appropriate sources of information for identifying potentially hazardous chemicals stored at the nearby facilities as these are reliable and trustworthy databases maintained by the Federal and State governments.

PSAR Table 2.2-2R lists all chemicals stored at facilities near the proposed site along with the maximum quantity in storage. PSAR Table 2.2-3R lists the maximum quantity of all chemicals that may transported on nearby I-40. PSAR Table 2.2-12R lists all chemicals stored on site at the proposed facility. These chemicals in storage or transported were screened for the potential to pose a credible hazard to the proposed facility based on (1) characteristics of the chemical, (2) quantity in storage or transit, and (3) distance between the location of the chemical and the power block of the proposed facility. Each chemical is screened for its potential to develop an overpressure reaching at least 1 pound per square inch (psi) at the power block (1) after explosion (detonation), (2) after vapor cloud explosion (deflagration), (3) due to thermal load after fire, and (4) due to toxic potential (causing immediate danger to life or health or asphyxiation of control room operator). Results of the screening analysis are given in PSAR Tables 2.2-5R for chemicals in offsite storage, 2.2-6R for chemicals that may be transported on I-40, 2.2-10R for flammable vapor cloud explosion, 2.2-10R for toxicity from offsite chemicals, and 2.2-13R for chemical in storage onsite.

The staff has reviewed the assessment of hazards, and the staff’s review is described below.

2.2.2.4.1 Explosions

TVA discussed the potential for detonation of explosives, munitions, chemicals, and liquid and gaseous fuels in PSAR Section 2.2.3.1.1. As hazards from potential detonations were reviewed previously by the staff as part of the review of the ESP SSAR, only new information is reviewed below.

TVA used the TNT Equivalency method to estimate the overpressure generated from such explosions, as given in RG 1.91, and compared it with the 1 psi threshold overpressure. The staff notes that TVA assumed the entire mass of the pressurized or liquefied gas detonates after a sudden tank rupture, which the staff finds appropriate and conservative.

Onsite Storage

Hydrogen stored on site in cylinders at the proposed facility is the nearest source of potential explosive gases to the RB. TVA used the methodology in Electric Power Research Institute (EPRI) NP-5283-SR “Guidelines for Permanent BWR Hydrogen Water Chemistry Installation” (1987) to estimate the overpressure generated from explosion of a cylinder full of hydrogen. Using the methodology in this document, TVA estimated the minimum separation distance needed between the hydrogen cylinders and the safety-related structures at the proposed facility to be 143 ft so that the overpressure would be 1 psi. In addition, a separation distance of 230 ft is needed to keep the overpressure generated at the safety-related structures at 1 psi, as stated in PSAR Section 2.2.3.1.1. The staff notes that the proposed facility design will have the hydrogen cylinders located more than 230 ft from the RB and CB, as stated in PSAR Section 2.2.3.1.1. In addition, the transportation route to be taken to replace these hydrogen cylinders would be a sufficient distance away so that an exploding cylinder will not affect the safety-related structures at the proposed facility during hydrogen transport. Based on the above discussion, the staff finds acceptable TVA’s conclusion that storage of hydrogen cylinders with associated high pressure piping would be located a large enough distance away from the RB and CB to prevent any damage in an explosion of hydrogen gas.

Nearby Facilities

In PSAR Section 2.2.3.1.1, TVA identified and evaluated facilities located near the proposed site for potential explosion hazard from stored chemicals. PSAR Table 2.2-5R lists the results of the evaluation. Chemicals at each identified facility were evaluated for the overpressure hazard using the TNT Equivalency method, and the results are given in PSAR Table 2.2-9R. The staff finds, based on the information provided in PSAR Table 2.2-9R, that the overpressure from an explosion of the entire quantity of each stored chemical at these nearby facilities would be below 1 psi, and therefore, potential for explosion of the stored chemicals at the nearby facilities would not affect safe operation or shutdown of the proposed facility.

Nearby Roadway/I-40

PSAR Table 2.2-3R lists the hazardous materials that may be potentially transported on I-40. This list was compiled from information on materials stored or produced in facilities located near I-40. The staff finds the approach to be reasonable and acceptable. TVA evaluated each material for its explosion potential based on its physical properties, as described in PSAR Table 2.2-6R. Only butane, gasoline, hydrogen, methanol, methyl chloroform, and propane were identified as needing further evaluation.

TVA evaluated these chemicals for potential explosion hazard using the TNT Equivalency method, and the results are given in PSAR Table 2.2-9R. PSAR Table 2.2-9R lists the estimated distance to the 1-psi overpressure limit from an explosion of the hazardous chemicals while being transported on I-40. Results given in PSAR Table 2.2-9R show that the estimated distance is always smaller than the distance between I-40 and the power block of the proposed facility. Consequently, the staff concludes that an explosion of hazardous materials while being transported on I-40 would not affect safe operation or shutdown of the proposed facility.

Nearby Pipelines

The NRC staff previously evaluated the hazards from the rupture of two nearby natural gas pipelines, Pipeline 1 and Pipeline 2, owned by Enbridge Inc., in the ESP FSER. As there is no new information regarding hazards from the rupture of these pipelines in the PSAR, the staff did not review this matter further for this report.

2.2.2.4.2 Explosion of Flammable Vapor Clouds

TVA analyzed the hazards to the proposed facility from ignition of vapor clouds generated from release of liquid or gaseous flammable materials nearby. This vapor cloud can drift towards the proposed facility by the prevailing atmospheric conditions and may ignite and explode if the concentration of the released chemical in the vapor cloud is within its flammability limits. As the staff previously reviewed the assessment of hazards from flammable vapor clouds in the ESP FSER, the staff only reviewed new and updated information presented in the PSAR.PSAR Section 2.2.3.1.2 identifies hydrogen in cylinders as the only chemical stored on site having a potential for vapor cloud explosion. The staff finds in PSAR Tables 2.2-9R and 2.2-12R that the hydrogen vapor cloud would no longer be flammable after traveling 230 ft from a rupture of a cylinder. As the safety-related structures at the proposed facility would be located more than 230 ft away from the hydrogen cylinder storage location, the staff finds that on site storage of hydrogen on site would not pose a vapor cloud explosion hazard to the proposed facility.

Nearby Facilities

PSAR Section 2.2.3.1.2.1 identified facilities within 25 mi of the proposed site that store potentially flammable/explosive materials. PSAR Table 2.2-2R lists the hazardous chemicals stored in each nearby facility. PSAR Table 2.2-9R identifies flammable chemicals and quantity stored in nearby facilities. In addition, the calculated distance to the point where the overpressure is just 1 psi is listed in this table and compared with the actual distance. PSAR Table 2.2-10R lists the distance to its LFL limit, distance to the 1 psi overpressure limit, and thermal radiation of 5 kilowatts per square meter (kW/m^2) for each chemical stored at these facilities. It should be noted that the selected threshold for thermal radiation is low; only plastic might melt at 5 kW/m^2 thermal radiation. Being constructed with reinforced concrete, the safety-significant structures can withstand significantly higher thermal radiation, as shown in NUREG/CR-3330 (Bennett 1983-TN13302).

The staff finds that results given in PSAR Table 2.2-10R show that the concentration of released materials in the vapor clouds would be diluted below the respective LFL value before reaching the proposed site. In addition, distance to the 1 psi overpressure limit always exceeds the distance of the proposed site from the storage locations of these chemicals. Therefore, the staff concludes that flammable vapor clouds from chemicals stored in the nearby facilities will not affect safe operation and shutdown of the proposed facility.

Nearby Roadways/I-40

As discussed previously, PSAR Table 2.2-3R identifies the hazardous materials that may be potentially transported on I-40. PSAR Table 2.2-6R identifies the following materials that require evaluation of potential flammable vapor cloud formation if released: acrylonitrile, butane, gasoline, methanol, methyl chloroform, methyltrichlorosilane, and propane. TVA assumed that butane and propane are transported in a high pressure tanker truck in accordance with 49 CFR 173.315 (TN298), at full capacity of 11,000 gallons (gal). Additionally, the maximum quantity of gasoline that can be transported in a tanker truck on highways is 8,500 gal. The staff finds the assumption of load carried by tanker trucks on highways is consistent with RG 1.91.

The staff finds that results given in PSAR Table 2.2-10R show that the concentration in the vapor cloud of all chemicals released while being transported on I-40 would fall below the respective LFLs before reaching the proposed site. In addition, the overpressure from an explosion of the released chemical would be less than 1 psi at the proposed site location. Therefore, based on above discussion, the staff concludes that explosion of the vapor cloud formed from release of a flammable chemical while being transported on I-40 would not pose a significant hazard to the proposed facility.

Nearby Pipelines

In the ESP SSAR, TVA used the ALOHA computer program to analyze the hazards posed by a complete break of two pipelines near the proposed site. The PSAR modifies a footnote in Table 2.2-4 of the ESP SSAR to identify that the pipelines are now owned by Enbridge Inc., but makes no other changes to the table. Section 2.2.3.1.2.3 of the ESP SSAR discussed the potential hazards from the rupture of these pipelines and provided the results of that analysis in Table 2.2-10. TVA did not change the results of that analysis with respect to the two pipelines in PSAR Table 2.2-10R. Therefore, because there is no new or additional information on potential vapor cloud explosion from rupture of these pipelines in the PSAR, the staff did not review this matter further.

2.2.2.4.3 Toxic Chemicals

In PSAR Section 2.2.3.1.3, TVA evaluated hazards from release of toxic chemicals at a nearby facility or on a transportation route. Materials potentially stored at these nearby facilities and transported on I-40 are given in PSAR Tables 2.2-2R and 2.2-3R, respectively.

Based on material properties and stored quantities, chemical concentration in the atmosphere was estimated at the proposed facility location using the guidance of RG 1.78 (NRC 2021-TN13248) or the ALOHA software. Chemicals with concentration above the immediately dangerous to life or health (IDLH) limit at the proposed site location due to toxicity or asphyxiating capacity are identified in PSAR Table 2.2-11R. TVA used a spectrum of meteorological conditions to identify the worst meteorological condition for each event. PSAR Table 2.2-11R summarizes the effects on the proposed facilities.

Nearby Facilities

PSAR Section 2.2.3.1.3.1 identifies the facilities within 25 mi of the proposed site that store potentially hazardous chemicals capable of forming a toxic vapor cloud. Each chemical identified at storage in these facilities was screened based on potential to form a toxic cloud that can carry the toxic chemical toward the proposed site under worst-case meteorological conditions. PSAR Table 2.2-5R lists chemicals identified in each facility requiring further evaluation of toxicity.

Materials identified for further assessment are listed in PSAR Table 2.2-11R. Based on material properties and quantity of stored chemicals, TVA estimated the chemical concentration near the power block of the proposed facility using the methodology in RG 1.78. The ALOHA program was also used to estimate the maximum distance a specific chemical travels in air before its concentration falls below its IDLH or asphyxiation limit. TVA used a spectrum of meteorological conditions to identify the worst meteorological condition for each chemical. Results are summarized in PSAR Table 2.2-11R. The estimated distance is then compared to the distance of the potential release point to the proposed facility.

Results given in PSAR Table 2.2-11R show that the concentration of each chemical in its toxic vapor cloud developed as a result of a spill of the entire amount in storage at the nearby facilities would fall below its IDLH value or asphyxiation limit. Therefore, the staff finds that accidental spill of all hazardous chemicals stored within 25 mi from the proposed facility would not have any adverse effects on safe operation or shutdown of the proposed facility.

<u>Nearby Roadways/I-40</u>

As the list of hazardous chemicals that may potentially be transported on I-40 has been updated by TVA, the NRC staff reviewed the revised PSAR Section 2.2.3.1.3.2, and the staff review is described below.

PSAR Table 2.2-6R identifies the chemicals, which may potentially be transported on I-40, that can form toxic vapor clouds. In accordance with 49 CFR 173.315, TVA assumed, based on the maximum capacity of MC-331 high pressure tanker trucks, that the maximum quantity of anhydrous ammonia and butane transported on I-40 would be 11,500 gal. Additionally, TVA assumed that the maximum quantity of chlorine on I-40 would be 22 tons using information on tanker truck capacity from the Chlorine Institute (Chlorine Institute, “Bulk Storage of Liquid Chlorine,” Pamphlet 5, October 2005). TVA also assumed that the maximum quantity of hydrochloric acid and nitric acid transported on roadways would be 6,000 gal based on the maximum transport quantity in an MC-312/DOT412 corrosion tanker truck. In addition, TVA assumed that gasoline would be transported in 8,500 gal capacity tanker trucks on I-40. Maximum transportable quantity of other chemicals (argon, carbon dioxide, helium, HFC-134A, methanol, methyl chloroform, propane, and sulfur dioxide) was assumed to be 50,000 lb following RG 1.91. TVA also assumed that the maximum quantity of acrylonitrile, chlorine dioxide, hydrofluoric acid, hydrogen chloride, methyltrichlorosilane, nitric oxide, and nitrogen dioxide transported on I-40 would be limited by the maximum quantity stored at nearby facilities and is given in PSAR Table 2.2-5R.

For each chemical that can be transported on I-40, TVA determined the distance to the point where the chemical concentration in air would reach its IDLH value. TVA mostly used the simplified approach given in RG 1.78. In addition, TVA also used the ALOHA computer program, if needed, to estimate the distance to the IDLH limit. This estimated distance is listed in PSAR Table 2.2-11R and compared with the shortest distance between the proposed site and I-40 (i.e., 5,800 ft) to screen in those chemicals that require further evaluation.

Results given in PSAR Table 2.2-11R show that the distance at which the identified toxicity limit IDLH for a toxic vapor cloud would be reached following an accidental release at the closest approach of I-40 is less than the minimum separation distance of the proposed site from I-40 for most of the chemicals listed in PSAR Table 2.2-6R, except anhydrous ammonia, chlorine, hydrochloric acid, and nitric acid. Therefore, based on the above discussion, the staff concludes that the identified toxic chemicals would not pose a hazard to safe operation or shutdown of the proposed facility, except anhydrous ammonia, chlorine, hydrochloric acid, and nitric acid, which are screened in for further assessment by TVA for control room habitability assessment, as stated in PSAR Section 2.2.3.1.3.2 and Table 2.2-11R. A vapor cloud of anhydrous ammonia reaches its IDLH value at a distance of 13,728 ft, as given in PSAR Table 2.2-11R. A chlorine vapor cloud is estimated to reach its IDLH value at 23,760 ft. In comparison, the distance between the proposed site and the roadway I-40 is only 5,800 ft. In addition, as noted in PSAR Table 2.2-11R, both hydrochloric acid and nitric acid could not be screened out following simplified method given in RG 1.78, Appendix A. Consequently, the staff finds that these four hazardous chemicals while being transported on I-40 can pose a threat to the habitability of the control room of the proposed facility.

<u>Nearby Pipelines</u>

PSAR Section 2.2.3.1.3.3 did not update any information from the ESP SSAR regarding toxicity hazard from release of natural gas from the nearby pipelines. Because the information was reviewed by the staff previously in the ESP FSER, it was not reviewed further for this report.

<u>Onsite Storage</u>

TVA listed in PSAR Table 2.2-12R the chemicals identified so far to be stored at the proposed facility. PSAR Table 2.2-12R also lists the quantity of each chemical stored in the identified storage location at the proposed facility. TVA conducted a screening analysis of all the onsite chemicals for potential to be a credible hazard if released. Results of the screening analysis are given in PSAR Table 2.2-13R. Most of the chemicals do not explode or pose a toxic hazard as they are not flammable and do not have an IDLH value. They also do not pose asphyxiation hazard.

As shown in PSAR Table 2.2-13R, only hydrogen and gasoline can pose explosion hazards. Fuel oil used in diesel generators or diesel pumps has extremely low vapor pressure and will not explode. Similarly, lubricating oil used in turbines will not explode due to very low vapor pressure. As discussed before, hydrogen will be stored in tubes outside the protected area at a distance larger than the minimum separation distance needed to eliminate an explosion hazard, as given in PSAR Section 2.2.3.1.1.

PSAR Table 2.2-13R states that the location where gasoline would be stored at the proposed facility has not yet been selected. TVA commits to selecting a location that poses no credible explosion hazard to the proposed facility, using guidance in RG 1.91.

TVA analyzed the toxicity of cryogenic nitrogen, hydrogen, sodium hypochlorite, sulfuric acid, sodium hydroxide, tetrafluoroethene (R-134a), and R410a for main control room habitability. TVA found that these chemicals do not impact the habitability of the main control room as the concentration of these chemicals in the control room remains below their respective IDLH values, as stated in PSAR Table 2.2-13R.

Although a spill of cryogenic nitrogen stored on site is not toxic it may pose a potential asphyxiation hazard to the operators in the control room by creating an oxygen-deficient environment if nitrogen enters the control room in sufficient quantity. Using the HABIT computer program, TVA determined the maximum concentration of nitrogen in the control room to be significantly lower than that required to be an asphyxiant. Therefore, the staff finds that a burst of the nitrogen storage tank at the proposed facility will not pose an asphyxiation hazard to control room personnel. In addition, TVA also determined that release of hydrogen will not pose an asphyxiation hazard to control room personnel, as stated in PSAR Table 2.2-13R.

Therefore, based on the information presented in PSAR Table 2.2-13R and above discussion, the staff concludes that accidental release of hazardous chemicals to be stored on site at the proposed facility would not pose a credible hazard. However, identification of all chemicals that may be stored on site has not yet been finalized. In PSAR Section 2.2.3.1.3, TVA commits to assessing all the chemicals to be stored on site for the potential to pose explosions, flammable vapor clouds, and toxic hazards once the final design of the proposed facility is complete.

2.2.2.4.4 Fires

The NRC staff has previously reviewed in the ESP FSER the potential fire hazards at the proposed facility from chemicals stored on site, at nearby industrial facilities, or transported on nearby routes, including pipelines. As TVA has provided new information on potential fire hazards, the staff's review is limited to the new information presented in PSAR Section 2.2.3.1.4.

Based on information presented in PSAR Table 2.2-13R, only gasoline, hydrogen, and fuel/lubricating oil stored on site can potentially pose a fire hazard. As discussed before, TVA commits to selecting a location that poses no credible explosion hazard to the proposed facility. As stated in PSAR Table 2.2-12R, hydrogen will be stored on site in cylinders outside the power block at the proposed facility. The separation distance from safety-related SSCs would be large enough to exclude fire and explosion hazards from rupture of one of these cylinders. Additionally, the staff finds that hydrogen, being lighter than air, would not generate a floating vapor cloud that could pose a fire hazard at the proposed power block. In addition, the amount of fuel/lubricating oil to be used in standby diesel generators or fire pumps would not be sufficient to pose a fire hazard. Additionally, PSAR Section 2.2.3.1.4 states that the onsite fuel storage facilities will be designed in accordance with applicable fire codes. Consequently, the staff finds that the safety of the proposed facility will not be impacted from any potential fires or smoke generated on site.

In addition, nearby homes, industrial facilities, and transportation routes are located too great a distance away to pose credible fire and/or smoke hazards to the proposed facility. Additionally, forests in the area would also be located too great a distance away from the proposed facility to pose a credible hazard. Moreover, the heating, ventilation, and air conditioning (HVAC) system at the control room will mitigate the effects of fire and smoke by filtering intake air out of harmful particles. In addition, any onsite fuel storage facilities would be designed according to applicable fire codes, and a fire protection system would be installed, as stated in PSAR Section 2.2.3.1.4. Therefore, based on the above discussion, the staff concludes that both fire and smoke, originating on or off the proposed facility site will not produce a credible hazard.

2.2.2.4.5 Collisions with Intake Structure

As there is no new information regarding hazards from the collision with intake structures in the PSAR, the staff did not review this matter further for this report.

2.2.2.4.6 Permit Condition 2.2-2

Permit Condition 2.2-2 (Permit Condition 2) in the ESP FSER states the following:

> Since location and design of the control room has not been established for the ESPA, an applicant for a COL referencing this ESP shall evaluate and demonstrate compliance with NRC regulations for the potential toxic chemicals for the control room habitability from the onsite storage of chemicals (to be identified in COL or CP) and also for the transported chemicals anhydrous ammonia, chlorine and nitric acid from highway I-40, where the concentration of these chemicals exceeded the respective IDLH limit at the CRN-1 power block area.

This permit condition has two parts. The first part deals with any new hazardous material selected to be stored on site at the proposed facility in future. The second part deals with three hazardous chemicals (anhydrous ammonia, chlorine, and nitric acid) that can be transported on nearby I-40 but affects the habitability of the control room at the proposed facility because of toxic vapor clouds.

PSAR Tables 2.2-11R and 2.2-13R show that all chemicals identified so far to be stored on site at the proposed facility do not affect the control room habitability. However, anhydrous ammonia, chlorine, hydrochloric acid, and nitric acid can cause a toxicity hazard at the Main Control Room while being transported on I-40. In addition, PSAR Section 2.2.3.1.3.2 states that if any new chemical is selected to be stored on site, TVA will analyze its impact on habitability of the control room of the proposed facility in addition to potential for explosion or formation of a flammable vapor cloud, and the results will be included in the OL application and accounted for in the final design of the proposed facility. The staff notes that TVA stated in PSAR Section 9.4.1.3 that design features of the Heating, Ventilation, and Cooling System (HVS) of the control room would offer protection for operators against anhydrous ammonia, chlorine, hydrochloric acid, and nitric acid. The outside air that would be the intake for the HVS would be instrumented to analyze presence of those toxic chemicals. The staff notes that the design of the control room HVS is not final; however, as stated in PSAR Section 9.4.1.3, design of the HVS would follow the guidance of RG 1.78, Revision 2. Consequently, the staff expects that the air exchange rate of the control room would be designed to keep the control room habitable consistent with guidance in RG 1.78.

The staff therefore concludes that the Permit Condition 2.2-2 from the ESP FSER is not needed to ensure adequate safety of the proposed facility, specifically for habitability of the control room. Therefore, Permit Condition 2.2-2 can be considered closed. However, TVA must provide the detailed design of the control room in the OL application, including the associated HVS, and show that the presence of toxic chemicals in the intake air of the control room HVS, so far identified or to be identified, as stated in PSAR Section 2.2.3.1.3.4, would be detected and appropriate actions would be taken to keep the control room habitable for the operators.

2.2.2.4.7 Conclusion

Based on the aforementioned discussions, the staff finds that TVA has identified and evaluated potential accidents related to the presence of hazardous materials or activities in the proposed site vicinity that could affect a nuclear power plant or plants that might be constructed on the proposed site. The staff reviewed the new and updated information provided in the PSAR and, for the reasons discussed above concludes that TVA has established site characteristics and design parameters acceptable to meet the requirements of 10 CFR 100.20(b) and 10 CFR

100.21(e) for determining the acceptability of the proposed site. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.3 Meteorology

To ensure that a nuclear power plant or plants can be designed, constructed, and operated on an applicant's proposed site in compliance with NRC's regulations, the NRC staff evaluates regional climatological and local meteorological information, including climate extremes and occurrences of severe weather phenomena that may affect the design, siting, and operation of a nuclear plant. The NRC staff also reviews information on the atmospheric dispersion (χ/Q) characteristics of a proposed nuclear power plant site to determine whether the radioactive effluents from postulated accidental releases, as well as from routine operational releases, comply with NRC regulations. As mentioned in Chapter 1 of this SER, the CRN Site was previously described in the "Clinch River Nuclear Site Early Site Permit (ESP) Application, Site Safety Analysis Report" (SSAR) (TVA 2019-TN5854), and portions of the SSAR were incorporated by reference into the preliminary safety analysis report (PSAR) of TVA's CPA. Because the ESP final safety evaluation report (FSER) issued for the CRN Site provided finality on the staff's findings for the ESP, this SER on the CPA PSAR is limited to evaluating the changes described by TVA between the submission of the SSAR and the CPA PSAR.

The NRC staff prepared Sections 2.3.1 through 2.3.5 of this report in accordance with the review procedures described in NUREG-0800 (NRC 2021-TN8013), "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition."

2.3.1 Regional Climatology

2.3.1.1 Introduction

In PSAR Section 2.3.1, "Regional Climatology," the applicant provided new and updated information regarding regional climatic conditions and the occurrence of meteorological phenomena (including both averages and extremes) that could potentially influence the design and affect the operating bases of safety- and non-safety-related structures, systems, and components (SSCs) for the proposed nuclear power plant.

PSAR Table 2.0-1R provides a list of characteristics that describe climatological conditions that might reasonably be expected to occur at the CRN Site. Site characteristics are the actual physical, environmental, and demographic features of a site and are used to verify the suitability of a proposed plant design for a site.

2.3.1.2 Regulatory Evaluation

The acceptance criteria for identifying regional climatological and meteorological information are based on meeting the relevant requirements of 10 CFR Part 100, "Reactor Site Criteria." The NRC staff considered the following regulatory requirements when reviewing the applicant's identification of regional climatological and meteorological information:

- 10 CFR 50.34(a)(1)(ii), as it relates to providing a safety assessment of the site, including site evaluation factors identified in 10 CFR Part 100 (TN249).
- 10 CFR 50.35, "Issuance of construction permits."
- 10 CFR 100.20(c)(2) (TN282), as it relates to the requirement that those meteorological characteristics of the site that are necessary for safety analysis or that might have an impact on plant design be identified and characterized as part of the NRC staff's review of the acceptability of the site
- 10 CFR 100.21(d), as it relates to the requirement that the physical characteristics of the site, including meteorology, "be evaluated and site characteristics established such that potential threats from such physical characteristics will pose no undue risk to the type of facility proposed to be located at the site."

The climatological and meteorological information assembled by the applicant in the CP application (in compliance with the above regulatory requirements) will be necessary to determine whether a proposed facility complies with the following requirement in Appendix A, "General Design Criteria for Nuclear Power Plants," of 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities":

- General Design Criteria 2, "Design Bases for Protection Against Natural Phenomena," as it relates to the requirement that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

The following are the relevant SRP acceptance criteria from NUREG-0800 (NRC 2021-TN8013), Section 2.3.1, "Regional Climatology":

- The description of the general climate of the region should be based on standard climatic summaries compiled by the National Oceanic and Atmospheric Administration (NOAA).
- Data on severe weather phenomena should be based on standard meteorological records from nearby representative National Weather Service (NWS), military, or other stations recognized as standard installations that have long periods of data on record.
- The tornado parameters should be consistent with Regulatory Guide (RG) 1.76, *Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants*, Revision 1 (NRC 2007-TN3294). Alternatively, an applicant may specify any tornado parameters that are appropriately justified, provided that a technical evaluation of site-specific data is conducted.
- The basic (straight-line) 100-year return period, 3-second gust wind speed should be based on appropriate standards, with suitable corrections for local conditions.
- To be consistent with RG 1.27 (NRC 2015-TN5907), *Ultimate Heat Sink for Nuclear Power Plants*, Revision 3, the ultimate heat sink (UHS) meteorological data that would result in the maximum evaporation and, if applicable, drift loss of water and minimum water cooling should be based on long-period regional records that represent site conditions. (The guidance in this RG does not apply to passive reactor designs that utilize a passive containment cooling system as the UHS.)

- The weight of the 100-year return period snowpack should be based on data recorded at nearby representative climatic stations and/or obtained from appropriate standards with suitable corrections for local conditions. The weight of the 48-hour probable maximum winter precipitation should be determined in accordance with hydrometeorological reports published by NOAA's Hydrometeorological Design Studies Center.

- Ambient temperature and atmospheric humidity statistics should be derived from data recorded at nearby representative climatic stations or obtained from appropriate standards with suitable corrections for local conditions.

- High air pollution potential information should be based on U.S. Environmental Protection Agency (EPA) studies.

- All other meteorological and air quality conditions identified by the applicant as design and operating bases should be documented and substantiated.

- Design Certification (DC)/COL-Interim Staff Guidance (ISG)-07, "Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures," which clarifies the NRC staff's position on identifying winter precipitation events as site characteristics and site parameters to determine normal and extreme winter precipitation loads on the roofs of seismic Category I structures.

To the extent applicable to the above-outlined acceptance criteria, the applicant applied the NRC-endorsed climatological and meteorological information selection methodologies and techniques in the following:

- RG 1.221, *Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants*, which provides criteria for selecting the design-basis hurricane parameters (NRC 2011-TN5931).

- NUREG/CR-7005, *Technical Basis for Regulatory Guidance on Design-Basis Hurricane Wind Speeds for Nuclear Power Plants* (NRC 2011-TN13289).

2.3.1.3 Technical Evaluation

2.3.1.4 Regional Climatology

The NRC staff reviewed PSAR Section 2.3.1 to ensure that the information provided in the CPA represents the complete scope of information relating to regional climatology. The staff's review confirmed the application addresses both existing climatological hazards in the PSAR and any information has been updated from the previously approved ESP, as further described below.

2.3.1.4.1 General Climate

Section 2.3.1.1 of the PSAR incorporates by reference the corresponding section of the SSAR, with the exception of updated references and revisions to regional climatological data, including precipitation totals and normal and maximum temperature values.

2.3.1.3.1 Regional Meteorological Conditions for Design and Operating Basis

The regional climatological (meteorological) conditions that are relevant to the design and operating bases of safety-related SSCs for the CRN Site are presented in Table 2.0-1R of the PSAR. These climate-related site characteristics were reviewed by the NRC staff in the previously approved SSAR for the related ESP application. The staff reviewed the site characteristics in Table 2.0-1R as part of its review of the PSAR to ensure that there were no changes that could impact the safety review findings from the staff's review of the ESPA. The information provided in Table 2.0-1R of the PSAR matches the site characteristic values provided in the previously approved ESPA. Therefore, the staff concludes that these values are acceptable.

2.3.1.3.2 Severe Weather

PSAR section 2.3.1.3, "Severe Weather," provides an update to the National Climatological Data Center (NCDC) Storm Events Database data period used to develop severe weather hazard characteristics for the Clinch River region. The following sections will summarize the changes that resulted from the change in period of record.

2.3.1.4.1 Thunderstorms, Hail, and Lightning

PSAR section 2.3.1.3.1 provides an update to the number of thunderstorms that have been observed in the region. This section updated the period of record used for these statistics that do not result in design-basis parameters. The CPA also updated the references used to determine the frequency of thunderstorms, hail, and lightning. The updated information provided in this section of the PSAR does not result in changes to the staff's conclusions and does not change any design-related parameters.

2.3.1.4.3.2 Extreme Winds

PSAR section 2.3.1.3.2 did not contain any changes that impact the safety findings made in the ESP FSER. PSAR Table 2.0-1R identifies the CRN Site-Related Design Parameter 100-year basic wind speed as 160 mph. This is discussed in PSAR Section 3.3.1.1, "Design Wind Speed and Recurrence Interval," as being a 3000-year return period value. Using the same ASCE/SEI 7-16 basic wind speed maps, the staff confirmed the 100-year return period value of 90 mph. The inclusion of a greater wind speed in PSAR Table 2.0-1R is a conservative assumption. Therefore, the staff finds the updated values in PSAR section 2.3.1.3.2 to be acceptable.

2.3.1.4.3.3 Precipitation Extremes

PSAR section 2.3.1.3.3 did not contain any changes that impact the safety findings made in the ESP FSER. The primary change from the SSAR to the PSAR was to revise the maximum estimates annual precipitation from 45-53 inches annually, to 46-55 inches annually. This change does not impact the safety findings for this report.

2.3.1.4.3.4 Tornadoes

Tornado Strike Probability

PSAR section 2.3.1.3.4 of the CRN-1 PSAR did not contain any changes that impact the safety findings made in the ESP FSER. Therefore, the staff did not perform further evaluation of the information for this report.

Design-Basis Tornado Parameters

PSAR section 2.3.1.3.4 subsection titled "Design-Basis Tornado Parameters," did not contain any changes from the ESPA other than the renumbering of Table 2.0-1R. The findings in this section continue to be based on Revision 1 of RG 1.76. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.4.3.5 Hurricanes

PSAR section 2.3.1.3.5 contained an update to the period of record for the hurricane database. This change did not impact the safety findings made in the ESP FSER. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.4.3.6 Winter Storm Events

PSAR section 2.3.1.3.6 contained updated reference numbers, which did not impact the safety findings made in the approved ESPA. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.4.3.6.1 Ice Storms

PSAR section 2.3.1.3.6.1 contained updated reference numbers, which did not impact the safety findings made in the approved ESPA. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.4.3.6.2 Normal and Extreme Winter Precipitation Events

PSAR section 2.3.1.3.6.2 contained changes to the period of record used for the winter precipitation analysis as well as minor changes to the maximum historical snowpack value. These changes did not impact the safety findings made in the approved ESPA. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.4.4 Design-Basis Dry- and Wet-Bulb Temperatures

PSAR section 2.3.1.4 contained updated reference numbers, which did not impact the safety findings made in the approved ESPA. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.3.3 Climate Changes

PSAR section 2.3.1.6 contained updated reference numbers. There are no new safety findings included in this section. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.4.6 Regional Air Quality Conditions

The applicant's discussion on regional air quality conditions in PSAR Section 2.3.1.7 is intended to provide a general understanding of the background and projected air quality conditions in the site region but does not result in the generation of site characteristics for use as a design basis. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.4.7.1 Background Air Quality

PSAR section 2.3.1.7.1 contained updated reference numbers. There are no new safety findings included in this section. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.4.7.2 Projected Air Quality

PSAR section 2.3.1.7.2 contained updated reference numbers. There are no new safety findings included in this section. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.1.4 Conclusion

The staff has reviewed the regional meteorological information provided by the applicant in the PSAR and the referenced CRNS ESP SSAR and, for the reasons given above, concludes that the applicant has established the meteorological characteristics at the site and in the surrounding area acceptable to meet the requirements of 10 CFR 100.20(c)(2) and 100.21(d) with respect to determining the acceptability of the site. The staff concludes that the identified design bases meet the requirements of 10 CFR Part 50, Appendix A, GDC 2. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.3.2 Local Meteorology

2.3.2.1 Introduction

PSAR Section 2.3.2, “Local Meteorology,” presents (1) summaries of local (site) meteorological conditions, (2) an assessment of the potential construction and operational influences of the plant and its facilities on the local meteorological conditions, (3) the impact of these modifications on plant design and operation, and (4) a topographical description of the site and its associated surroundings.

In PSAR Section 2.3.2, the applicant provided the following information:

- A description of the local (site) meteorology in terms of airflow, atmospheric stability, temperature, water vapor, precipitation, fog, and potential cooling tower effects.
- An assessment of how the construction and operation of the nuclear power plant and associated facilities that are planned to be built on the proposed site will influence the local meteorology, including the effects of plant structures, terrain modification, and heat and moisture sources resulting from plant operation.
- A topographical description of the site and its environs.

In Section 2.3.2 of this report, the NRC staff verifies that the applicant has identified and considered the meteorological and topographical characteristics of the site and the surrounding area, as well as changes to those characteristics that may be caused by the construction and operation of the proposed facility.

2.3.2.2 Regulatory Evaluation

The acceptance criteria associated with the relevant requirements of the Commission regulations for local meteorology are given in Section 2.3.2 of NUREG-0800 (NRC 2021-TN8013).

The applicable regulatory requirements for identifying local meteorology are:

- 10 CFR 50.34(a)(1)(ii) (TN249), as it relates to providing a safety assessment of the site, including site evaluation factors identified in 10 CFR Part 100.
- 10 CFR 50.35, "Issuance of construction permits."
- 10 CFR 100.20(c)(2) and 10 CFR 100.21(d) with respect to the consideration given to the local meteorological characteristics of the site (TN282).

The climatological and meteorological information assembled by the applicant in the CP application (in compliance with the above regulatory requirements) will be necessary to determine whether a proposed facility complies with the following requirement in Appendix A, "General Design Criteria for Nuclear Power Plants," of 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities":

- GDC 2, "Design Bases for Protection Against Natural Phenomena," as it relates to consideration of the most severe local weather phenomena that have been historically reported for the site and surrounding area with sufficient margin for the limited accuracy, quantity and period of time in which the historical data have been accumulated and that are reflected in the design bases for structures, systems, and components important to safety.

The related acceptance criteria from Section 2.3.2 of NUREG-0800 are as follows:

- Local summaries of meteorological data based on onsite measurements in accordance with RG 1.23, *Meteorological Monitoring Programs for Nuclear Power Plants*, Revision 1 (NRC 2007-TN278), and NWS station summaries or other standard installation summaries from appropriate nearby locations (e.g., within 80 km [50 mi]) should be presented.
- A complete topographical description of the site and environs out to a distance of 80 km (50 mi) from the plant.
- A discussion and evaluation of the influence of the plant and its facilities on the local meteorological and air quality conditions should be provided. Applicants should also identify potential changes in the normal and extreme values resulting from plant construction and operation. The acceptability of the information is determined through comparison with standard assessments.
- The description of local site airflow should include wind roses and annual joint frequency distributions of wind speed and wind direction by atmospheric stability for all measurement levels using the criteria provided in RG 1.23, Revision 1.

2.3.2.3 Technical Evaluation

According to the applicant, short-term site-specific meteorological data gathered from the CRN Site meteorological monitoring program during the period from April 21, 2011, to June 30, 2013, were the primary basis for the meteorological dispersion analysis. The applicant also gathered data from previous onsite measurements and climatological records from the first-order NWS stations at Oak Ridge, Knoxville, and Chattanooga, Tennessee, and from the Watts Bar Nuclear Plant (all of which are located in East Tennessee) to provide additional data to establish the representativeness of the 2-year on-site monitoring data summaries and potential site conditions.

In addition, the applicant described the topography around the site as a primary influencer on local climate. Based on discussions of the local topography in SSAR Section 2.3.2 and site visits by the NRC staff, the information regarding local climate and the topography is acceptable to the staff.

2.3.2.3.1 Normal and Extreme Values of Meteorological Parameters

PSAR section 2.3.2.1 did not contain any changes from the text of the ESPA. Therefore, the staff did not perform further evaluation of the information for this report.

2.34.2.3.1.1 Winds

PSAR section 2.4.2.1.1 included updates to the wind roses for Chattanooga TN and Oak Ridge, TN. The staff compared the wind roses in the ESPA to the wind roses in the PSAR and determined that no large differences in wind patterns exist. Therefore, the staff finds the new information did not contain any changes that impact the safety findings made in the approved ESPA and the staff did not perform further evaluation of the information for this report.

.2 Air Temperature

PSAR section 2.3.2.1.2 did not contain any changes that impact the safety findings made in the approved ESPA. This section of the PSAR updated the normal and extreme temperature values in Tables 2.3.2-5R and 2.3.2-6R to include more recent data. These changes are all within the expected range for the CRN site and are therefore acceptable to the staff.

Atmospheric Moisture

PSAR Section 2.3.2.1.3 did not contain any changes that impact the safety findings made in the approved ESPA. This section of the PSAR updated the atmospheric moisture values in Table 2.3.2-7R to include more recent data. These changes are all within the expected range for the CRN site and are therefore acceptable to the staff.

2.3.2.4.1.1.4 Precipitation

PSAR Section 2.3.2.1.4 provided updated precipitation estimates based on NOAA Atlas 14 Point Precipitation Frequency Estimates in PSAR Table 2.3.2-16R. The staff compared the updated tabled with the values include in the ESPA and determined that the values were comparable for each time period. Therefore, the staff found the updated values to be acceptable.

2.3.2.4.1.1.5 Fog

PSAR section 2.3.2.1.5 did not contain any changes that impact the safety findings made in the approved ESPA. This section of the PSAR updated the occurrence of fog in Table 2.3.2-13R to include more recent data. These changes are all within the expected range for the CRN site and are therefore acceptable to the staff.

2.3.2.4.1.1.6 Atmospheric Stability

PSAR section 2.3.2.1.6 did not contain any changes from the text of the ESPA. Therefore, the staff did not perform further evaluation of the information for this report

2.3.2.3.2 Potential Influence of the Plant and Its Facilities on Local Meteorology

PSAR section 2.3.3.2 states that a specific cooling tower design has not yet been determined for the CRN site. However, the ESPA assumed that the cooling towers will be linear, back-to-back cell, mechanical draft cooling towers and confirmed that salt deposition rates in the highest category are not expected. The SSAR states that the minimum distance to the switchyard is approximately 1,184 ft and the minimum distance to the transformers is approximately 721 ft. The salt deposition rate is highest in the winter with a value of 203.09 kilograms per square kilometer per month (kg/km^2/month) at 200 m in the west-southwest direction.

The NRC staff inspected the input and output files provided by the applicant for the SACTI computer code for estimating the impacts from fogging, icing, and drift deposition from the operation of the mechanical draft cooling towers for the previously approved ESPA. The staff found that there is a minimal threat of fogging and icing in the vicinity immediately surrounding the cooling towers. The staff finds the applicant's conclusion acceptable.

The specific cooling tower design for the CRN site has not yet been finalized; however, TVA provided updated analyses in PSAR Section 2.3.2.2, assuming linear, back-to-back mechanical draft cooling towers (LMDCTs), to demonstrate conformance with NUREG-0800 guidance. Results indicate no high-category salt deposition, with the nearest offsite vegetation receptor located approximately 900 feet (274 meters) away and not expected to experience significant impacts. The highest salt deposition occurs during winter, with a maximum of 354.52 kg/km^2/month at 200 meters, while the limiting plant component is the transformer area at approximately 721 feet (220 meters), where peak deposition is 203.09 kg/km^2/month. These results show minimal impact to both vegetation and plant infrastructure, supporting the suitability of the assumed cooling tower configuration. Additional plume characteristics, including water deposition and plume behavior metrics, were reviewed by the staff at the ESP stage. The salt deposition rates near the switchyard were re-evaluated for this report and determined to be less than the original analysis for the ESP. Since these values have been revised to show less salt deposition, the staff finds this description and evaluation to be acceptable.

PSAR section 2.3.2.2 states that "the specific cooling tower design has not been determined for the CRN site." While the applicant provided distances and updated evaluations of cooling tower impacts in the PSAR, the staff is retaining ESP COL Action Item 2.3-1 to confirm the final details of the cooling tower plume characteristics once the design has been finalized at the OL stage.

COL Action Item 2.3-1: An applicant for a COL or a CP referencing this ESP should verify the cooling tower plume characteristics described in the ESP. Future COL or CP applications referencing this ESP should also include an evaluation of the cooling tower plume impacts on the switchyard, as designed, and any impacts on safety-related air intakes and the adjacent cooling tower.

2.3.2.3.3 Local Meteorological Conditions for Design and Operating Bases

The local meteorological conditions for the design and operational bases were provided by the applicant in PSAR Section 2.3.1 and are reviewed by the NRC staff in SER Section 2.3.1.

2.3.2.4 Conclusion

The staff has reviewed the information provided in the PSAR and the referenced CRN-1 ESP SSAR and, for the reasons given above, concludes that the identification and consideration of the meteorological, air quality, and topographical characteristics of the site and the surrounding area are acceptable and meet the requirements of 10 CFR 100.20(c) and 10 CFR 100.21(d), with respect to determining the acceptability of the site. The staff also concludes that the identified design bases meet the requirement of 10 CFR Part 50, Appendix A, GDC 2. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.3.3 Onsite Meteorological Measurements Program

2.3.3.1 Introduction

In Section 2.3.3 of the PSAR, "Onsite Meteorological Measurements Program," the applicant presented information concerning the onsite meteorological measurements program that was in place to support the ESP application and is used to support the PSAR.

In PSAR Section 2.3.3, the applicant provided the following information:

- a description of meteorological instrumentation, including siting of sensors, sensor performance specifications, methods and equipment for recording sensor output, the quality assurance (QA) program for sensors and recorders, and data acquisition and reduction procedures
- hourly meteorological data, including consideration of the period of record (POR) and amenability of the data for use in characterizing atmospheric dispersion conditions

2.3.3.2 Regulatory Evaluation

In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the onsite meteorological measurements program are given in Section 2.3.3 of NUREG-0800 (NRC 2021-TN8013).

The applicable regulatory requirements for identifying onsite meteorological measurements program are as follows:

- 10 CFR 50.34(a)(1)(ii) (TN249), as it relates to providing a safety assessment of the site, including site evaluation factors identified in 10 CFR Part 100.

- 10 CFR 50.35, "Issuance of construction permits."
- 10 CFR 100.20(c)(2), with respect to the meteorological characteristics of the site that are necessary for safety analysis or that may have an impact upon plant design in determining the acceptability of a site for a nuclear power plant (TN423).
- 10 CFR 100.21(c), with respect to the meteorological data used to evaluate site atmospheric dispersion characteristics and establish dispersion parameters such that (1) radiological effluent release limits associated with normal operation can be met for any individual located offsite and (2) radiological dose consequences of postulated accidents meet prescribed dose limits at the exclusion area boundary (EAB) and the outer boundary of the low population zone (LPZ).
- 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," Principal Design Criterion (PDC 19), "Control Room," with respect to the meteorological considerations used to evaluate the personnel exposures inside the control room during radiological and airborne hazardous material accident conditions.
- Section IV.E.2 of 10 CFR Part 50, Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," with respect to the onsite meteorological information available for determining the magnitude and continuously assessing the impact of the releases of radiological materials to the environment during a radiological emergency.
- 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criteria," with respect to meteorological data used in determining the compliance with numerical guides for design objectives and limiting conditions for operation to meet the requirement that radioactive material in effluents released to unrestricted areas be kept as low as is reasonably achievable.
- 10 CFR Part 20, "Standards for Protection Against Radiation," Subpart D, "Radiation Dose Limits for Individual Members of the Public," with respect to the meteorological data used to demonstrate compliance with dose limits for individual members of the public (TN283).

The following RG is applicable to this section:

- RG 1.23, Meteorological Monitoring Programs for Nuclear Power Plants, Revision 1 (NRC 2007-TN278)

2.3.3.3 Technical Evaluation

Using the approaches and methodologies described in NUREG-0800, Section 2.3.3, the NRC staff reviewed the PSAR. The applicant used the pre-application onsite meteorological measurements program at the CRN Site to collect data and support the ESPA. This same data is used to support the PSAR.

2.3.3.3.1 Onsite Meteorological Measurements Program

2.3.3.3.1.1 Meteorological Measurements History

To support the CRN site ESPA, and subsequent CPA, the 110 m primary meteorological tower was reactivated to collect meteorological data at the 10 and 60 m levels from June 1, 2011, through May 31, 2013. This tower was originally operated to support the construction of the Clinch River Breeder Reactor Project. The 110 m primary tower used to collect this data was removed at the end of the observation period. A new tower will be installed to collect data during the CRN site operational phase, as stated in SSAR Section 2.3.3.1, "Meteorological Measurements History."

Primary Meteorological Facility

The applicant states in Section 2.3.3 of the PSAR that to support the operational phase, a new meteorological tower will be installed. This new tower and instrumentation will be designed to meet the requirements of RG 1.23.

2.3.3.4.1.2.1 Instrument Maintenance

This section of the PSAR did not contain any changes that impact the safety findings made in the approved ESPA. Therefore, the staff did not perform further evaluation of the information for this report.

2.3.3.4.1.2.2 Data Collection and Analysis

This section of the PSAR did not contain any changes that impact the safety findings made in the approved ESPA. Therefore, the staff did not perform further evaluation of the information for this report.

Operational Meteorological Program

In SSAR Section 2.3.3.3, "Operational Meteorological Program," the applicant stated that a new tower will be installed to collect data during the CRN site operational phase and the resulting meteorological program will be consistent with the guidance given in RG 1.23. The meteorological monitoring system used to collect onsite measurements for the ESPA was dismantled and removed after collecting the necessary data.

2.3.3.4 Conclusion

The staff has reviewed the information provided in the PSAR and the referenced CRN-1 ESP SSAR and, for the reasons given above, concludes that the applicant has established consideration of the onsite meteorological monitoring program and the resulting database, which are acceptable and meet the requirements of 10 CFR 100.20 and 10 CFR 100.21, PDC 19, 10 CFR Part 20, and Appendices E and I to 10 CFR Part 50 with respect to determining the acceptability of the site. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.3.4 Short-Term (Accident) Diffusion Estimates

In PSAR Section 2.3.4, the applicant presented this specific information on atmospheric dispersion estimates for postulated accidental airborne releases of radioactive effluents to the EAB and the outer boundary of the LPZ:

- an atmospheric transport and diffusion model to calculate dispersion estimates (atmospheric dispersion factors, relative concentrations, or χ/Q values) for postulated accidental radioactive releases,
- meteorological data summaries used as input to this dispersion model,
- diffusion parameters,
- determination of χ/Q values used for assessment of consequences of postulated radioactive atmospheric releases from design-basis accidents.

2.3.4.1 Introduction

Short-term dispersion estimates are used to determine the amount of airborne radioactive materials expected to reach a specific location during an accident situation. These dispersion estimates address the requirement for conservative atmospheric dispersion (relative concentration) factor (χ/Q value) estimates at the EAB and at the outer boundary of the LPZ for postulated design-basis accidental radioactive airborne releases.

2.3.4.2 Regulatory Evaluation

The acceptance criteria associated with the relevant requirements of the Commission regulations for local meteorology are given in Section 2.3.4 of NUREG-0800 (NRC 2021-TN8013).

The applicable regulatory requirements for identifying local meteorology are:

- 10 CFR 50.34(a)(1)(ii)(D) with respect to an assessment of the plant design features intended to mitigate the radiological consequences of accidents, which includes consideration of site meteorology, to evaluate the offsite radiological consequences at the EAB and LPZ (TN249).
- 10 CFR Part 50, Appendix A, PDC 19, "Control Room," with respect to the meteorological considerations used to evaluate the personnel exposures inside the control room during radiological and airborne hazardous material accident conditions.
- 10 CFR 100.21(c)(2), with respect to the atmospheric dispersion characteristics used in the evaluation of EAB and LPZ radiological dose consequences for postulated accidents (TN282).

2.3.4.3 Technical Evaluation

PSAR section 2.3.4 contained one minor change to replace a reference to RG 1.206 in section 2.3.4.2 of the ESP SSAR with a reference from NUREG-0800. This change from the previously approved ESPA did not result in the need for any additional analysis and therefore the staff did not have to perform an updated safety review for this report..

2.3.4.4 Conclusion

Based on the meteorological data provided by the applicant in the PSAR, the referenced Clinch River ESP SSAR, and an atmospheric dispersion model that is appropriate for the characteristics of the site and release points, the staff concludes that the applicant's atmospheric dispersion estimates continue to be acceptable and meet the relevant requirements of 10 CFR 100.21(c)(2). This conclusion is based on the conservative assessments of post-accident atmospheric dispersion conditions that have been made by the applicant and the staff from the applicant's meteorological data and appropriate diffusion models. These atmospheric dispersion estimates are appropriate for the assessment of consequences from (1) radioactive releases for DBAs in accordance with 10 CFR 50.34(a)(1)(ii)(D) and 10 CFR 100.21(c)(2) and (2) onsite and offsite releases of radiological and hazardous materials in accordance with PDC 19. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.3.5 Long-Term (Routine) Diffusion Estimates

2.3.5.1 Introduction

Long-term dispersion estimates are used to determine the amount of airborne radioactive materials expected to reach a specific location during normal operations. These dispersion estimates address the requirement concerning atmospheric dispersion and dry deposition estimates for routine releases of radiological effluents to the atmosphere.

2.3.5.2 Regulatory Evaluation

The acceptance criteria identified in NUREG-0800 (NRC 2021-TN8013), Section 2.3.5 for calculating atmospheric dispersion estimates for routine releases of radiological effluents are based on meeting the relevant requirements of 10 CFR Part 50 and 10 CFR Part 100. The NRC staff considered the following regulatory requirements when reviewing the applicant's calculation of atmospheric dispersion estimates for routine releases of radiological effluents:

- 10 CFR 50.34(a)(1)(ii) (TN249), as it relates to providing a safety assessment of the site, including site evaluation factors identified in 10 CFR Part 100.
- 10 CFR 50.35, "Issuance of construction permits."
- 10 CFR 100.20(c)(2) (TN282), as it relates to the requirement that the meteorological characteristics of the site that are necessary for safety analysis or that might have an impact on plant design be identified and characterized as part of the staff's review of the acceptability of a site
- 10 CFR 100.21(c)(1), as it relates to the requirement that site atmospheric dispersion characteristics be evaluated and dispersion parameters established to ensure that radiological effluent release limits associated with normal operation from the type of facility to be located at the site can be met for any individual located offsite

Characterization of atmospheric transport and diffusion conditions is necessary for estimating the radiological consequences of routine releases of radioactive materials to the atmosphere in order to demonstrate compliance in the COLA, with the numerical guides for doses contained in 10 CFR Part 50, Appendix I.

These RGs apply to this section:

- RG 1.23, Revision 1 (NRC 2007-TN278), which provides criteria for establishing and operating an acceptable onsite meteorological measurements program for the collection of basic meteorological data needed to support plant licensing and operation.

- RG 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I*, Revision 1, as it relates to calculating offsite doses (NRC 1977-TN90).

- RG 1.111, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors*, Revision 1, as it relates to calculating offsite doses (NRC 1977-TN91).

The related acceptance criteria from NUREG-0800, Section 2.3.5 are as follows:

- a detailed description of the atmospheric dispersion and deposition models used by the applicant to calculate annual average concentrations in the air and the amount of material deposited as a result of routine releases of radioactive materials to the atmosphere

- a discussion of atmospheric diffusion parameters, such as vertical plume spread (σz), as a function of distance, topography, and atmospheric conditions

- meteorological data summaries (onsite and regional) used as input to the dispersion and deposition models

- points of routine release of radioactive material to the atmosphere, including the characteristics (e.g., location and release mode) of each release point

- the specific location of potential receptors of interest (e.g., the nearest vegetable garden, nearest resident, nearest milk animal, and nearest meat cow in each 22½-degree direction sector within a 5 mi radius of the site)

- the χ/Q and D/Q values to be used for assessment of the consequences of routine airborne radiological releases as described in RG 1.206, Section 2.3.5.2: (1) maximum annual average χ/Q values and D/Q values at or beyond the site boundary and at specified locations of potential receptors of interest using appropriate meteorological data for each routine venting location and (2) estimates of annual average χ/Q values and D/Q values for 16 radial sectors to a distance of 50 mi (80 km) from the plant using appropriate meteorological data

2.3.5.3 Technical Evaluation

PSAR Section 2.3.5 contained one minor change to replace a reference to RG 1.206 in section 2.3.5.2 of the ESP SSAR with a reference from NUREG-0800. This change from the previously approved ESPA did not result in the need for any additional analysis and therefore the staff did not have to perform an updated safety review for this report.

2.3.5.4 Conclusion

Based on the meteorological data provided by the applicant in the PSAR, the referenced Clinch River ESP SSAR, and an atmospheric dispersion model that is appropriate for the characteristics of the site and release points, the staff concludes that representative atmospheric dispersion and deposition factors have been calculated for 16 radial sectors from the site boundary to a distance of 50 mi (80 km) as well as for specific locations of potential receptors of interest from the site. The characterization of atmospheric dispersion and deposition conditions is acceptable to meet the criteria described in RG 1.111 and is appropriate for the evaluation to demonstrate compliance with the numerical guides for doses contained in Subpart D of 10 CFR Part 20 and Appendix I to 10 CFR Part 50. The staff also finds that the applicant has established acceptable site characteristics and design parameters that meet the requirements of 10 CFR 100.20(c)(2) and 10 CFR 100.21(c)(1). Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.4 Hydrologic Engineering

2.4.1 Introduction

PSAR Section 2.4 describes safety-related hydrologic site characteristics, including external hazards associated with flooding, low water, ice effects, groundwater, and radionuclide transport in surface and ground water. Most of these hazards at the site were previously evaluated and approved in the ESP FSER and thus are considered to have finality. The PSAR supplements that review by providing updated, site-specific information on local intense precipitation flooding, groundwater conditions, and radionuclide transport in water following construction.

The PSAR hydrology section also addresses four COL Action Items carried forward from the ESP: site grading and stormwater management (Action Item 2.4-1), flood protection (Action Item 2.4-2), and groundwater and radwaste transport controls (Action Items 2.4-3 and 2.4-4). Additional details are provided in PSAR Section 2.4. Because PSAR Sections 2.4.12 and 2.4.13 present new analyses of groundwater behavior and radionuclide transport, the staff's review focuses on these areas.

2.4.1.1 Regulatory Evaluation

The acceptance criteria for identifying hydrologic site characteristics are based on compliance with the applicable requirements of 10 CFR Parts 50, 52, and 100. The staff's review considered the following:

- 10 CFR 50.34(a)(1)(ii) (TN249), as it relates to a description and safety assessment of the site, including site evaluation factors identified in 10 CFR Part 100.
- CFR 50.35, "Issuance of construction permits."
- 10 CFR 100.20(c)—requiring identification and characterization of hydrologic site features necessary for safety analysis or that could affect plant design (TN282).
- 10 CFR 100.21(d)—requiring evaluation of physical site characteristics, including hydrology, to ensure potential hazards pose no undue risk to the type of facility proposed to be located at the site.

- 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena"—requiring that safety-related SSCs be designed to withstand floods and other natural phenomena without loss of safety function.

- 10 CFR Part 20, Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," with respect to effluent concentrations and the unity rule (TN283).

In addition, the staff's review considered the following guidance:

- NUREG-0800 (NRC 2021-TN8013), Standard Review Plan (SRP) Sections 2.4.1–2.4.14, "Hydrologic Engineering"; Section 11.2, "Liquid Waste Management System"; and Branch Technical Position (BTP) 11-6, "Postulated Radioactive Releases Due to Liquid-Containing Tank Failures."

2.4.1.2 Hydrologic Description and Technical Evaluation

PSAR Section 2.4.0 states that a single BWRX-300 SMR, developed by GEH, is planned for CRN-1. A final grade elevation of 814.5 ft North American Vertical Datum of 1988 (NAVD88) (mean sea level) will be established to provide flood protection for Safety Class 1 (SC1) SSCs. The Clinch River will not supply SC1 water systems but will provide makeup water for the cooling tower serving the normal heat sink. The staff reviewed the information in PSAR Sections 2.4.0 and 2.4.1 and found that the information in the application acceptably addressed the requirements related to hydrologic site characterization.

2.4.1.3 Floods

Local Intense Precipitation (LIP) Flooding

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Other Flooding Mechanisms

For all other flooding mechanisms (i.e., riverine flooding, dam failure, storm surge, tsunami, ice effects, and channel diversion), TVA adopted the ESP hazard estimates without modification. PSAR Section 2.4.2.2 states that river flood levels, including waves generated by landslides or seiches, would remain below the site grade with adequate margin. The Clinch River will continue to serve as the source of cooling tower makeup water. The staff reviewed the river flood information provided in the PSAR and finds that TVA's approach and data in the PSAR are valid and acceptable.

Flood Protection

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2.4.1.4 Low Water

PSAR Section 2.4.11 addresses the potential effects of low-water conditions on safe plant operation and shutdown. TVA stated that the Clinch River arm of the Watts Bar Reservoir will serve as the water supply source for non-SC1 SSCs, including normal plant cooling, demineralized water supply, and the liquid radwaste treatment system. Water for these systems will be supplied from a pump intake structure located in the reservoir downstream of Melton Hill Dam.

To assess water availability, TVA evaluated potential reservoir depletion below the winter/normal minimum pool elevation using the stage–storage rating curve, in conjunction with conservative assumptions for plant demand, inflows, and outflows. The long-term average weekly discharge from Melton Hill Reservoir is approximately 4,800 cubic feet per second (cfs), which substantially exceeds the CRN-1's projected demand of 28.5 cfs. Based on this evaluation, TVA concluded that available reservoir storage, combined with minimum required dam releases during drought conditions, would provide adequate water supply for plant operations and for other users. TVA further stated that the non-SC1 water supply is not susceptible to low-water conditions caused by surges, seiches, tsunamis, dam failures, or other external hydrologic events.

The staff reviewed the new and additional information provided in the PSAR on the potential effects of low-water conditions on safe plant operation and shutdown, and confirmed that the Watts Bar Reservoir, a non-safety-related water supply source, has adequate capacity to support safe operation and shutdown of CRN-1 under severe drought conditions. Based on this review, the staff finds TVA's consideration of low-water conditions acceptable, as the evaluations incorporate appropriate analyses with sufficient conservatism and margin, consistent with the requirements of 10 CFR 100.20(c).

2.4.1.5 Groundwater

PSAR Section 2.4.12 provides information regarding groundwater conditions at the CRN site. TVA stated that the plant will not rely on groundwater for cooling, potable water, or other operational needs and that there are no active or anticipated groundwater users at or near the plant site. TVA reported that groundwater generally flows southward from the plant site toward the Clinch River, with the shortest flow path from the site boundary to the river being approximately 1,200 ft. The estimated advective groundwater travel time along this pathway is approximately 308 days (0.84 years).

Appendix 2.4.12C, "Groundwater Flow Model," describes the site's hydrogeologic framework, consisting of fill, residual soil, weathered bedrock (regolith), and shallow competent bedrock that behaves as a porous medium. The lower shear zone is composed of calcite-filled and cemented fractures that are healed and, therefore, not expected to provide secondary porosity or preferential flow paths. The RB foundation will be embedded approximately 130 ft below grade. To support the hydrogeologic analysis, TVA conducted aquifer pumping tests at eight wells to estimate transmissivity, storage coefficients, and hydraulic conductivity values.

For the ESP application, TVA developed post-construction groundwater models to evaluate groundwater behavior at the site using two-dimensional vertical profile models (Profiles A and C) implemented with MODFLOW-SURFACT, Version 3.0. During the ESP review, the staff reviewed and approved TVA's groundwater modeling. For the CPA, TVA updated the groundwater model to reflect the revised plant site location, applying a uniform recharge rate of 8.9 inches per year and a hydraulic conductivity of 1.5 ft per day for construction fill.

The staff reviewed the groundwater evaluation in Appendix 2.4.12C of the PSAR, including the hydrogeologic assumptions, boundary conditions, recharge estimates, and hydraulic property values, and verified that the model appropriately represents site conditions. The staff compared the model results with site-specific data, such as aquifer test results and observed groundwater levels, and finds the analysis reasonable and consistent with the guidance in SRP Section 2.4.12 and accepted hydrogeologic practices. The staff confirmed that predicted groundwater levels will not adversely affect safety-related SSCs, including the RB foundation. Therefore, the staff determined the applicant's groundwater evaluation is acceptable because the site characteristics related to the maximum groundwater level demonstrate compliance with the guidance in SRP Section 2.4.12.

Dewatering

PSAR Section 2.4.12C.7 states that excavation for the RB will extend approximately 129.5 ft below grade, which is far below the groundwater table and about 50 ft below the low-water level of the Clinch River. TVA proposed to backfill with lean concrete between the excavation depth and the bottom of the basemat. TVA does not propose a permanent dewatering system but will use temporary dewatering during construction to maintain a dry excavation and ensure foundation stability. The proposed methods include horizontal gravity drains, sump pumping, and cement grouting. Groundwater extraction impacts will be monitored using a network of observation wells and, if necessary, nearby stream gauges.

In its exemption request (TVA 2023-TN10326), TVA provided additional details on excavation and dewatering controls. These include:

- installation of ground support systems (e.g., rock bolts, wire mesh, drains, pressure grouting), with additional support such as steel beams or reinforced concrete rings,

- compliance with ESP-006 permit condition #4, requiring removal of unsuitable material above the foundation level and investigation of geologic features that could affect stability,

- collection of geotechnical and hydrogeologic data during excavation to confirm that early construction activities do not pose undue risk to public health and safety, and

- a conceptual excavation plan describing excavation method, temporary dewatering systems, anticipated impacts, and approaches for construction support and stabilization.

TVA concluded that these measures would ensure that excavation and temporary dewatering activities do not pose an undue risk to public health and safety.

The staff reviewed the applicant's submittals in accordance with NUREG-0800 SRP Section 2.4.12. TVA identified the excavation depth relative to the groundwater table and river levels and described temporary dewatering methods to maintain excavation stability. The staff finds that the proposed drainage, sump pumping, and grouting methods are consistent with standard industry practices for controlling groundwater inflow during deep excavations, and that the proposed dewatering plan meets the acceptance criteria specified in SRP Section 2.4.12.

The staff also reviewed the associated exemption request (TVA 2023-TN10326) referenced in the CPA and confirms that the proposed dewatering plan (including physical ground support systems, monitoring excavation conditions, and removing unsuitable material) is consistent with and carried out in accordance with ESP-006 permit conditions. These measures provide assurance that groundwater inflow and hydrostatic pressures will be controlled and that the stability of safety-related foundations will be maintained during construction.

Based on the staff's review, as discussed above, the staff finds that the applicant has adequately addressed dewatering requirements during construction. The proposed temporary dewatering methods, monitoring commitments, and excavation meet the acceptance criteria specified in SRP Section 2.4.12. Therefore, the staff determines that the applicant's approach to dewatering is acceptable.

Variances from ESP

PSAR Enclosure 3 includes three variances from the ESPA related to groundwater:

- CRN ESP VAR 2.0-2—Groundwater Level: TVA requested approval to use a maximum groundwater level of 814.5 ft for foundation structures in the power block area, rather than the 816.1 ft level identified in the ESPA. TVA supported this variance with updated modeling that incorporated more recent site data and updated software.

- CRN ESP VAR 2.4.12-1—Groundwater Levels Model: TVA requested approval to use the proposed design for pre- and post-construction groundwater modeling in place of the plant parameter envelopment conceptual design used in the ESP.

- CRN ESP VAR 2.4.12C-1—Groundwater Vistas Software: TVA requested approval to use Groundwater Vistas Version 8.19, Build 4, rather than Version 6.07, Build 10, used in the ESPA.

The staff reviewed the applicant's justification for each variance against the guidance in NUREG-0800 Section 2.4.12 and RG 1.206. For VAR 2.0-2, the staff evaluated TVA's updated groundwater modeling. The staff notes that the revised maximum groundwater level of 814.5 ft is consistent with the final plant grade elevation and reflects a more accurate parameter for foundation design. For VAR 2.4.12-1, the staff notes that replacing the ESPA conceptual design with the proposed plant design provides a more realistic assessment of pre- and post-construction groundwater conditions. The staff verifies that the modeling framework, boundary conditions, and hydrogeologic assumptions are consistent with accepted practice and demonstrate compliance with the guidance in SRP Section 2.4.12. For VAR 2.4.12C-1, the staff confirms that the updated Groundwater Vistas Version 8.19 incorporates improved numerical capabilities and produces more reliable results for simulating site-specific hydrogeologic conditions compared to the version used in the ESPA.

Based on its review, the staff determines that the applicant has provided sufficient technical justification for the three groundwater-related variances. Collectively, these variances are consistent with accepted practice and demonstrate compliance with the guidance in SRP Section 2.4.12. Therefore, the staff determines that the applicant's approach to groundwater-related variances in the CPA is acceptable.

2.4.1.6 Accidental Releases of Liquid Effluents to Water

PSAR Section 2.4.13 evaluates the potential for accidental releases of radioactive liquid effluents to surface and groundwater at the plant site. In accordance with SRP BTP 11-6, TVA postulated a tank failure as the initiating event. TVA selected the RWST, with a capacity of 165,000 gallons and an inventory of approximately 2.43×10^3 curies of unprocessed reactor coolant, as the bounding source term. They assumed an instantaneous release of 80 percent of the tank volume to the groundwater.

TVA modeled radionuclide transport using a conceptual site model, identified the nearest potential receptor at the Clinch River right bank, and compared the estimated concentrations and doses at this receptor with the acceptance criteria outlined in BTP 11-6 and 10 CFR Part 20, Appendix B. The applicant's conceptual site model assumes radionuclide migration from the RWST through construction fill and shallow fractured bedrock to the Clinch River. The shortest modeled distance is approximately 1,200 ft, with an estimated advective travel time of 308 days. TVA concluded that this scenario provides adequate decay time, resulting in concentration and dose well below regulatory limits (0.62 mrem versus 100 mrem).

Conceptual Site Model

During its review, the staff evaluated TVA's primary conceptual site model for radionuclide transport in water, based on the shortest groundwater flow path from the southern edge of the plant boundary to the Clinch River (~1,200 ft). The staff reviewed the applicant's methodology, assumptions, and results against SRP Section 2.4.13 and BTP 11-6. The staff also reviewed site hydrogeology, topographic data, and hydrogeologic figures in the PSAR. PSAR Figure 2.4.12C-19 shows potential upward groundwater flow into an unnamed pond. This suggests that effluent could enter the pond before reaching the river. Therefore, the staff considered an alternative site model in which radionuclide effluent from the RWST at the north end of the power block area travels through groundwater to this pond (~550 ft long) and then flows about 600 ft over surface water to the right bank of the Clinch River (see Figure 2.4-1). In this pathway, effluent would travel roughly 1,200 ft through groundwater to reach the pond. Groundwater contour maps (PSAR Figures 2.4.12-20R through 2.4.12-28R) show the flow may first trend southeast and then turn south. For conservatism, the staff assumes a straight-line path as shown in PSAR Figure 2.4-1. While this pathway is more realistic, it is bounded by the applicant's primary conceptual site model, which uses a shorter path and therefore a shorter travel time. The travel time through the surface water portion is much shorter than through groundwater (days versus years). As a result, this alternative pathway would still produce doses well within regulatory limits, consistent with the primary conceptual site model.

Based on this review, the staff finds that the applicant has adequately evaluated the conceptual site model, including consideration of different pathways, for analyzing accidental releases of liquid effluents to groundwater at the CPA site. The staff finds that the analysis demonstrates compliance with the guidance in SRP Section 2.4.13 and BTP 11-6. Therefore, the staff determines that the applicant's analysis of radionuclide transport in groundwater in the CPA is acceptable.

Radionuclide Concentration and Dose in Water

TVA conducted a radionuclide transport analysis to estimate concentrations and doses at a receptor located outside the site boundary. The analysis began with a conservative screening model and was refined using more realistic approaches. Groundwater transport and reservoir dilution were modeled analytically, consistent with methods previously reviewed and approved by the staff in the ESP FSER. TVA estimated minimum dilution factors and maximum radionuclide concentrations at the receptor point, accounting for decay, advection, dilution, and sorption. Distribution coefficients (K_d values) were consistent with those previously reviewed and approved in the ESP FSER. None of the estimated concentrations exceeded the effluent concentration limits, and the sum of concentration-to-effluent concentration limit ratios was 0.0434, far below unity, demonstrating compliance with 10 CFR Part 20. Using the LAPTAP II model, TVA calculated a total effective dose equivalent (TEDE) of 0.62 mrem to an adult, well below the 100 mrem limit specified in 10 CFR 20.1301.

The staff reviewed TVA's analysis against the guidance in SRP Sections 2.4.13 and 11.2, and BTP 11-6, and makes the following findings:

- Source Term: TVA conservatively summed parent and progeny inventories without reducing parent activity, overestimating total activity and resulting in conservative concentration and dose estimates. The staff concludes this methodology is acceptable.

- Radionuclide Concentrations: The staff performed spot checks of peak radionuclide concentrations in PSAR Table 2.4.13-1R, focusing on progeny species. Using the U.S. EPA Radionuclide Decay Chain Calculator (EPA 2020-TN13249), staff verified TVA's estimates. Differences in progeny peak concentrations were minor (approximately 0.024 curies [Ci], which is significantly less than the total peak inventory of 2,620 Ci) (see Table 2.4.13-1R of PSAR), demonstrating that TVA's estimates are reasonable and acceptable.

- Doses and Compliance: The staff confirmed that the applicant's modeling conservatively bounds potential doses to the public. Both the unity rule, described in Appendix B to 10 CFR Part 20, and the 100 mrem TEDE limit are met with substantial margin.

The staff performed a confirmatory analysis of radiological decay for progeny species using the validated ORNL method (EPA 2020-TN13249). The ORNL method is a reliable modeling approach that is more accurate than simple LAPTAP-based calculations because it simulates changing concentrations of multiple isotopes over time and accounts for radioactive decay, neutron transmutation, and fission in a nuclear reactor. The staff confirms that TVA's concentration estimates differ only slightly from the staff's calculations, and the differences are minor. TVA's radionuclide transport analysis is consistent with regulatory requirements and guidance, including BTP 11-6, Appendix B to 10 CFR Part 20, and 10 CFR 20.1301. Therefore, the staff concludes that the applicant's radiological consequence analysis is acceptable.

2.4.1.7 Technical Specifications and Emergency Operation Requirements

TVA stated that no emergency protective measures are required to minimize the impact of hydrology-related events on SC1 SSCs; consequently, none are included in the plant's technical specifications or emergency operating procedures. This is because the proposed design does not use an SC1 cooling water source from the Clinch River arm of the Watts Bar Reservoir. After reviewing the potential hydrologic hazards, including flooding and low-water conditions, and their impacts on the proposed plant as discussed in PSAR Section 2.4, the staff determines that the effects of hydrologic hazards on SC1 facilities are minimal. Therefore, the staff concurs with TVA's determination that technical specifications and emergency requirements for hydrologic hazards are not necessary.

2.4.2 Conclusion

Based on its review of the PSAR, the staff confirmed that the applicant successfully demonstrated that the hydrologic characteristics of the CRN Site pose no safety-related impact. The applicant provided sufficient information regarding groundwater (PSAR Section 2.4.12) and radionuclide transport in surface and ground water (Section 2.4.13) and considered historical natural phenomena with sufficient margin to establish acceptable hydrologic site characteristics for design purposes. The staff therefore concludes that the applicant has met the relevant requirements in Appendix B to 10 CFR 20; GDC 2; 10 CFR 100.20(c); and 10 CFR 100.23(d). Additionally, the applicant addressed COL Action Items 2.4-3 and 2.4-4 and applicable variances from the ESPA, while COL Action Items 2.4-1 and 2.4-2 will be addressed during the OL stage. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.5 Geology, Seismology, and Geotechnical Engineering

PSAR Section 2.5 provides new and updated information on the seismological and geological characteristics of the site and surrounding region to permit an analysis of the proposed site for load bearing capability and seismic activity. The application follows the format of NUREG-0800 (NRC 2021-TN8013), and as such the PSAR includes the following sections:

- 2.5.1, "Geologic Characterization Information"
- 2.5.2, "Vibratory Ground Motion"
- 2.5.3, "Surface Deformation"
- 2.5.4, "Stability of Subsurface Materials and Foundations"
- 2.5.5, "Stability of Slopes"

Regulatory Evaluation

The acceptance criteria for identifying site characteristics pertaining to geology, seismology, and geotechnical engineering are based on compliance with the applicable requirements of 10 CFR Parts 50 and 100. The applicable regulatory requirements related to geology, seismology, and geotechnical engineering are as follows:

- 10 CFR 50.34(a)(1)(ii) requires a description and safety assessment of the site on which the facility is to be located (TN249)
- 10 CFR 50.35, "Issuance of construction permits."
    -
- 10 CFR 100.21(d) and 10 CFR 100.23 require the applicant to describe the seismological and geological characteristics of the site (TN282).
- 10 CFR 100.23(d)(1) requires that the safe shutdown earthquake (SSE) ground motion for the site be characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface.
- 10 CFR 50 Appendix S, Section IV(a)(i) requires the horizontal SSE at the foundation level of the structures to be an appropriate response spectrum with a peak ground acceleration of at least 0.1 g.

The applicable guidance for the evaluation of geology, seismology, and geotechnical engineering of the site can be found in NUREG-0800 Section 2.5.1 through 2.5.5 and in the following documents:

- RG 1.208, A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion" Revision 0, March 2007 (NRC 2007-TN5858)

- NUREG-2115, Central and Eastern U.S. Seismic Source Characterizations for Nuclear Facilities, (NRC 2012-TN3810)

- NUREG-2213, Updated Implementation Guidelines for SSHAC Hazard Studies, October 2018 (NRC 2018-TN13288)

- RG 1.132, Site Investigations for Foundations of NPPs, Revision 3, December 2021 (NRC 2021-TN13247)

- RG 1.138, Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants, Revision 3, December 2014 (NRC 2014-TN5903)

- RG 1.198, Procedures and Criteria for Assessing Seismic Soil Liquefaction at NPP Sites, Revision 0, November 2003 (NRC 2003-TN5906)

In accordance with 10 CFR 50.34(a)(1)(ii), 10 CFR 100.21(d), and 10 CFR 100.23, the applicant should provide sufficient information on the seismological and geological characteristics of the site and surrounding region to permit an analysis of the proposed site for load bearing capability and seismic activity. This analysis should include derivation of the site-specific ground motion response spectrum (GMRS) and support analysis of the structures and seismic effects on SSCs at the proposed site. The GMRS is determined based on the geological, seismological, and engineering characteristics of the site and its environs. The size of the region to be investigated and the type of data pertinent to the investigations is described in RG 1.208 and should be determined based on an initial evaluation of the regional seismic hazards and their potential impact on the proposed facility. The applicant should summarize the relevant studies describing the site, the investigations performed, and the investigation results and conclusions. Detailed geological information should be documented in a separate report that is available for the staff to audit.

2.5.1 2.5.1 Geologic Characterization Information

PSAR Section 2.5.1 summarizes the geologic characterization information developed from a series of site investigations by TVA and its contractors, including for the Clinch River Breeder Reactor, site investigations performed to support development of the SSAR for the ESP application, and the supplemental 2023 site investigations conducted to support the selected design for the CPA. Updates to this PSAR section from the Clinch River Nuclear Site ESP site investigations were augmented based on the applicant's 2023 site investigations and geologic events or information obtained subsequent to the ESP issuance.

The staff reviewed PSAR Section 2.5.1.1.4.3.2, which describes new information characterizing the Dandridge-Vonore Fault Zone (DVFZ) within the Eastern Tennessee Seismic Zone (ETSZ). The staff noted that the applicant concluded that the results of ongoing studies of paleoseismic studies are preliminary and do not indicate that the DVFZ significantly increases the hazard at the nearby Y-12 location and there is not sufficient evidence to treat the ETSZ as a repeated large magnitude (RLME) seismic source within the seismic source characterization model. The staff reviewed this new information against the acceptance criteria and determined that the applicant adequately characterized the geologic characteristics of the DVFZ based on available information and associated paleoseismic studies to support the conclusion that this is not an RLME to be included in the seismic source characterization model.

The staff reviewed the description of the karst evaluation of the proposed site in PSAR Section 2.5.1.2.3.4. The applicant noted that the distribution of cavities was consistent with identified trends. However, the staff noted that the most recent 2023 site investigations identified only two dissolution features greater than 0.1 ft—one in the Witten Formation and one in the Rockdell Formation. The staff confirmed this with the information provided in PSAR Section 2.5.1.2.6.5. The staff noted that dissolution features larger than 0.1 ft were not encountered in the foundation-bearing Benbolt Formation at the CRN Site.

The staff reviewed PSAR Section 2.5.1.2.4.3.4, which describes the shear fracture zones encountered in the subsurface of the site, particularly within the Benbolt and Rockdell Formations, with one occurrence noted in the Witten Formation. The applicant noted that geologic mapping of the power block area during excavation would further characterize any shear fracture zones with respect to rock mass assessment for bearing capacity. Additionally, the staff noted that PSAR Section 2.5.1.2.6.10 indicates that TVA plans to conduct detailed geologic mapping of the excavation walls during construction to document any near-surface dissolution features and verify any changes in cavity size and abundance with depth. The applicant further stated that the NRC staff would be notified when excavations are open for inspection.

The staff previously identified the need to perform geologic mapping of the foundation-level materials as part of the ESP review. This was included as Permit Condition 3 in the referenced ESP, which requires:

> An applicant for a COL or CP that references this ESP shall perform detailed geologic mapping of excavations for safety-related engineered structures; examine and evaluate geologic features discovered in those excavations; and notify the Director of the Office of

> Nuclear Reactor Regulation, or the Director's designee, once excavations for safety-related structures are open for examination by NRC staff.

The staff recommends that this permit condition from the ESP be included in this CP and be revised as follows.

> TVA shall perform detailed geologic mapping of the excavations for the safety-related engineered structures; examine and evaluate the geologic features discovered in those excavations; and, once geologic mapping information from the excavations for safety-related structures is available for examination by the NRC, notify the Director of the Office of Nuclear Reactor Regulation, or the Director's designee, as specified in 10 CFR 50.4.

The staff also reviewed PSAR Section 2.5.1.2.5.2.1, which describes a subsurface petroleum feature that was encountered in one of the groundwater observation wells installed as part of the ESP geotechnical exploration. The staff reviewed the applicant's explanation that the petroleum product was a naturally occurring hydrocarbon in the lower portion of the Benbolt Formation at a depth of approximately 320 ft below the ground surface. Four boreholes from the 2023 site investigations observed petroleum in the rocks of the Rockdell Formation or the base of the Benbolt Formation. The applicant noted that the presence of naturally-occurring crude is a mitigatable issue that can be planned for during construction and operation of an SMR at the proposed site. The staff noted that the applicant would consult with excavation and blasting subcontractors to determine a remedy and path forward if petroleum contamination is detected.

The staff has reviewed the available information provided in the PSAR and the referenced Clinch River Nuclear Site ESP SSAR and, for the reasons given above, concludes that the applicant has investigated the geological characteristics of the site and its environs in sufficient scope and detail to permit an adequate evaluation, is acceptable and meets the requirements of 10 CFR Part 50, Appendix A; GDC 2; and 10 CFR 100.23. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.34(a)(1)(ii) and 10 CFR 50.35.

2.5.2 Vibratory Ground Motion

This section describes TVA's updated GMRS, developed for the ESPA to incorporate the requirements for the selected technology and layout at the location of CRN-1 the CRN Site. Specifically, the CPA describes the development of performance-based surface response spectra (PBSRS), performance-based in-structure response spectra (PBIRS), and foundation input response spectra (FIRS), instead of GMRS. To develop the PBSRS, PBIRS, and FIRS, the applicant decided to revise the ESPA probabilistic seismic hazard analysis (PSHA) and site response calculations to incorporate new information and approaches. The staff's review of PSAR Section 2.5.2 therefore focuses on TVA's revisions and updated results and conclusions.

2.5.2.1 Seismicity

For the CRN Site ESPA, TVA developed a catalog consisting of the earthquake catalog published as part of the CEUS-SSC model (NUREG-2115), which included an update from the beginning of 2009 through mid-September 2013. In PSAR Section 2.5.2.1, the applicant determined that the ESP seismicity catalog required an additional update and adopted the earthquake catalog that was developed as part of the PSHA for the Y-12 National Security Complex (Y-12), which is provided in PSAR table 2.5.2-2R. The Y-12 study updated the earthquake catalog using the CEUS-SSC methodology to include events through December 23, 2018, which is provided in PSAR table 2.5.2-2R.

The seismicity catalog is used to determine M_{max} and recurrence parameters (i.e., a- and b-values) for characterization of seismic source zones (see SE Section 2.5.2.2). In PSAR Section 2.5.2.2.6.2, TVA referred to a statistical test performed as part of the Y-12 PSHA to determine whether new data in the earthquake catalog warranted recalculation of recurrence parameters for the distributed seismicity zones. Although the results of the test did not conclusively require recalculation of the recurrence parameters, the recurrence parameters were recalculated using the Y-12 updated catalog (following the CEUS-SSC methodology) for the distributed source zones that make significant contributions to the seismic hazard at the Y-12 site. In PSAR Section 2.5.2.4.3.1, TVA indicated that it used revised a- and b- values, based on the Y-12 updated catalog, for the following sources: Non-Mesozoic-and-Younger Extended prior-narrow (NMESE-N), Mesozoic-and-Younger Extended prior-wide (MESE-W), Study Region (STUDY-R), Paleozoic Extended Zone-Narrow (PEZ-N), Paleozoic Extended Zone-wide (PEZ-W), Mesozoic-and-Younger Extended prior-Narrow (MESE-N), Midcontinent-Craton alternative A (MIDC-A), Extended Continental Crust-Atlantic Margin (ECC-AM), Illinois Basin Extended Basement (IBEB), and Reelfoot Rift (RR).

In PSAR Section 2.5.2.1.3, TVA determined that it was not necessary to update the Y-12 earthquake catalog beyond 2018. The applicant based this determination on a recent SSHAC Level 2 PSHA study performed for ORNL; this study updated the CEUS-SSC catalog through July 2023 (LCI, 2024). Specifically, the ORNL study involved a comparison of the smoothed seismicity rates computed for the Y-12 project with post-Y-12 earthquake counts from the ORNL earthquake catalog, which indicated no significant changes in seismicity rates.

PSAR Section 2.5.2.1.4 also discusses significant site region earthquakes (i.e., E[**M**] 5.0 or greater occurring within 200 mi from the CRN Site), which included the August 9, 2020, Sparta earthquake, associated with the Little River Fault, located approximately 188 mi east-northeast of the CRN Site. The applicant concluded that future earthquakes associated with the Little River Fault are adequately represented by the CEUS SSC distributed seismicity source zones in which it is located. The staff determined that this conclusion is supported by the comparison of the smoothed seismicity rates for the Y-12 and updated ORNL catalogs (as summarized above).

The staff reviewed PSAR Section 2.5.2.1 and determined that the applicant followed an acceptable approach to compile the regional earthquake catalog. Specifically, the applicant used the methodology employed by the CEUS-SSC study (NUREG-2115). As part of its confirmatory analysis, the staff developed a supplementary earthquake catalog covering the CRN Site region from December 23, 2018, through December 31, 2025. The staff used the U.S. Geological Survey (USGS) National Earthquake Information Center earthquake catalog[1] for this analysis. As a result, the staff determined that the applicant's regional earthquake catalog adequately characterizes the seismicity of the 320 km region surrounding the CRN Site. Furthermore, the staff concludes that the seismicity catalog, as described by the applicant in PSAR Section 2.5.2.1, forms an adequate basis for the seismic hazard characterization of the site and meets the requirements of 10 CFR 100.23.

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1 National Earthquake Information Center (NEIC), NEIC Catalog Search, https://earthquake.usgs.gov/earthquakes/search/

2.5.2.2 *Seismic Source Characterization Model*

In PSAR Section 2.5.2.2.5, the applicant evaluated post -CEUS-SSC studies performed for other sites in the region. This evaluation resulted in several modifications to the CEUS-SSC model.

In PSAR Section 2.5.2.4.3.1, the applicant indicated that it used corrected M_{max} distributions from EPRI (Technical Report 3002005684, 2015) for the following sources: Paleozoic Extended Zone-Narrow, Paleozoic Extended Zone-Wide, Midcontinent-Craton Alternative A through IDC-D, Extended Continental Crust-Atlantic Margin, and Illinois Basin Extended Basement. The staff notes that this EPRI report documents an error that was identified in the published M_{max} distributions for several of the CEUS-SSC seismotectonic source zones. The report documents evaluations to assess the impacts on the recurrence parameters, PSHA, and GMRS at two sites in or near the zones with the greatest M_{max} changes. The results showed that there are negligible impacts on the recurrence parameter results as well as the calculated seismic hazard and GMRS. Furthermore, the report concluded that it was not necessary to incorporate the corrected M_{max} values into the CEUS-SSC model and published report. As such, the staff concludes that it is acceptable to include the updated M_{max} values.

Eastern Tennessee Seismic Zone

PSAR Section 2.5.2.2.5.1, the applicant discussed recent investigations performed for the ETSZ, which included several post CEUS-SSC paleoseismic studies. Based on its detailed review of these studies, which included Cox et al. (2022) and Thompson Jobe et al. (2024), the applicant concluded that the results of the ongoing paleoseismic studies in the ETSZ are preliminary and do not provide adequate evidence for defining the ages and repeat times of earthquakes and therefore do not provide adequate evidence for defining an RLME seismic source for the ETSZ. The staff also reviewed these recent references and agrees that the results of ongoing paleoseismic studies do not provide adequate evidence for defining an ETSZ RLME source.

New Madrid Seismic Zone

In the CEUS-SSC model, the New Madrid Seismic Zone (NMSZ) RLME is modeled by the following five RLME sources: the New Madrid Fault System (NMFS), Eastern Rift Margin-North (ERM-N), Eastern Rift Margin-South (ERM-S), Marianna, and Commerce Fault Zone (Commerce) sources. In PSAR Section 2.5.2.2.5.3.1, the applicant discussed several studies that provide relevant new information on the NMSZ and were used to update the NMSZ RLME sources for the CRN Site that will host CRN-1.

NMFS: The NMFS RLME consists of the New Madrid South fault, the New Madrid North fault, and the Reelfoot thrust. The applicant indicated that it made several modifications to the NMFS based on the USGS 2023 National Seismic Hazard Model (NSHM23), which is summarized in Thompson Jobe et al. (2024). This includes the following modifications as described in PSAR Section 2.5.2.2.5.3:

- Blytheville Arch fault name was changed to the Axial Fault (AF), and the fault was extended approximately 35 km to the southwest based on seismic reflection data.
- The short and long depictions of the Reelfoot Thrust fault source (RFT-S [Reelfoot Thrust-Short] and RFT-L [Reelfoot Thrust-Long]), respectively) are renamed to NMW [New Madrid

West] and Reelfoot faults, with minor changes to their geometries. The southeastern extent of the Reelfoot fault is moved to the southwest to align with new observations of deformed late Pleistocene terraces. In addition, a deviation from the NSHM23 included modification of the northwest end of the Reelfoot fault source so that it directly connects with the NMW source to allow for combined rupture on these two faults (because the PSHA software used for the CRN-1 Site does not allow ruptures to "jump" across fault discontinuities; the applicant indicated that this minor change is insignificant to hazard.

The applicant also evaluated numerous studies related to the M_{max} distribution for the NMFS RLME (i.e., Boyd and Cramer (2014), Cramer and Boyd (2014), Chung and Rogers (2015), Ramirez-Guzman et al. (2015)). The applicant concluded that no revisions to the CEUS-SSC are required to account for this new magnitude data because the new data fall within the range. The staff reviewed the referenced studies and confirmed the applicant's conclusion.

The applicant reviewed several new recurrence-related studies applicable to the NMFS (i.e., Page and Hough (2014), Craig and Calais (2014), Boyd et al., (2015), as well as new paleoseismic event ages provided in Tuttle et al. (2020), Gold et al. (2019). The applicant concluded that no changes were made to the recurrence of large magnitude earthquakes in the NMFS RLME. However, the applicant modified the weighting of the two alternative models for large-earthquake recurrence of the RLME source as originally characterized in the CEUS-SSC model. Specifically, the Poisson (time independent) model and the Brownian Passage Time or "renewal" (time-dependent) model were weighted 0.75 and 0.25 when on the "All In" branch. The applicant assigned equal weight to the Poisson and renewal models of time dependance for the "All In" branch and stated that "given the apparent quasi-periodic behavior of the NMFS over the last few earthquake cycles and the relatively fast loading rate implied by the high rate of earthquake occurrence, this increased weight to the renewal model is justified."

In response to audit question A-2.5-12, the applicant quantified the impact of the modifications to the NMFS RLME as summarized above. These modifications resulted in decreases in total rock hazard compared to the total rock hazard using the original CEUS-SSC characterization in NUREG-2115. Specifically, for respective annual exceedance frequencies (AFEs) of 10^{-4} and 10^{-5} the maximum observed decreases in spectral acceleration are 7.94 percent and 3.50 percent at 1 Hz. The applicant indicated that this change is largely attributable to the changes in weighting of the Poisson and renewal models (rather than due to the geometry changes). The staff did not perform a detailed evaluation of TVA's modifications to the NMFS due to the small impact that these changes had on total hazard at the CRN Site. The staff determined that TVA's modified NMFS is therefore acceptable to use as input to the CRN Site PSHA.

ERM-N and ERM-S: In PSAR Section 2.5.2.2.5.3.2 the applicant discussed changes to the geometries of the ERM-N and ERM-S source zones. These northeast-trending RLME sources are modeled as a narrow, elongated "fault-like" source zones in the CEUS-SSC model. Following the NSHM23, the applicant collapsed these polygonal source zones into fault sources with single traces, given the relatively good definition of the fault at the surface and at depth (i.e., Thompson Jobe et al. [2022] and Shumway et al. [2024]). In the NSHM23, the southern extent of the ERM-N source is also extended 12 km to the south. Names of the alternative southern extensions of ERM-S are Crittenden Country and River Picks. The River Picks name is changed to Meeman-Shelby in the NSHM23, and this new name is adopted for the CRN Site. In response to audit question A-2.5-13, the applicant quantified the geometry changes summarized above. These changes resulted in very small decreases in total rock hazard when compared to the total hazard using the original CEUS-SSC characterization in NUREG-2115. For the ERM-S, and for respective AFEs of 10^{-4} and 10^{-5}, the maximum observed decreases in spectral acceleration are 0.1 percent and 0.05 percent at 1 Hz. Decreases corresponding to the EMR-N are even smaller. The staff did not perform a detailed review of TVA's modifications to the ERM-N and ERM-S source zones as the staff determined that TVA's modifications are acceptable at the CRN Site due to the minimal impact of this source zone on total hazard.

Commerce: The applicant stated that in the CEUS-SSC model, this source is modeled as a northeast trending narrow, elongated "fault-like" source zone, which is "leaky" at both ends. The applicant collapsed this polygonal source zone to a fault source with a single 75-km-long trace given the relatively good definition of the fault at the surface and at depth following the NSHM23. In response to audit question A-2.5-14, the applicant quantified the geometry changes summarized above. These changes resulted in very small decreases in total rock hazard compared to the total rock hazard using the original CEUS-SSC characterization in NUREG-2115. A maximum observed decrease in spectral acceleration of 0.02% and 0.01% is observed at 1 Hz for AFEs of 10^{-4} and 10^{-5}, respectively. The staff did not perform a detailed review of TVA's modifications to the Commerce source zone as the staff determined that TVA's modifications are acceptable at the CRN Site due to the negligible impact on total hazard.

Marianna: The applicant reviewed several new studies related to this RLME source, which included Odum et al. (2016) and Tuttle et al. (2020). However, based on the conclusion in the NSHM23 documentation (i.e., Thompson et al. [2024]) the applicant determined that no updates are required. The staff reviewed the referenced studies and confirmed the applicant's conclusion.

<u>Charleston Seismic Source</u>

In PSAR Section 2.5.2.2.5.4, the applicant stated that it adopted the augmented SSHAC Level-2 study performed for the Savannah River Site (Reference 2.5.2-198). In PSAR Section 2.5.2.2.5.4.1, the applicant evaluated new information that post-dates the Savannah River Site characterization of the Charleston RLME and determined that none required further additional modifications to this source zone. These studies included Pratt et al. (2022), Shah et al. (2023), Bilham and Hough (2023), Bilham and Hough (2024), Hough and Bilham (2024).

PSAR Section 2.5.2.2.5.4.2 summarizes the modifications made to the CEUS-SSC model for the Charleston seismic source zone for the Savannah River Site and adopted by the applicant. The applicant indicated that it replaced the "Narrow" source geometry with a new "1886 Rupture" source geometry representing the Chapman et al (2016) hypothesized source of the 1886 earthquake. In addition, the applicant equally weighted Poisson and renewal models, which reflects an additional change to the CEUS-SSC characterization of this source zone. The staff notes that, with respect to the Charleston RLME, Section 6.1.2.5 of NUREG-2115, states that for the narrow source zone, the Poisson model is assigned a weight of 0.9, and the renewal model is assigned a weight of 0.1. The applicant also stated that it increased the weight from 0 to 0.1 on the renewal model for the Local Zone.

The applicant also stated that additional modifications to this source zone included increasing the range of permissible rupture strikes, dips, and fault styles for all three Charleston source alternatives. In addition, the applicant stated that the zone boundaries for the 1886 Rupture and Local zones are leaky. In response to audit question A-2.5-15, the applicant quantified the changes summarized above for AFEs ranging from 10^{-3} to 10^{-5} and spectral accelerations of 1 Hz, 10 Hz, and PGA. These changes resulted in very small decreases in total hazard when compared to the total rock hazard using the original CEUS-SSC characterization in NUREG-2115. A maximum observed decrease in spectral acceleration of 0.03 percent and 0.05

percent is observed at 1 Hz for AFEs of 10^{-4} and 10^{-5}, respectively. The staff did not perform a detailed review of TVA's modifications to the Charleston source zone; instead, the staff determined that TVA's modifications are acceptable at the CRN Site due to the negligible impact on total hazard.

In summary, TVA modified several seismic source zones (i.e., the NMFS, ERM-N, Commerce and Charleston RLME sources) from the original CEUS-SSC model, which has been previously endorsed by the NRC in Section 2.5.2 of NUREG-0800 (NRC 2021-TN8013). The applicant demonstrated that each modified source zone resulted in decreases in total hazard when compared to the original CEUS-SSC model. Furthermore, the applicant showed that none of source zone modifications significantly impacted the seismic hazard at the CRN Site. For these reasons, the staff determined that the applicant adequately characterized the seismic sources that have the potential to impact seismic hazard at the CRN Site.

2.5.2.3 Ground Motion Model

In PSAR Section 2.5.2.4.2, the applicant stated that it used the Next Generation Attenuation for Central and Eastern North America project (NGA-East) (Goulet et al., 2018) ground motion model (GMM) in the hard rock PSHA for the CRN Site. The NRC evaluated and endorsed the NGA East model in Research Information Letter (RIL) 2020-11 (NRC 2020-TN13246). However, the applicant indicated that it made several modifications to the published NGA-East model; these modifications are summarized below.

The NGA-East Project adopted two alternatives to represent the shape of ground-motion residuals: traditional lognormal distribution with a weight of 0.2 and a mixture of two normal distributions with weight of 0.8. Based on the Idaho National Laboratory (INL) SSHAC Level 3 (2022) GMC study, the applicant adopted the mixture model with a weight of one for the CRN Site. In addition, the modified weights by the INL (2022) study are applied to the low, central, and high branches of the NGA-East single-station sigma logic tree (i.e., with respective weights of 0.15,0.55, and 0.3) to account for the small bias in the total single-station sigma, which is due to the ground motion residuals being spatially correlated. In response to audit question A-2.5-17, TVA summarized the results of a sensitivity analysis to assess the impact of adopting the mixture model, with a weight of one, as well as the modified weights to the single-station sigma logic tree. In summary, implementing both modifications resulted in an increase in reference rock ground motions across the entire frequency range of 0.1 to 100 Hz, with a maximum observed increase of less than ~9 percent at AFEs in the 10^{-4} to 10^{-6} range. In lieu of performing a detailed review, the staff determined that these modifications are acceptable at the CRN Site because overall increase is relatively small (i.e., less than 10 percent); this determination is further supported by the staff's confirmatory total hazard results (see SE Figures 2.5.2-1 and 2.5.2-2), which are similar to TVA's total hazard results.

The applicant also modified the NGA-East GMM based on the findings of Ramos-Sepulveda et al. (2024); this study found a consistent overprediction of ground motions at short periods (i.e., 0.01-0.6 seconds, including peak ground acceleration [PGA]) and underprediction at long periods and developed adjustment factors to correct for this bias. According to PSAR Section 2.5.2.4.2, the NGA-East GMM with adjustment factors of Ramos-Sepulveda et al. (2024) is given a logic tree weight of 0.5; the "as published" NGA-East GMM is also given a logic tree weight of 0.5. PSAR Section 2.5.2.4.2 indicates that the weight of 0.5 assigned to the NGA-East GMM (with adjustment factors) is based on the 2023 USGS NSHM. Specifically, the 2023 USGS weight of 0.5 is due to the recency of observations of misfits and the USGS desire for greater understanding of the causes of this effect. In addition, the USGS indicated that these data are predominantly from small magnitudes and that there may be effects that would differ from larger magnitudes.

The staff reviewed Ramos-Sepulveda et al. (2024) and determined that the study is oriented towards the USGS NSHM and developing adjustment factors to provide compatibility in the joint application of the NGA-East GMMs and site amplification models developed by an expert panel. The staff notes that although Ramos-Sepulveda et al. (2024) provides some recommendations in which only the hard-rock GMMs are to be applied, they state that the amount of this adjustment is uncertain and suggest the use of a logic tree in which different fractions of the smoothed model adjustment factors are attributed to the hard-rock GMM. In summary, the staff concludes that the use of the Ramos-Sepulveda et al. (2024) adjustments at the CRN Site is not appropriate due to the uncertainty for hard-rock GMM applications.

In response to audit question A-2.5.2-18, the applicant performed a sensitivity study to justify retaining a weight of 0.5 for the Ramos-Sepulveda et al. (2024) adjustment factors in its PSHA calculations, rather than re-calculating the hazard. The applicant determined that applying a weight of 0.5 to the Ramos-Sepulveda et al. (2024) adjustment factors resulted in a reduction in ground motions of up to approximately 16 percent (for AFEs ranging from 10^{-4} to 10^{-6}) at frequencies greater than 0.5 Hz; at lower frequencies, this adjustment resulted in an increase in ground motions of up to 22 percent. In the critical frequency range of 1 to 10 Hz, the Ramos-Sepulveda et al. (2024) adjustment factors resulted in a reduction in ground motions of 13.5 percent at 10 Hz, which decreased to 6 percent at 1 Hz.

Based on the applicant’s sensitivity analysis, the staff determined that applying a weight of 0.5 to the Ramos-Sepulveda et al. (2024) adjustment rather than re-calculating the hazard without the adjustment, is adequate because the percent increase in ground motion would be relatively small. Furthermore, as noted above, staff’s confirmatory PSHA results are very similar to TVA’s results (see Figures 2.5.2-1 and 2.5.2-2).

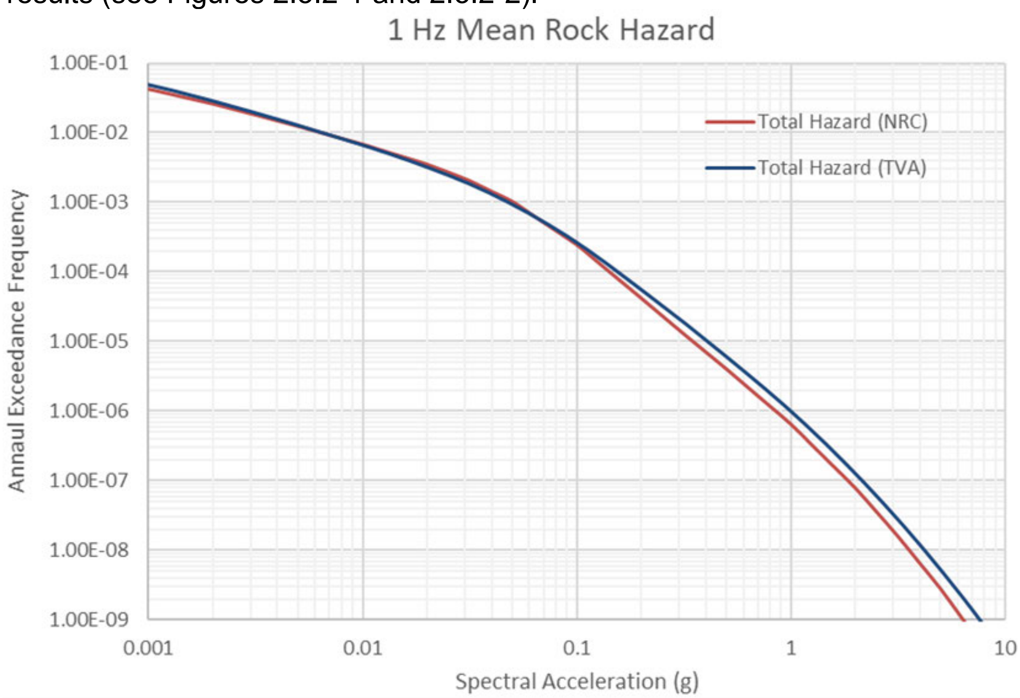

Figure 2-1 Comparison of TVA’s 1 Hz mean rock hazard curve (blue line) with the staff’s 1 Hz mean rock hazard curve (red line).

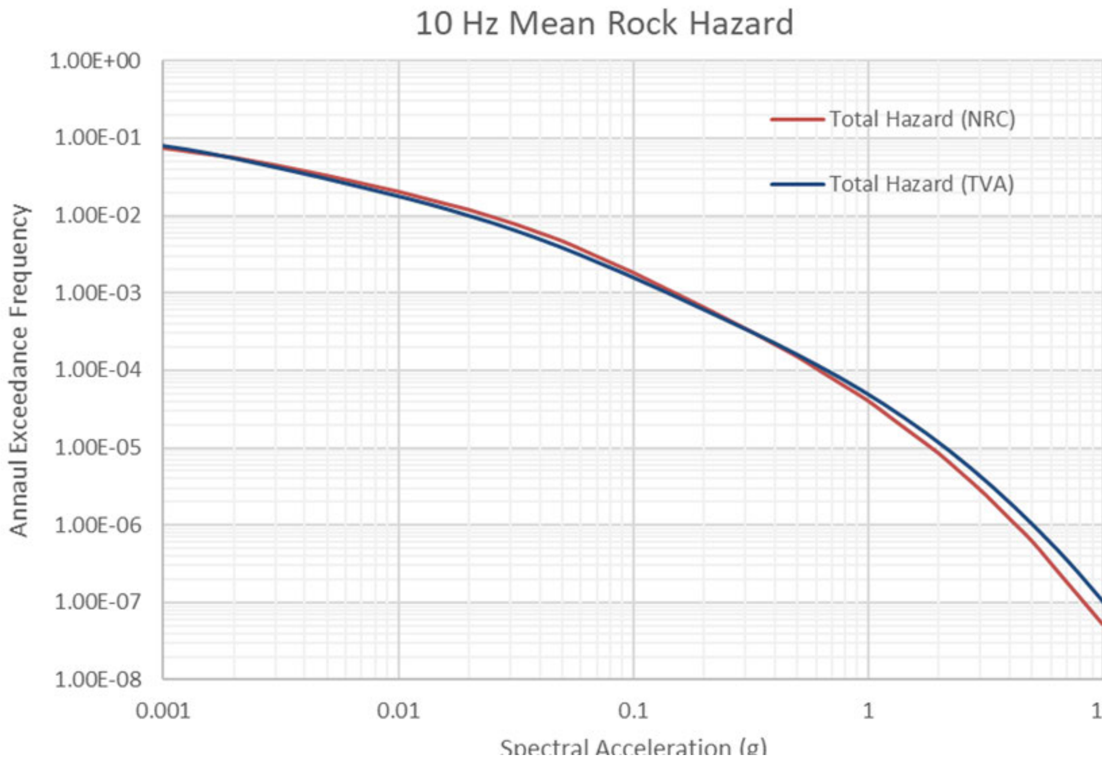

Figure 2-2 Comparison of TVA's 10 Hz mean rock hazard curve (blue line) with the staff's 10 Hz mean rock hazard curve (red line).

2.5.2.4 Probabilistic Seismic Hazard Analysis

In PSAR Section 2.5.2.4.3, the applicant stated that its hard rock PSHA calculation used the CEUS-SSC seismic source characterization model with modifications (discussed throughout PSAR Section 2.5.2.2), and the NGA-East GMM with adjustments (PSAR Section 2.5.2.4.2).

The applicant's PSHA results include the mean rock hazard curves for all 23 frequencies and PGA are provided in PSAR Table 2.5.2-17R. In addition, the contributions to rock hazard from the total of all background sources and each individual RLME source (i.e., Charleston, Commerce, ERM-N, ERM-S, Marianna, NMFS, and Wabash) for 1 and 10 Hz are plotted in PSAR Figure 2.5.2-37R and Figure 2.5.2-38R. The applicant stated that the total mean hazard for 1 Hz is dominated by the NMFS and the background sources for AFEs of 10^{-3} and 10^{-4}; the relative contribution of the background sources increases with decreasing AFE, such that at an AFE of 10^{-5} the hazard is dominated by the background sources (see PSAR Figure 2.5.2-37R). As shown in PSAR Figure 2.5.2-38R, the total mean hazard for 10 Hz is dominated by the background sources. PSAR Figures 2.5.2-39R and Figure 2.5.2-40R plot the contributions to the 1 Hz and 10 Hz hazard by individual background sources. The dominant background sources are Paleozoic Extended Zone-Narrow, Study-R, and NMESE sources, which are host source zones for the CRN-1 Site.

PSAR Section 2.5.2.4.3.3 describes the deaggregation of the hard rock hazard results. PSAR Figures 2.5.2-46R through 2.5.2-51R provides the low-frequency (LF) and high-frequency (HF) deaggregation plots for each mean AFE. The LF plot represents the average deaggregation of the 1 and 2.5 Hz spectral acceleration hazard; the HF plot represents the average deaggregation of the 5 and 10 Hz spectral acceleration hazard. Based on these results, the applicant calculated controlling earthquake magnitudes and distances for a suite of 11 mean AFEs ranging from 10^{-2} to 10^{-7} and are provided in PSAR Table 2.5.2-18R; these are used to develop input control motions for site response analyses at the CRN Site, which is discussed in PSAR Section 2.5.2.5. In addition, the applicant developed mean rock uniform hazard response spectra (UHRS) for mean AFEs of 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6}, which are provided in PSAR Table 2.5.2-19R.

The staff reviewed the applicant's PSHA methodology for reference rock in the PSAR sections noted above. Based on this review, the staff determined that the applicant's PSHA calculation is consistent with the guidance in RG 1.208. The staff also performed a PSHA calculation to confirm the applicant's PSHA results; the staff's calculation did not include any of the modifications to the original CEUS-SSC model or NGA-East GMM that the applicant made (as described in PSAR Sections 2.5 and 2.5.2.4.2). A comparison of the staff's mean rock hazard result with the applicant's mean rock hazard results for 1 and 10 Hz are shown in Figures 2.5.2-1 and 2.5.2-2, respectively. While the results are similar, the applicant's calculated 1 Hz and 10 Hz total rock hazard curves are slightly more conservative than the NRC staff's calculated total rock hazard at AFEs below ~2×10^{-4}. In the 10^{-5} to 10^{-6} AFE range, differences in spectral acceleration of less than ~20 percent are observed. The results of the staff's confirmatory PSHA calculation also provide confidence that the totality of TVA's modifications to the original CEUS-SSC model and NGE-East GMM do not significantly differ from the original CEUS-SSC model and NGA-East GMM as endorsed by the NRC in Section 2.5.2 of NUREG-0800.

2.5.2.4 Site Response

PSAR Section 2.5.2.5 describes the development of the site amplification factors used in the determination of the FIRS, PBIRS, and PBSRS for the CRN Site. As noted in PSAR Section 2.5.2.5.5.3, site response analyses were performed to calculate the site amplification factors associated with the PBSRS, PBIRS, and FIRS control points. According to the applicant, the PBSRS control point is at the ground surface at elevation of 814.5 ft, the PBIRS control point is at the top of the rock, 37.5 ft below the surface at elevation of 777 ft (235 m), and FIRS control point is 115 ft below the surface at elevation of 699.5 ft. The applicant further noted that for the PSBRS control point at the ground surface, site response analyses were performed consistent with a geologic outcrop analysis for a free surface condition according to ISG-017, "Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses" (NRC 2009-TN13250). The PBIRS and FIRS control point site response calculations are consistent with a full column outcrop analysis according to ISG-017.

<u>Site Response Inputs</u>

In PSAR Section 2.5.2.5.1, the applicant described the development of a shear-wave velocity (V_s) base-case profile for the CRN Site, which consists of a "shallow" profile extended by attaching a "deep" profile down to the Precambrian basement. The applicant's site response profile is provided in PSAR Table 2.5.2-22R. With respect to the development of the shallow potion of the V_s profile, the applicant summarized the geotechnical and geophysical tests performed in both 2013 and 2023 at the CRN Site. Notably, compressional (P) and shear (S) wave (P-S) suspension logging, performed by Geovision, which are summarized in PSAR Figure 2.5.2-23R. The results of the applicant's downhole and Spectral Analysis of Surface Waves (SASW) surveys, performed by the University of Texas at Austin, are summarized in PSAR Figure 2.5.2-54R. The applicant noted that compared to the Geovision data, the University of Texas data showed higher variability in the top 138 ft. based on comparisons between the different approaches. Specifically, the applicant noted large differences between the SASW and downhole measurements, as well as inconsistencies between what would be expected based on the boring logs. The applicant stated that "after an evaluation of all the available data, the Geovision suspension logging data were used to develop the rock V_S profile."

Staff reviewed Table 2 and 4 in Appendix II to the S&ME Data Report CRN Site Supplemental geotechnical investigation, which provide the depth to bedrock and stratigraphic descriptions and rock quality designation (RQD), respectively. The staff compared this to the information documented on the boring logs and core photos provided in Appendix IV, "GEOvision Clinch River Nuclear Site Borehole Geophysics" to determine if there is geologic evidence for the lower V_s from the SASW method. The staff also reviewed the V_s data and features identified by acoustic televiewer from the GEOvision Conventional Downhole Geophysics and P-S suspension logging report provided in the electronic reading room. Based on the features documented in the boring logs and identified by acoustic televiewer (ATV), as well as the characterization of the subsurface geologist units, depth to bedrock, and RQD, the staff confirmed the V_s data from SASW is not consistent with the geologic units and features documented in the core boring logs. Accordingly, the staff determined that the applicant's use of only the V_s from the GEOvision suspension logging is appropriate because it is most representative of the geologic conditions in the subsurface of the CRN Site.

The applicant stated that it extended the shallow portion of the V_s profile down to uniform hard rock, which corresponds to the Precambrian basement at a depth of approximately 11,000 ft. With respect to the development of the deep V_s profile, the applicant stated that at depths below the shallow V_s profile where there are no measured V_s data, the geologic profile shown in PSAR Figure 2.5.4-16 was used to extend the profile. The applicant indicated that there is no data for the deeper units at the CRN Site, which include the Consuaga shale, Rome Formation sandstone, and Pumpkin Valley shale. The applicant stated that it obtained data from the deep SASW surveys that were performed at the Watts Bar Nuclear Plant Unit 2 (URS Corp, 2019).

In PSAR Section 2.5.2.5.1.1, the applicant stated that for each best-estimate (BE) base-case V_s profile, lower- and upper-range profiles (LR and UR, respectively) were calculated following guidance in EPRI guidance document "Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic" (EPRI 2012-TN7751). Specifically, the applicant applied a factor of 1.28 to the best-estimate base-case V_s profiles corresponding to an epistemic σ_{ln} of 0.2; below a depth of 541 ft, a factor of 1.57 was used corresponding to a σ_{ln} of 0.35 according to the EPRI SPID guidance document. The resulting LR and UR V_s values are also provided in PSAR Table 2.5.2-22R. The staff determined that the applicant adequately accounted for epistemic uncertainty by developing the LR and UR V_s profiles using the SPID recommendations.

PSAR Section 2.5.2.5.3 describes the modulus reduction and damping (MRD) curves the applicant used as inputs to its site response analysis. To represent epistemic uncertainty, three models are developed and referred to as Material Model 1 (M1), Material Model 2 (M2), and Material Model 3 (M3) in PSAR Tables 2.5.2-22R and 2.5.2-23R, and have respective weights of 0.33, 0.33, and 0.34. The applicant noted that the site response profile at the CRN Site consists of three general strata: (1) soil (engineered fill on top of the existing fill and residual soil), (2) in situ weathered rock, and (3) in situ unweathered rock. In PSAR Table 2.5.2-22R (Case 1), M1 is represented by EPRI Soil curves (new fill), EPRI Clay curves with PI=30 (existing fill and residuum), Rollins et al. (2020) Gravel curves (gravelly soil), followed by EPRI Rock (limestone), and linear below 500 ft; M2 is represented by the Peninsular Range Soil curve (new fill), EPRI Clay curves with PI = 40 (existing fill and residuum), linear (with low-strain damping of M1), and linear below 500 ft; M3 is represented by Rollins et al. (2020) Gravel (new fill), Clinch River soil (existing fill and residuum), EPRI rock (gravelly soil), Clinch River rock (limestone) and linear below 500 ft.

The staff reviewed the applicant's MRD curves and determined that the applicant used the appropriate curves to characterize the materials at the CRN Site. Specifically, the applicant adequately accounted for epistemic uncertainty by considering M1, M2, and M3, which included a range of appropriate published models as well as curves based on site-specific testing.

A significant input to site response analysis is kappa. In PSAR Section 2.5.2.5.2, the applicant stated that it employed an empirical equation for estimating kappa developed from earthquake recordings at five dam sites in the TVA region (TVA, 2020). The applicant stated that the resulting kappa for the BE V_s profile is 0.0173 sec. With respect to representing epistemic uncertainty in site kappa, the applicant followed the recommendations in Appendix B of the EPRI SPID guidance document. The resulting kappa values for the LR and UR profiles are provided in PSAR table 2.5.2-24R. The staff determined that the applicant's kappa values are acceptable as they are based on earthquake recordings in the site region and also are consistent with literature values for similar rock types and thicknesses (e.g., Campbell, 2009). Furthermore, the staff performed confirmatory site response analysis using the applicant's kappa values as well as values obtained using Campbell (2009); the resulting PBSRS using the two sets of kappa values (shown in Figure 2.5.2-3) are similar.

<u>Site Response Analyses and Results</u>

PSAR Section 2.5.2.5.5 describes the site response analysis. As stated in PSAR Section 2.5.2.5.5.2, the applicant employed a 1D RVT-based equivalent-linear site response approach (1D). In addition to the soil profile properties summarized above, input (control) motions need to be specified. For RVT, this is the Fourier amplitude spectrum of the input rock (outcrop) motion. In PSAR Section 2.5.2.5.5.2, the applicant stated that the basis for the control motions are the magnitudes and distances specified by the hazard deaggreation. The applicant's control motions are developed from the LF and HF deaggregated magnitudes and distances listed in PSAR Table 2.5.2-18R. The applicant developed 11 HF and 11 LF response spectra using NGA East scenario spectra. The staff reviewed the applicant's approach to developing the HF and LF spectra. The staff concluded that the applicant's site response approach and control motions are acceptable as they cover an appropriate range of hazard-significant amplitudes (associated with an AFE range of 10^{-2} to 10^{-7}) and spectral shapes.

PSAR Section 2.5.2.6 states that in the CRN Site ESPA, a series of two-dimensional (2-D) sensitivity analyses using SASSI were performed to evaluate the potential 2-D effects on earthquake ground motions due to the dipping nature of the underlying stratigraphy beneath the CRN-1 Site (approximately 33 degrees) (Figure 2.5.4-12). Because the new proposed layout of CRN-1 with the selected SMR technology at the CRN Site is in the vicinity of Location A, the staff determined that the results of the sensitivity analysis presented in the CRN Site ESPA are applicable to the new proposed layout. As such, the staff concludes that the applicant's 2-D sensitivity study is acceptable based on the confirmatory analysis performed as part of the ESPA review.

In PSAR Section 2.5.2.5.5.3 the applicant stated that site amplification factors were calculated for each combination of input control motion, randomized V_s profile, and each of the three material models for each of the base-case, LR, and UR profiles and PBSRS, PBIRS, and FIRS control points. PSAR Figures 2.5.2-70R through 2.5.2-70R show the median and standard deviation site amplification factors for the base-case, LR, and UR profiles using all 11 input control motions for the PBSRS. The applicant indicated that it used ISG-017 to develop the FIRS and PBIRS.

In PSAR Section 2.5.2.7, the applicant indicated that it used Approach 3 (per the SPID) to calculate the site-specific hazard curves for the PBSRS, PBIRS, and FIRS control points, which involved convolving the rock hazard curves with the amplitude-dependent mean and standard deviation of site amplification. The resulting mean hazard curves at 10 Hz and 1 Hz for the PBSRS, PBIRS, and FIRS control points are provided in PSAR Figures 2.5.2-81R through 2.5.2-86R. The applicant also developed vertical control point hazard curves by convolving the horizontal site-specific hazard curves with a suite of median V/H ratios to derive the corresponding vertical site-specific hazard curves. PSAR Figures 2.5.2-90R through 2.5.2-92R present the mean horizontal and vertical UHRS at AFEs of 10^{-4}, 10^{-5}, and 10^{-6}.

In PSAR Section 2.5.2.5.6, the applicant indicated that it used the Pezeshk et al. (2022) model to calculate vertical-to-horizontal (V/H) ratios for the CRN Site; this model is developed from earthquakes selected from the NGA-East database. The applicant's resulting V/H ratios are provided in PSAR Table 2.5.2-40. The applicant stated that in developing the V/H ratios, it considered magnitudes ranging from moment magnitude **M** 5.9 to 6.0 and distances of 8 to 15 km. The applicant further stated that these values are associated with the deaggregated magnitudes and distances for PGA at AFEs of 10^{-4} and 10^{-5}.

The staff determined that the use of Pezeshk et al. (2022) V/H model is appropriate because of the applicability of the NGA-East dataset to the CRN Site region (in comparison to other published models). Furthermore, the selected earthquake recordings that comprise the NGA-East database, for the most part, cover the range of magnitudes corresponding to the high- and low-frequency hazard deaggregation for AFEs ranging from 10^{-4} to 10^{-5} (PSAR Figures 2.5.2-46R through 2.5.2-49R). Furthermore, as shown in Figures 10 and 11 of Pezeshk et al. (2022), the model predicts V/H ratios that are generally similar to, or higher than, other published models at frequencies below ~10 Hz.

The staff concludes that the applicant's site response methodology and results are acceptable because the applicant followed the general guidance provided in RG 1.208 in its site response calculations and used an adequate range of input parameters. The staff further concludes that the applicant's use of ISG-17 is appropriate to use for the development of the FIRS and PBIRS. The staff's confirmatory analysis also showed that the applicant's calculations are acceptable. Comparison of the staff's resulting PBSRS with the applicant's PBSRS is shown in Figure 2.5.1-3. The applicant and staff's GMRS are similar at frequencies below ~5 Hz. The applicant's GMRS is more conservative than the staff's GMRS at frequencies above ~5 Hz. The staff determined that some of this conservatism is due to the applicant's use of a broader range of MRD curves (i.e., M1, M2, and M3), while the staff only considered a single set of MRD curves.

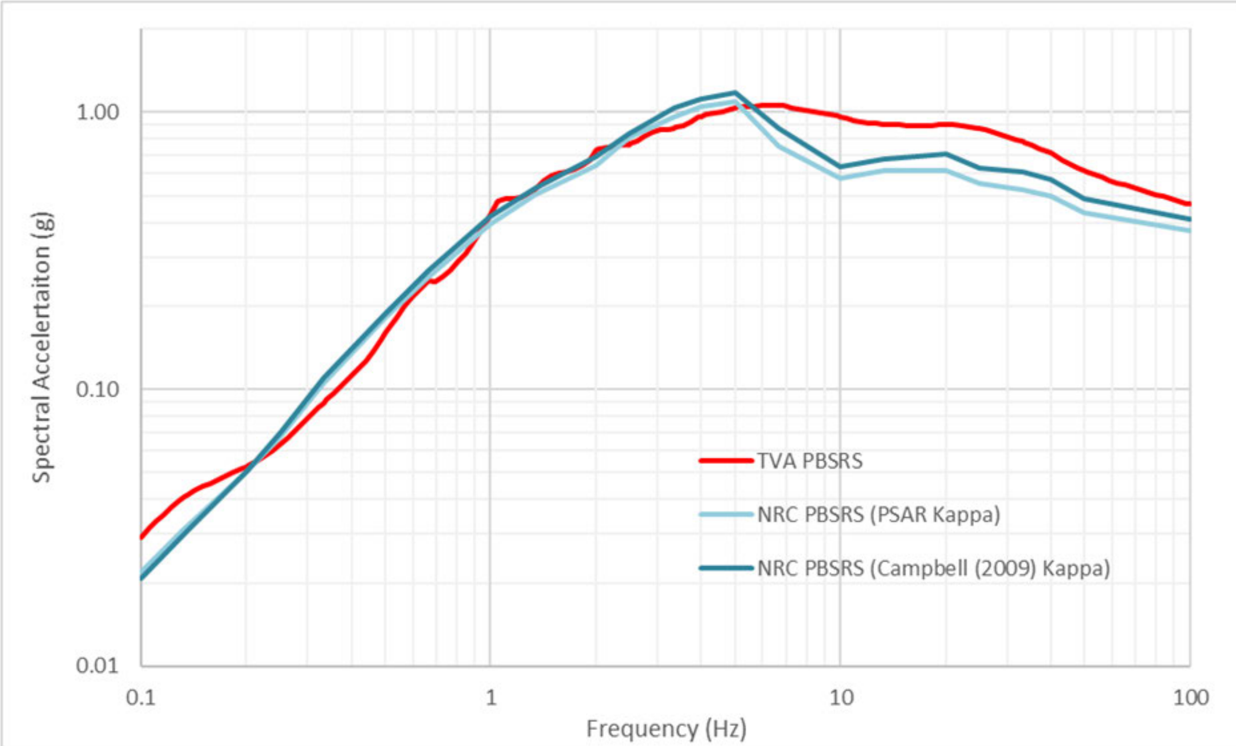

Figure 2-3 Comparison of TVA's horizontal PBSRS (red curve) with the staff's horizontal PBSRS (light and dark blue curves).

2.5.2.5 Site-Specific Ground Motion Response Spectra

PSAR Section 2.5.2.5.8 states that the horizontal site-specific FIRS, PBIRS, and PBSRS are developed by scaling the respective 10^{-4} site-specific mean UHRS by appropriate design factors as detailed in RG 1.208. To capture the characteristics of site amplification at spectral frequencies other than the 23 at which the PSHA is performed, the applicant interpolated the UHRS to 158 spectral frequencies between 0.1 and 100 Hz using the mean amplified spectral shapes available for each control point. The resulting horizontal FIRS, PBIRS, and PBSRS are provided in PSAR Figure 2.5.2-93R. PSAR Figure 2.5.2-95R provides the horizontal and vertical FIRS, PBIRS, and PBSR. As described in SE Sections 2.5.2.4 and 2.5.2.5, the staff performed a confirmatory PSHA and site response analysis and developed PBSRS using the performance-based approach outlined in RG 1.208. A comparison of the staff's PBSRS with TVA's PBSRS is shown in Figure 2.5.2-3. Despite the differences in rock hazard curve inputs (see Figures 2.5.2-1 and 2.5.2-3), as well as input MRD curves (as described in Section 2.5.2.5 of this SER), the results are similar. The staff notes that the staff's PBSRS is lower at frequencies above ~5 Hz, which is largely due to the applicant's use of a wider range of MRD curves. As such, the staff determined that the applicant's horizontal PBSRS is adequate.

Because the applicant used the standard procedures outlined in RG 1.208 to calculate the final horizontal and vertical FIRS, PBIRS and PBSRS, the staff determined that they are adequate and meet the requirements in 10 CFR 100.23(d)(1) and 10 CFR Part 50, Appendix S, Section IV(a)(1)(i). Therefore, the NRC staff finds that the information provided by the applicant is sufficient and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.34(a)(1)(ii) and 10 CFR 50.35.

2.5.3 Surface Deformation

PSAR Section 2.5.3 summarizes information related to the potential for tectonic and nontectonic surface deformation at the proposed site developed from a series of site investigations by TVA and its contractors,, including for the Clinch River Breeder Reactor, the site investigations performed to support development of the SSAR for the ESP application, and the supplemental 2023 site investigations conducted to support the selected design for the CPA. Updates to this section from the Clinch River Nuclear Site ESP site investigations were augmented based on the applicant's 2023 site investigations and geologic events or information obtained subsequent to the ESP issuance.

The staff reviewed the new information provided in the PSAR based on additional studies conducted since the issuance of the Clinch River Nuclear Site ESP. The staff's review and conclusion of the paleoseismic studies in the ETSZ, particularly in the DVFZ, are documented in Section 2.5.1.3 of this SER.

PSAR Section 2.5.3 also discusses investigations into the 2020 Sparta, North Carolina, earthquake and the Little River Fault. The staff noted that because the epicenter of the Sparta earthquake and the surface trace of the Little River Fault are over 180 mi from the CRN Site, there is no potential for surface deformation from the Little River Fault at the proposed CRN Site. Consideration of the Sparta earthquake and Little River Fault as it relates to seismic hazards is addressed in Section 2.5.2.3 of this SER. The staff reviewed the information on surface deformation against the acceptance criteria and determined that the proposed CRN Site will not be affected by surface deformation from the Little River Fault.

The staff has reviewed the available information provided in the PSAR and the referenced Clinch River Nuclear Site ESP SSAR and, for the reasons given above, concludes that the site has been adequately evaluated for the potential for future surface deformation that may affect the design and operation of the proposed facility and meets requirements of 10 CFR Part 50, Appendix A; GDC 2; 10 CFR 100.21(d); 10 CFR 100.23(c); and 10 CFR 100.23(d)(2). Therefore, the NRC staff finds that the information provided by the applicant is sufficient and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.34(a)(1)(ii) and 10 CFR 50.35.

2.5.4 Stability of Subsurface Materials and Foundations

2.5.4.1 Introduction

Section 2.5.4 of the PSAR, addresses the properties and stability of the soil and rock underlying the site that could affect the safe design and siting of CRN-1. In accordance with NUREG-0800 (NRC 2021-TN8013) Section 2.5.4, the staff's review encompasses the following areas:

(1) geologic features of the site and vicinity
(2) static and dynamic engineering properties of soil and rock strata underlying the site
(3) the relationship of the foundations for safety-related facilities and the engineering properties of underlying materials
(4) results of geophysical surveys, including in-hole and surface-based investigations
(5) excavation and backfill plans and engineered earthwork criteria
(6) groundwater conditions and piezometric pressures in critical strata as they affect the loading and stability of foundation materials

(7) responses of site soils and rocks to dynamic loading
(8) liquefaction potential and consequences of liquefaction of subsurface soils
(9) earthquake design bases
(10) results of investigations and analyses conducted to determine foundation material stability, deformation, and settlement under static and dynamic conditions
(11) criteria, references, and design methods used in static and seismic analyses of foundation materials
(12) techniques and specifications to improve subsurface conditions to provide suitable foundation support

As discussed below, the staff concludes that the applicant has provided sufficient information to characterize the stability of subsurface materials and foundations for the CRN-1 CPA. The applicant has selected the BWRX-300 reactor technology and performed supplemental site investigations to address technology specific requirements.

2.5.4.2 Summary of Application

PSAR Section 2.5.4 provided updated site-specific information to support the siting of a BWRX-300 SMR at the CRN Site. The CPA PSAR incorporates by reference and supplements the ESPA SSAR Section 2.5.4 and integrates the results of a 2023 supplemental geotechnical investigation. The updated investigation was conducted to obtain technology-specific data for the selected reactor design and included additional borings, laboratory testing, and geophysical surveys. The applicant provided revised geologic and stratigraphic interpretations, updated rock mass properties using the Geological Strength Index (GSI) and Hoek-Brown failure criterion, and performed three-dimensional finite element (3-D FE) modeling to evaluate bearing capacity, settlement, and heave. The applicant also evaluated the presence and potential impact of karst features, updated groundwater conditions, and provided new dynamic response data. The CPA PSAR addresses and resolves most of the COL Action Items identified in the ESP-SER. Because the bearing capacity and settlement criteria for the proposed reactor technology and associated structures have not yet been finalized, four COL Action Items remain open and the evaluation deferred to the OLA stage.

The applicant provided supplemental site- specific information based on 2023 CRN-1 site investigation program, which was conducted to address the proposed reactor technology. This includes updates to geologic features (e.g., discontinuities and shear fracture zones), properties of subsurface materials, and foundation assessments. The applicant stated that the raw data from 2023 investigation are presented in PSAR References 2.5.4-66 (Rizzo, 2024) and 2.5.4-67 (S&ME, 2024) with some data pending further analyses. These results supplement the 2013 CNR-1 site datasets from the ESP application. The applicant originally identified two locations (location A and location B) for the ESP application. For the CPA the applicant selected the vicinity of location A as the location for the proposed CRN-1, with a finished plant grade elevation of 814.5 ft North American Vertical Datum of 1988 (NACD88). The foundation embedment for the vertical shaft of the reactor building is at depth of 115 ft (699.5 ft NAV88) below finished grade.

The applicant stated that the stratigraphic units underlying the power block area remain predominantly the Newala Formation (Knox group), the Blackford formation, the Lincolnshire formation (Eidson and Fleanor members), and the Rockdell and Benbolt Formations (Chickamauga group), consistent with the ESP SSAR.

The applicant provided updates to discontinuities based on ATV data from the 2023 investigation which are consistent with 2013 data. The applicant also updated the characterization of shear- fracture zones, noting they are incorporated into the average GSI rating for each stratigraphic unit. The applicant indicated that similar healed shear-fracture zones were identified in the 2023 borings, primarily in the Rockdell Formation, with limited occurrences in the Benbolt and Witten Formations.

The applicant provided a request for variance from the ESP and a referenced NRC-approved topical report, and made commitments related to ESP permit conditions and COL/CP action items. The following is a summary of the technical context of each of the aforementioned topics. Section 2.5.4.4 below addresses each topic, outlining the applicant's approach and the staff's review methodology, before presenting the staff's findings and conclusions regarding the adequacy of the site's subsurface characterization.

Variance

CRN Site ESP VAR 2.0-1: The applicant submitted a variance request, CRN Site ESP VAR 2.0-1, to revise the finished grade elevation of the nuclear island excavation area from 821 ft (as specified in the ESPA) to 814.5 ft. The applicant indicated that this change reflects the optimized layout for the proposed design and is used consistently throughout the PSAR, including in the geotechnical and structural evaluations. The applicant indicated that the variance is supported by updated analyses demonstrating that the revised elevation does not adversely affect the safety or performance of the foundations.

Licensing Topical Report NEDO-33914-A Limitations and Conditions

The PSAR references NRC-approved Licensing Topical Report (LTR) NEDO-33914-A, "BWRX-300 Advanced Civil Construction and Design Approach" (GE Hitachi 2022-TN13022), as part of the basis for the seismic analysis and design approach for seismic Category I structures. Section 8.0 of the NRC SE for this LTR states that an applicant referencing the LTR for construction and design features as part of a licensing application should address the five Limitations and Conditions (L&Cs) or provide justification for any deviations.

- *L&C #1 – Interface Characteristics Testing:* Laboratory testing of large-scale, site-specific samples should support the estimation of strength and deformation parameters for geologic discontinuities and structural interfaces.

- *L&C #2 – Stable Excavation:* The excavation for the RB shaft should be evaluated for stability, including the identification and treatment of potentially unstable rock blocks. Earth pressure loads and any temporary reinforcement measures are considered in the assessment of subgrade suitability.

- *L&C #3 – Isotropic and Homogeneous Rock Mass:* Rock mass classification systems used in the LTR assume isotropic and homogeneous behavior. The site-specific discontinuity sets should support this assumption.

- *L&C #4 – Site-Specific Application of the HCSCP:* The hazard-consistent strain-compatible properties (HCSCP) methodology, proposed for developing dynamic subgrade properties, should be demonstrated to be valid when applied to a specific site.

- *L&C #5 – Nonlinear SSI Analysis:* For sites with high seismicity or highly nonlinear subgrade conditions, the use of nonlinear soil-structure interaction (SSI) analysis should be considered.

ESP COL Action Items

The suitability of the CRN Site is established in the ESP, which is incorporated by reference in the CPA PSAR. As part of the ESP, the NRC staff identified 16 COL Action Items requiring additional site investigation activities to be performed following the selection of specific reactor technology and final plant location. These COL Action Items, outlined in the ESP SER Section 2.5.4, guide the geotechnical engineering evaluations necessary for the CPA. They address critical subsurface concerns such as shear-fracture zones, karstic cavities, weathered rock, groundwater impacts, and dynamic loading responses. The CPA shall demonstrate compliance by incorporating site-specific investigations, confirmatory testing, and engineering design measures that ensure the stability and integrity of foundations for safety-related structures under all design conditions.

ESP Permit Condition

ESP-006 Permit Condition #4

In accordance with ESP-006 Permit Condition #4, an applicant for a COL or a CP that references this ESP shall remove the material above elevation 225.9 m (741 ft) NAVD 88 in areas where safety-related structures will be located to minimize the adverse effects of discontinuities, weathered and shear-fracture zones, and karst features on the stability of subsurface materials and foundations. The applicant shall perform additional geotechnical investigations, in accordance with RG 1.132, at the bottom of excavation level for safety related structures, if geologic features that may adversely impact the stability of subsurface materials and foundations are encountered.

2.5.4.3 Regulatory Basis

The regulatory basis for the evaluation of the stability of subsurface materials and foundations for CRN-1 is established through the applicable requirements of the regulations and guidance documents. These include:

- 10 CFR Part 50, Appendix A, General Design Criteria (GDC) (TN249):
  - GDC 1, “Quality Standards and Records,” which requires that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed
  - GDC 2, “Design Bases for Protection Against Natural Phenomena,” which requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, without loss of capability to perform their safety functions
- 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” which establishes quality assurance requirements for the design, construction, and operation of SSCs that prevent or mitigate the consequences of postulated accidents.

- 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," which applies to the design of nuclear power plant SSCs important to safety to withstand the effects of earthquakes

- 10 CFR 100.23, which outlines the geologic and seismic sitting criteria and the investigations required to determine site suitability (TN282)

- 10 CFR 50.34(a)(1)(ii) requires a description and safety assessment of the site on which the facility is to be located

- 10 CFR 50.35, "Issuance of construction permits."

The NRC staff's review of PSAR Section 2.5.4 is guided by the acceptance criteria in NUREG-0800, Section 2.5.4, "Stability of Subsurface Materials and Foundations." The staff also considers relevant guidance from the following RGs:

- RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Revision 3, December 2021 (NRC 2021-TN13247)

- RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," Revision 3, December 2014 (NRC 2014-TN5903)

- RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites," Revision 0, November 2003 (NRC 2003-TN5906)

2.5.4.4 Technical Evaluation

The NRC staff reviewed the information presented in Section 2.5.4 of the PSAR in accordance with the guidance in NUREG-0800 Section 2.5.4, to evaluate the adequacy of the applicant's assessment of the stability of subsurface materials and foundations at the CRN-1 site. The staff reviewed updates from the 2023 supplemental site investigations, which were tailored to the proposed design.

The staff's evaluation focused on verifying that the applicant provided sufficient site-specific geotechnical data, analyses, and design considerations to support the safe siting and construction of the proposed facility. The review also assessed whether the applicant adequately addressed the site-specific geologic and subsurface conditions and incorporated technology-specific requirements for the proposed design.

The applicant incorporates by reference Section 2.5.4 of the CRN-1 ESP SSAR, with specific replacement and supplemental information provided in the CPA PSAR. The staff previously found the ESP SSAR information acceptable, as documented in the CRN-1 ESP SER (TVA 2017-TN5387), subject to the resolution of permit conditions and COL/CP action items. The staff's evaluation of the CPA information is provided in the subsections below.

Variance

CRN ESP VAR 2.0-1

The NRC staff evaluated the applicant's request for variance CRN ESP VAR 2.0-1, as described in CPA PSAR Section 2.0. The ESP SSAR established a finished grade elevation of approximately 821 ft NAVD88 for the nuclear island area, based on the PPE approach to ensure adequate margin for foundation stability and other site characteristics. In the CPA, the applicant requests a variance from this ESP site characteristic to a new finished grade elevation of 814.5 ft to accommodate the optimized layout of the proposed design. The applicant stated that this revised elevation was used consistently throughout the CPA PSAR evaluations and does not compromise safety.

The NRC staff assessed the potential impacts of the revised finished grade on subsurface stability and foundation performance. The staff noted that the lower grade reduces the required thickness of engineered backfill from approximately 21 ft to 14.5 ft, which could influence excavation depth, groundwater interactions, and foundation embedment.

The staff confirmed that the 814.5 ft elevation is consistently applied throughout the CPA PSAR, including in geotechnical evaluations, excavation plans, and foundation design. The foundation assessment model presented in PSAR Section 2.5.4.13 incorporates the revised finished grade and evaluates the performance of the RB and surrounding structures accordingly. The RB foundation embedment depth is 115 ft below the revised finished grade of 814.5 ft, resulting in a foundation elevation of 699.5 ft NAVD88. The staff noted that this is within the ESP bounding assumption that foundation embedment would not exceed elevation 683 ft NAVD88 (208.2 m). The staff also noted that the updated karst evaluation and excavation support system design reflects the revised excavation geometry and grade. The staff reviewed the results of the bearing capacity, settlement, heave, and lateral earth pressure evaluations in PSAR Sections 2.5.4.10 and 2.5.4.13, which demonstrate that under the revised site conditions, the foundation remains stable and within the acceptable performance criteria established in the ESP.

Based on its review, the staff concludes that the applicant has adequately demonstrated, through updated site-specific investigations and modeling, that the change in finished grade elevation from 821 ft to 814.5 ft remains within the geotechnical design established in the ESP. The change does not invalidate previous conclusions in the ESP FSER or adversely affect the stability of subsurface materials and foundations. Therefore, the staff finds that Variance CRN ESP VAR 2.0-1 is acceptable.

<u>LTR NEDO-33914-A Limitations and Conditions</u>

The CRN-1 PSAR references the NRC-approved LTR NEDO-33914-A, “BWRX-300 Advanced Civil Construction and Design Approach” (GE Hitachi 2022-TN13022), as part of the technical basis for the seismic analysis and design of Seismic Category I structures. Section 8.0 of the NRC staff’s SE for this LTR specifies that any applicant referencing the LTR for construction and design features must address the five associated L&Cs in their application or provide adequate justification for any deviations. The staff’s evaluation of the applicant’s compliance with these L&Cs is provided below.

L&C #1 Interface Characteristics Testing

The NRC staff reviewed the applicant’s approach to addressing L&C #1 from the NRC staff’s SE for the BWRX-300 LTR NEDO-33914-A (NRC 2022-TN13243), which requires that large-size samples be tested in the laboratory to obtain acceptable estimates of strength and deformation parameters for discontinuities and interfaces.

As described in PSAR Section 2.5.4.3.3, the applicant conducted a site-specific geotechnical investigation in 2023 to support the selected design. The investigation included continuous rock and sediment sampling in 16 geotechnical boreholes, undisturbed soil sampling in 11 boreholes, and downhole geophysical surveys in 8 boreholes. The NRC staff reviewed the scope of this investigation and confirmed that it was appropriately designed to characterize the subsurface conditions relevant to the RB foundation. The NRC staff also reviewed the laboratory testing program described in PSAR Sections 2.5.4.2.3 and 2.5.4.3.2.6. The applicant stated that laboratory testing was performed in accordance with applicable American Society for Testing and Materials (ASTM) standards and included direct shear testing of rock core samples containing natural discontinuities. The NRC staff reviewed the results of the supplemental geotechnical investigation, which are documented in PSAR References 2.5.4-66 (Rizzo 2024) and 2.5.4-67 (S&ME 2024). The staff noted that the applicant used a triple-tube core barrel system (HQ3), which yields a core diameter less than100 mm. The HQ3 size is consistent with industry practice and provides sufficient material for direct shear testing of discontinuities, enabling the applicant to obtain acceptable estimates of strength and deformation parameters for discontinuities and interfaces, as required by L&C #1. The improved core recovery and sample integrity associated with HQ3 coring is important for reliable interface testing. In addition, the applicant conducted high-resolution ATV logging to collect borehole deviation data. The staff reviewed the ATV images and confirmed that the applicant identified features such as bedding planes, voids, and fractures. The applicant further analyzed the fracture orientation data using stereonet plots to identify dominant joint sets and their spatial distribution. These data were used to support the GSI classification and to inform the interface modeling in the Foundation Interface Analysis (FIA). The staff found that the stereonet analysis provided a statistically sound basis for characterizing the orientation and variability of natural discontinuities in the rock mass.

The NRC staff further reviewed the applicant’s use of these test results in the FIA, as described in PSAR Section 2.5.4.13. The FIA incorporated interface elements between the RB shaft and the surrounding rock mass, as well as along stratigraphic boundaries (e.g., the Benbolt–Rockdell contact). The applicant stated that a strength reduction factor (Rinter = 0.7) was applied to represent the interaction between the RB structure and the surrounding media. These parameters were implemented in a 3-D FE model developed using Midas-GTS-NX, which was used to evaluate excavation stability, bearing capacity, and settlement.

In addition to direct shear testing, the applicant employed several alternative methods to quantify the mechanical behavior of subsurface materials and interfaces. These included the use of the GSI classification system and the Generalized Hoek-Brown failure criterion to estimate rock mass strength and deformation modulus. The applicant also performed resonant column torsional shear testing on rock samples to evaluate dynamic shear modulus and damping properties. Downhole and surface geophysical surveys, including P-S suspension logging and SASW, were used to develop shear and compression wave velocity profiles. These data informed the development of the FIA model and were used to derive equivalent Mohr-Coulomb parameters for interface elements. The staff finds that these alternative methods, when combined with the laboratory testing program, provide a comprehensive and technically sound basis for characterizing the mechanical behavior of the subsurface and the interfaces relevant to the RB foundation.

Based on its review of the supplemental site investigation, laboratory testing, stereonet analysis, and interface modeling, the NRC staff finds that the applicant provides a comprehensive basis for characterizing the strength and deformation properties of subsurface interface. The use of direct shear testing on samples containing natural discontinuities, the application of empirical and numerical methods to supplement laboratory data, and the incorporation of these parameters into the FIA model demonstrate that the interface behavior has been adequately characterized for the purposes of seismic and static stability evaluations. Therefore, the staff concludes that the applicant has adequately addressed Limitation and Condition #1 of the NRC staff's SE for LTR NEDO-33914-A.

L&C # 2 Stable Excavation

The NRC staff reviewed the applicant's approach to addressing excavation stability for the deeply embedded RB shaft, as required by L&C #2 of the NRC staff's SE for LTR NEDO-33914-A. This L&C requires that the applicant demonstrate that the RB shaft excavation will remain stable during and after construction, and that any temporary support systems do not contribute to the final structural performance of the RB.

The NRC-approved exemption request (NRC 2024-TN13244) authorizes early excavation and installation of an initial ground support system prior to construction permit issuance. This exemption allows for the use of stabilization measures such as rock bolts, wire mesh, sprayed gunite, horizontal drains, and pressurized grout, as well as soldier beams and compression rings. The initial ground support system will be abandoned in place and will not serve any structural function in the completed RB. As described in the approved exemption, a 5-foot-wide annulus filled with lean concrete will be installed after construction permit issuance to separate the RB from the excavation and any abandoned support elements, ensuring structural independence consistent with LTR NEDO-33914-A. The staff notes that while not explicitly credited in the exemption, this lean concrete annulus also may contribute to shear resistance and slippage mitigation by providing confinement and frictional resistance between the RB and the surrounding rock mass.

PSAR Section 2.5.4.13 describes a 3-D FE model, developed using Midas-GTS-NX, to simulate excavation sequences, lateral earth pressures, and deformation behavior of subsurface materials surrounding the RB shaft. The staff reviewed the assumptions and results of the Foundation Interface Analysis (FIA) model, which includes a 25-foot-thick disturbed rock zone, reduced rock mass properties based on lower-bound GSI values, and the use of interface elements to simulate potential slip or separation. The analysis results indicate minimal total settlement (<0.05 in.), limited heave (<0.022 in.), and lateral deformations within acceptable limits.

As part of its review, the staff evaluated the lateral deformation results presented in PSAR Figure 2.5.4-34, which depicts the RB shaft wall deformations after structural loading. The results show symmetrical deformation patterns within the Benbolt Formation and overlying soils, with slightly higher deformations on the sides adjacent to the Turbine and Radwaste Buildings, attributed to their larger footprints and higher loads. The staff finds that the modeling results support the conclusion that the RB shaft will remain stable during and after excavation and that any temporary support systems do not contribute to the final structural performance of the RB.

In addition, PSAR Section 2.5.4.12 outlines TVA's commitment to a comprehensive instrumentation and monitoring program during excavation and construction. This includes tracking displacement, slope movement, heave, settlement, and pore pressure changes. In accordance with ESP Permit Condition #3 and the approved exemption request, TVA will perform detailed geologic mapping during each excavation lift prior to stabilization, ensuring real-time identification and evaluation of geologic features such as discontinuities, shear zones, and karst features, supporting safe excavation and foundation preparation.

The NRC staff acknowledges that, as described in PSAR Section 3.8.4.1.4 and consistent with Section 5.1.3 of NEDO-33914-A, the applicant intends to use the results of the FIA to validate the static earth pressure loads applied in the 1-g SSI analysis. While this validation remains a future activity, the staff finds the proposed methodology acceptable and notes that its successful completion will provide additional confirmation that the design earth pressures are conservative and appropriately reflect the interaction between the RB structure and the surrounding geologic media.

Based on the modeling results, monitoring commitments, and the NRC-approved exemption request, the staff concludes that the applicant has provided sufficient information to support its conclusion that the RB shaft excavation will remain stable during and after construction, and that the design complies with Limitation and Condition #2 of the NRC staff's SE for LTR NEDO-33914-A.

L&C # 3 Isotropic and Homogeneous Rock Mass

The NRC staff reviewed the applicant's approach to addressing L&C #3 from the NRC staff's SE for the BWRX-300 LTR NEDO-33914-A, which requires that the rock mass classification systems used (e.g., GSI) assume the rock mass is isotropic and homogeneous. This assumption implies that the rock mass must contain enough discontinuity sets such that its deformational behavior can be considered isotropic and homogeneous.

As described in PSAR Section 2.5.4.2.4.4, the applicant applied the GSI classification system and the Generalized Hoek-Brown failure criterion to characterize the rock mass strength and deformation modulus. The NRC staff notes that the GSI methodology, as applied, assumes the rock mass behaves as a continuous, isotropic, and homogeneous medium due to the presence of multiple intersecting discontinuity sets.

The FSER for the NRC-approved ESP-006 contains the 2013 geologic and geotechnical characterization of the CRN Site which identified that the rock mass at the CRN Site contains five distinct joint sets that define the blockiness of the rock mass (ESPA Sections 2.5.1.2.6 and 2.5.4.2.4.4). This condition satisfies the fundamental assumption of the GSI methodology and the Generalized Hoek-Brown failure criterion, which require that the rock mass behaves as a continuous, isotropic, and homogeneous medium due to the presence of multiple intersecting discontinuities.

The 2023 supplemental geotechnical investigation, conducted to support the applicant's selected design, further confirmed the validity of the rock mass characterization. The NRC staff reviewed the results of this investigation, as documented in PSAR References 2.5.4-66 (Rizzo, 2024) and 2.5.4-67 (S&ME, 2024), and found that the data were consistent with the earlier ESPA findings. The NRC staff found that the applicant's use of stereonet analysis to characterize the orientation and variability of natural discontinuities supported the basis for applying the GSI methodology. The stereonet data presented in PSAR Section 2.5.4.1.3.1 revealed two dominant joint sets consistent with the two dominant sets of 2013 data. The applicant confirmed the presence of additional secondary joint sets through ATV logging. These data were used to support the GSI classification and to inform the interface modeling in the FIA.

Based on the NRC-approved ESP-006 and the staff's review of the 2023 supplemental geotechnical investigation along with the applicant's stereonet data, the NRC staff concludes that the applicant has demonstrated that the rock mass at the CRN Site contains a sufficient number of joint sets to be considered isotropic and homogeneous for the purposes of rock mass strength and deformation modeling. Therefore, the staff finds that the applicant has adequately addressed Limitation and Condition #3 of the NRC staff's SE for LTR NEDO-33914-A.

L&C # 4 Site Specific Application of the Hazard Consistent Strain-Compatible Properties

The NRC staff reviewed the applicant's approach to addressing L&C #4 from the NRC staff's SE for the BWRX-300 LTR NEDO-33914-A. This condition requires the applicant to demonstrate that the HCSCP methodology is valid when applied to a specific site.

As described in PSAR Section 2.5.2.5.9, the applicant implemented the HCSCP methodology consistent with both the LTR and the EPRI SPID guidance document (EPRI 1025287), which has been previously endorsed by the NRC. The applicant conducted a site-specific PSHA and applied a performance-based site response analysis to derive strain-compatible properties. This process incorporated both aleatory variability and epistemic uncertainty by developing multiple V_s profiles and using randomized simulations, consistent with SPID and American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) 4-16.

The NRC staff considers SPID to be an acceptable framework for the site-specific application of HCSCPs, as it reflects both regulatory expectations and industry's best practices for seismic evaluation. Developed collaboratively by the NRC, EPRI, NEI, and other stakeholders, SPID provides a comprehensive methodology for conducting PSHA, performance-based site response analysis, and the treatment of uncertainty. It supports the use of multiple base-case profiles, probabilistic modeling, and strain-compatible property development, all of which are consistent with ASCE/SEI 4-16. The staff found that the applicant's implementation adhered to this framework and was appropriately applied to the CRN-1.

The applicant developed HCSCPs for V_s, primary compression wave velocity (V_p), and damping ratios for shear and compression waves (D_s and D_p), which were used to support the development of the PBSRS and the FIRS. These properties were derived using hazard-consistent input motions and assumed to follow a log-normal distribution, in line with SPID recommendations, to capture variability in dynamic behavior. According to the applicant, the probabilistic approach preserved the hard rock annual probability of exceedance.

To account for variability in dynamic material behavior, the applicant used distributions of strain-compatible properties developed during the site amplification factor analysis. For the seismic SSI) analysis, the applicant applied a bounding approach by pairing UB damping with LB velocities, and vice versa, at each depth. This ensured that the full range of potential subgrade stiffness and energy dissipation characteristics was captured.

The NRC staff confirmed that the strain-compatible profiles preserved the original geologic layering and depth-dependent material characteristics of the site by reviewing Figures 2.5.2-96R through 2.5.2-99R in the PSAR. These figures present the BE, LB, and UB profiles for V_s, V_p, and D_s and D_p) shown both down to the hard rock basement and within the top 200 ft. Through this review, the staff observed that the stratigraphic layering remained consistent across all cases, indicating that the geologic structure was preserved. Additionally, the velocity profiles maintained depth-dependent trends, demonstrating that the material characteristics with depth were not altered by the strain-compatible adjustments. The damping profiles reflect strain-compatible values that vary with depth, consistent with the expected behavior of geologic materials under seismic loading. Near-surface materials exhibit higher damping due to greater strain potential, while deeper, more competent rock layers exhibit lower damping, indicating low strain, elastic behavior under seismic loading. This consistency across the BE, LB, and UB cases confirmed that the strain-compatible adjustments were applied in a manner that preserved the site's geotechnical structure while incorporating strain SSI-dependent dynamic behavior, supporting their use in the seismic analysis.

Based on its review of PSAR Section 2.5.2.5.9 and supporting geotechnical analyses, the NRC staff concludes that the applicant's implementation of the HCSCP methodology is consistent with SPID and ASCE/SEI 4-16 and meets the intent of L&C #4. The use of hazard-consistent, strain-compatible properties provides reasonable assurance that the seismic input and subgrade behavior have been properly characterized for use in the SSI analysis.

L&C # 5 Nonlinear SSI Analysis

The NRC staff reviewed the applicant's approach to addressing L&C #5 from the NRC staff's SE for the BWRX-300 LTR, which requires that the applicant evaluate the need for nonlinear SSI analysis in high seismicity regions or where subgrade materials exhibit significant nonlinearity.

As described in PSAR Section 3.7.2.9.6, the applicant did not perform a nonlinear SSI analysis for the CRN-1 application. The applicant's justification is based on the results of the FIA presented in PSAR Section 2.5.4.13, which indicates that the RB is embedded in competent rock and exhibits nearly linear elastic behavior under Safe Shutdown Earthquake (SSE) loading. The applicant further explains that the high-frequency content of the ground motion results in low-amplitude subgrade strains, making nonlinear effects negligible.

The NRC staff evaluated this justification in the context of ASCE/SEI 4-16, which recommends performing nonlinear SSI analysis when strain levels in the subgrade materials exceed the linear threshold or when significant rock mass discontinuities may influence the seismic response of the structure. The staff reviewed Figures 2.5.2-96R through 2.5.2-99R, which present the hazard-consistent strain-compatible profiles for V_s, V_p, and D_s and D_p corresponding to the PBSRS and FIRS at the CRN Site. These profiles include BE, LB, and UB curves and demonstrate that the strain-compatible damping values vary with depth, consistent with the expected behavior of geologic materials under seismic loading. Near-surface materials exhibit higher damping due to greater strain potential, while deeper, more competent rock layers exhibit lower damping, indicating low strain, elastic behavior under SSE conditions.

The staff also reviewed the applicant's FIA, which incorporates a 3-D FE model of the RB and surrounding rock mass. The FIA results confirmed that the RB is embedded primarily in competent rock, and that the induced strains during the SSE remain within the linear elastic range. This conclusion is supported by the detailed analysis presented in PSAR Section 2.5.4.13.1, which includes simulation of excavation and construction sequences. PSAR Figure 2.5.4-33, which presents the lateral pressures acting on the RB shaft walls, and Figure 2.5.4-34, which shows the corresponding lateral deformations, demonstrate that the RB shaft remains laterally stable under full design loading conditions. PSAR Figures 2.5.4-35 through 2.5.4-37 show the distribution and profiles of total bearing pressure beneath the RB and adjacent foundations, confirming uniform load transfer and no signs of stress concentrations that could compromise stability. Settlement and heave analyses, presented in PSAR Figures 2.5.4-38 through 2.5.4-40 and Figure 2.5.4-49, and Table 2.5.4-33R, indicate that total settlement beneath the RB mat foundation is less than 0.05 in., and heave due to excavation is less than 0.022 in. both within acceptable limits and primarily attributed to recompression rather than new consolidation or elastic deformation. These results confirm that the excavation and construction stages did not result in stress redistributions or deformations that would compromise the RB shaft or surrounding media.

The NRC staff also reviewed the applicant's SSI analysis results and supporting geotechnical data for the RB, as documented in PSAR Appendix Sections 3B through 3H. The applicant used site-specific shear wave velocity profiles, GSI classification, and laboratory testing of rock core samples to characterize the rock mass. These data demonstrated that the rock is laterally continuous, exhibits high stiffness, and contains no significant zones of weakness or discontinuities that would necessitate nonlinear modeling.

The SSI analysis, which included a detailed 3-D FE model and a range of subgrade and interface sensitivity cases, showed that seismic displacements were minimal. PSAR Appendix Section 3C, Table 3C-6 reports an enveloped seismic displacement of 0.01 in. at the RB mat foundation and 0.55 in. at the RB roof. Additionally, PSAR Appendix Section 3H.4 states that the RB exterior wall shows acceptable demand-to-capacity ratios for the below grade portions, based on the bounding load combinations evaluated. While some localized exceedances were noted near grade, particularly where the thick grade slab intersects the RB exterior wall around the steam tunnel, the applicant attributed them to high thermal and pressure demands from accident scenarios, not seismic loading. The overall evaluation confirms that the stress demands in the RB exterior wall remain within acceptable limits when compared to the material yield strength of 65 ksi, as specified in PSAR Table 3H-1.

Based on this information, the NRC staff concludes that the applicant's geotechnical characterization and modeling provide reasonable assurance that the rock mass underlying the RB will behave in a stable and elastic manner under SSE loading. The analysis demonstrates that the RB is embedded in competent rock, with induced strains remaining within the linear elastic range, and that excavation and construction activities did not result in stress redistributions or deformations that would compromise the stability of the RB shaft or surrounding media. The modeling results, including lateral pressure and deformation profiles, bearing pressure distributions, and settlement and heave evaluations, support the assumption of low strain levels and uniform load transfer into the subsurface. Given the demonstrated elastic response of the foundation system and the absence of significant nonlinearity in rock mass behavior, the NRC staff finds the decision not to perform a nonlinear SSI analysis acceptable for the CRN-1 site and finds the applicant has satisfied the requirements of L&C #5.

ESP COL Action Items

- COL Action Item 2.5-1

The NRC staff reviewed PSAR Sections 2.5.4.1.3.1 through 2.5.4.1.3.3 of the PSAR to evaluate the applicant's response to COL Action Item 2.5-1, which requires further evaluation of shear-fracture zones and weathered fracture zones following the selection of a final reactor technology and site layout.

To support this evaluation, the staff confirmed that the applicant conducted a supplemental site-specific subsurface investigation in 2023 for the selected design. This investigation included 16 geotechnical boreholes, 4 of which were deep borings located at the proposed RB shaft. These borings were drilled to the full depth of the planned excavation and provided continuous rock core and ATV data. The staff reviewed this data to assess fracture orientation, frequency, and condition, as well as overall rock mass quality.

The applicant identified healed shear-fracture features in the Rockdell, Benbolt, and Witten formations. These features were not identified as laterally continuous across multiple borings. Based on their characteristics and age, the applicant concluded that these are healed, non-tectonic features and not indicative of ongoing or recent tectonic activity. The staff reviewed the applicant's interpretation and found it reasonable based on the data provided.

The applicant also provided updated engineering properties for residual soils, weathered rock, and bedrock based on laboratory and in situ testing, including pressure meter and seismic velocity tests. These data were used to update parameters such as unit weight, elastic moduli, and strength characteristics. The staff finds that the applicant employed state-of-the-art methods consistent with RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants", Revision 3 and RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants", Revision 3.

The staff further reviewed the applicant's use of the GSI methodology to characterize the rock mass. As documented in PSAR Section 2.5.4.2.4.4, GSI values derived from the 2023 investigation were consistent with those from the 2013 investigation. The staff found that the applicant appropriately incorporated these values into the development of rock mass strength and deformation properties, which were used in a 3-D FE model to evaluate foundation performance, including bearing capacity, settlement, and excavation stability.

In addition, the staff noted the applicant's commitment, consistent with ESP Permit Condition #3, to perform geologic mapping during excavation to identify and characterize any features not captured during drilling.

Based on its review, the NRC staff concludes that the applicant has provided sufficient site-specific geologic and geotechnical information, including data from the four deep borings at the RB location, to support the conclusion that the identified shear-fracture and weathered fracture zones do not pose a hazard to the safe design and construction of safety-related structures. Therefore, under 10 CFR 100.23, the staff finds the applicant's approach and commitment acceptable and concludes that COL Action Item 2.5-1 is adequately addressed.

- COL Action Item 2.5-2

The NRC staff reviewed Section 2.5.4.13 of the PSAR to evaluate the applicant's response to COL Action Item 2.5-2, which requires re-evaluation of the potential impacts of karstic cavities on foundation stability for safety-related structures following the selection of a final reactor technology and site layout.

As described in PSAR Section 2.5.4.1.4, the applicant identified two karstic cavities during the 2023 investigation, both smaller than 1 ft in height and located in the Witten and Rockdell Formations. These findings are consistent with the 2013 investigation, which identified most cavities at depths less than 100 ft and with heights less than 11 ft.

To evaluate the potential impact of undetected cavities, the applicant developed a 3-D FE model as part of a FIA. The model incorporated two hypothetical 15-ft diameter spherical cavities—one located 5 ft beneath the RB mat foundation and another adjacent to the RB shaft and 2 ft below the top of unweathered rock beneath the Radwaste Building, the heaviest surface structure.

The staff reviewed the modeling approach and confirmed that the applicant incorporated site-specific geologic and geotechnical parameters, including rock mass properties derived from GSI classifications, disturbance factors (D = 0.7), and interface elements to simulate bedding planes and potential discontinuities. The model also accounted for construction sequences, groundwater conditions, and excavation-induced stress relief.

The applicant concluded that the presence of such cavities, even under conservative assumptions, did not result in unacceptable deformations or compromise the stability of the RB foundation or surrounding structures. The staff reviewed the results of the 3-D FE simulations, as documented in PSAR Table 2.5.4-33R, and found that the estimated settlement (<0.05 in.) and heave (<0.022 in.) were minimal and within acceptable limits. The staff also noted that the applicant's use of LB material properties and conservative assumptions regarding the disturbed rock mass zone provided a robust basis for the analysis.

In addition, the applicant committed to performing geologic mapping during excavation to identify and mitigate any previously undetected voids, consistent with ESP Permit Condition #3.

Based on its review and in accordance with 10 CFR 100.23, the NRC staff concludes that the applicant has provided sufficient site-specific geologic and geotechnical information, including a conservative evaluation of undetected karstic cavities. Therefore, the staff finds the applicant's approach acceptable and concludes that COL Action Item 2.5-2 is adequately addressed.

- COL Action Item 2.5-3

The NRC staff reviewed PSAR Sections 2.5.4.3.3, 2.5.4.4.3, 2.5.4.5.2.3, and 2.5.4.12, of the PSAR to evaluate the applicant's response to COL Action Item 2.5-3, which requires applicants referencing ESP-006 to perform additional surface geophysical surveys and confirmatory subsurface investigations during excavation and construction to detect and mitigate cavities that could adversely affect foundation performance.

In PSAR Section 2.5.4.3.3, the applicant described the confirmatory drilling and borehole testing program, which included 16 geotechnical boreholes and 8 boreholes with downhole geophysical testing. These tests included acoustic televiewer imaging, V_P and V_S wave velocity logging, gamma logging, and other methods to characterize the subsurface conditions and validate geophysical anomalies. The staff reviewed the scope and execution of the confirmatory drilling program and found it to be consistent with the intent of COL Action Item 2.5-3, providing sufficient coverage to identify potential features of concern such as cavities or zones of weakness.

As described in PSAR Section 2.5.4.4.3.1, the applicant conducted surface geophysical surveys during the 2023 supplemental site investigation using SASW at three array locations. These surveys were designed to detect subsurface anomalies, including potential voids, and to supplement the geophysical data collected during the 2013 investigation. The SASW results were used to develop shear wave velocity profiles and inform the geotechnical model. The NRC staff reviewed the methodology and found that the applicant's development of site-specific velocity profiles was appropriate for identifying potential subsurface anomalies that could impact foundation performance.

PSAR Section 2.5.4.5.2.3 further supports the applicant's response by detailing the excavation approach for the foundation bedrock. The RB will be founded in the Benbolt Formation, and excavation into this rock will be performed using controlled blasting techniques. The applicant anticipates that the excavation will expose unweathered rock and that the excavation floor will be irregular, requiring dental concrete to establish a level foundation grade. The PSAR acknowledges that blasting will disturb the rock mass and assumes a 25-foot-thick disturbed zone beneath the RB foundation, with a disturbance factor of 0.7 applied in the geotechnical analysis. The staff confirmed that this assumption is consistent with the FIA described in PSAR Section 2.5.4.13. The applicant also commits to geologic mapping of the exposed rock faces during excavation to identify any additional support or stabilization needs. As stated in PSAR Section 2.5.1.2.6.10, detailed geologic mapping of excavation walls during construction will allow TVA to document the characteristics of dissolution features in the near-surface carbonate rock units and verify whether cavities decrease in size and abundance with depth, as predicted by the 2013 CRN-1 SMR subsurface investigation. This mapping will support the evaluation of potential impacts on foundation bearing capacity and groundwater flow.

To address the potential for undetected cavities, the applicant developed a karst mitigation plan as described in PSAR Section 2.5.4.12. The plan includes geologic mapping during excavation, ground penetrating radar and multi-frequency electromagnetic surveys at the base of excavation lifts, and core drilling to confirm anomalies. If voids are identified, the applicant proposed to implement grouting as a remedial measure. A grouting program that meets regulatory requirements will be developed and implemented at the CRN Site, as stated in response to Audit Item CRN-1 A-2.5-9 (TVA 2025-TN13044). The staff reviewed this approach and found it to be consistent with industry practices for karst detection and mitigation.

Based on its review, the NRC staff concludes that the applicant has provided a comprehensive approach to detect and mitigate subsurface cavities that could affect foundation performance. This approach includes real-time geologic mapping, targeted geophysical surveys during excavation, and a grouting program, as needed. The NRC staff notes that under the 10 CFR Part 50 licensing framework, these mitigation measures, particularly grouting, will be subject to NRC inspection and oversight during construction. This regulatory oversight ensures that foundation conditions for safety-related structures remain acceptable throughout the construction process. Furthermore, this oversight is reinforced by the quality assurance requirements in Appendix B to 10 CFR Part 50, which include provisions for design control, control of special processes, inspection, and defect reporting under 10 CFR 50.55(e). Therefore, the staff finds the applicant’s approach acceptable and concludes that COL Action Item 2.5-3 is adequately addressed.

- COL Action Item 2.5-4

Reserved in accordance with ESP-006.

- COL Action Item 2.5-5

The NRC staff reviewed PSAR Sections 2.5.4.2.3, 2.5.4.2.4.4, and 2.5.4.3.3 to evaluate the applicant’s response to COL Action Item 2.5-5, which requires additional testing to determine rock mass properties and to further characterize rock shear strength along bedding planes with discontinuities and fracture zones in areas where safety-related structures will be located. The staff noted that the applicant conducted a supplemental geotechnical investigation in 2023 to support the selected design and to verify subsurface conditions at the excavation level. As part of this program, the applicant performed 16 geotechnical borings, including deep borings at the center and perimeter of the RB shaft, and conducted borehole geophysical surveys (e.g., ATV and seismic velocity logging), surface geophysical surveys (e.g., SASW), and laboratory testing of rock samples. The NRC staff confirmed that these investigations were performed in accordance with RG 1.132.

The staff reviewed the laboratory testing program described in Section 2.5.4.2.3, which included unconfined compressive strength, triaxial compression, and direct shear tests to determine the engineering properties of intact rock and discontinuities. The NRC staff also evaluated the applicant's use of the GSI classification and the Hoek-Brown failure criterion, as described in Section 2.5.4.2.4.4, to develop rock mass strength and deformation properties. The staff noted that the GSI methodology assumes the rock mass behaves as a homogeneous and isotropic medium, which is valid when multiple intersecting discontinuity sets are present. The NRC staff reviewed stereonet data and ATV logs and found that the rock mass at the site hosting CRN-1 contains enough joint sets to support the assumption of isotropy and homogeneity. The NRC-approved ESP identified five distinct joint sets that define the blockiness of the rock mass, satisfying the assumptions of the GSI and Hoek-Brown methodologies. The 2023 supplemental geotechnical investigation confirmed the presence of two dominant joint sets consistent with the 2013 data, and additional secondary sets were identified through ATV logging, further validating the applicability of these rock mass models. The staff also reviewed the results of the 2023 GSI classifications and strength calculations and found them to be consistent with the 2013 data. Based on its review, the NRC staff concludes that the applicant has adequately addressed COL Action Item 2.5-5 by performing site-specific testing and analysis, consistent with NRC guidance.

- COL Action Item 2.5-6

The NRC staff reviewed PSAR Section 2.5.4.5 to evaluate the applicant's response to COL Action Item 2.5-6, which requires specific details regarding the lateral and vertical extent of excavation consistent with the selected reactor technology. The applicant provided excavation plans tailored to the proposed design, defining a vertical embedment at 115 ft below finished plant grade elevation of 814.5 ft to elevation 699.5 ft for the RB and within the Benbolt Formation. The excavation is described as a deep vertical shaft with limited lateral extent, constrained by the RB shaft diameter and construction methods, and supported by compression rings and soldier pile systems. In the NRC-approved exemption request from requirements of 10 CFR 50.10(c), which allows certain early excavation work, the applicant committed to removing material above elevation 741 ft (NAVD88) in the RB area, consistent with ESP Permit Condition #4. The CPA's foundation embedment remains bounded by the PPE value evaluated in the ESP (138 ft), which assumed a conservative excavation footprint and depth to ensure site suitability for a range of reactor technologies. Based on its review and the previously approved exemption request for early excavation, the NRC staff concludes that the applicant has provided sufficient geologic and engineering information to define the excavation limits for the selected reactor technology and to support early excavation activities; therefore, COL Action Item 2.5-6 is adequately addressed.

- COL Action Item 2.5-7

The NRC staff reviewed PSAR Section 2.5.4.5 and referenced the NRC-approved early excavation exemption request to evaluate the applicant's response to COL Action Item 2.5-7, which requires specification of excavation procedures and methods that will not adversely impact the integrity of foundation subsurface materials. The applicant described a deep vertical shaft excavation tailored to the proposed design, supported by a combination of soldier pile systems and reinforced concrete compression rings to maintain excavation stability and minimize disturbance to surrounding materials. The applicant provided technology-specific engineered earthwork plans that include temporary slope protection and ground support measures such as rock bolts, wire mesh, horizontal gravity drains, pressurized grout for water ingress control, steel soldier beams with timber lagging, and reinforced concrete compression rings. The applicant plans to achieve dewatering through gravity drains to maintain dry excavation conditions. The applicant plans to support these measures by geologic mapping conducted prior to the application of stabilization measures, and a comprehensive instrumentation and monitoring program consistent with LTR NEDO-33914-A. The monitoring program includes tracking of slope movement, heave, pore pressure changes, and settlement during and after excavation to detect and mitigate any potential impacts to subsurface integrity. The NRC staff notes that these excavation support and monitoring activities will be subject to inspection and oversight under the 10 CFR Part 50 licensing framework, including quality assurance requirements in Appendix B and defect reporting under 10 CFR 50.55(e). Based on its review and the previously approved exemption request, the NRC staff concludes that the applicant has provided sufficient information to demonstrate that excavation will be conducted in a manner that preserves the integrity of foundation subsurface materials and allows for timely detection and mitigation of adverse conditions; therefore, COL Action Item 2.5-7 is adequately addressed.

COL Action Item 2.5-8

The NRC staff reviewed PSAR Sections 2.5.4.5.3 and 2.5.4.5.4 of the CPA to evaluate the applicant's response to COL Action Item 2.5-8. This action item requests detailed design information for backfill materials, including source identification, quantity estimates, material properties, placement specifications, applicable industry standards, and related Inspections, Tests, Analyses, and Acceptance Criteria if applicable. The applicant described the use of granular backfill conforming to the gradation requirements of Type A aggregate per the Tennessee Department of Transportation Standard Specifications, with the option to produce material onsite from excavated Benbolt Formation rock or to import it from nearby commercial quarries. In PSAR Section 2.5.4.5.3 the applicant committed to implementing a detailed field and laboratory testing program during the design stage to evaluate the engineering properties of materials obtained either onsite or offsite, including gradation, density, soundness, durability, strength, and dynamic properties. The applicant indicated that a test pad will be constructed to establish placement and compaction methods, with compaction targeted at 95 percent of the maximum dry density per ASTM D1557 "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort."

In accordance with COL Action Item 2.5-8 of the approved ESP, the applicant shall evaluate the hydraulic characteristics of the in-place backfill such as permeability and porosity and ensure consistency with the groundwater flow model described in PSAR Section 2.4.12. The staff acknowledges that backfill sourcing, placement, and verification activities will be subject to inspection and oversight under the 10 CFR Part 50 licensing framework, including quality assurance requirements in Appendix B to 10 CFR Part 50 and defect reporting under 10 CFR 50.55(e). Based on its review of the PSAR and the applicant's commitments, the NRC staff concludes that the applicant has provided sufficient preliminary information to support the backfill design approach. However, full resolution of COL Action Item 2.5-8 involves confirmation that the hydraulic characteristics of the in-place backfill are consistent with the groundwater model assumptions or are otherwise demonstrated to have no adverse impact on the site conceptual model. Therefore COL Action Item 2.5.4-8 remains open, pending resolution at the OLA stage.

- COL Action Item 2.5-9

The NRC staff reviewed PSAR Sections 2.5.4.6 and 2.5.4.13 to assess the applicant's response to COL Action Item 2.5-9, which requires a detailed design of dewatering and groundwater control during excavation and construction, including a monitoring plan and an evaluation of the impact of dewatering on foundation stability. In its review of PSAR Section 2.5.4.6, the staff noted that the applicant characterized groundwater levels based on observation wells installed during the 2013 site investigation, identifying groundwater generally above the top of bedrock within the weathered rock. The applicant committed to developing a dewatering and control plan during excavation and construction.

The NRC staff evaluated the applicant's use of a seepage analysis, described in PSAR Section2.5.4.13, to estimate pore pressures during excavation. The staff confirmed that the analysis modeled staged excavation of the RB vertical shaft, with groundwater drawdown and interaction between the support of excavation system (including anchored soldier pile walls and compression rings) and surrounding materials. The staff noted that the seepage analysis accounted for excavation in lifts, with the internal water level lowered incrementally to the base of each lift, while the external groundwater level remained at the initial elevation (800 ft). A long-term design groundwater level of 814.5 ft, coinciding with the final plant grade elevation, was assumed as the final condition after surface building construction. The staff noted that the estimated pore pressures were used as input for a 3-D FE stress-deformation model, which simulated the mechanical response of the soil and rock mass during excavation. This included evaluation of groundwater drawdown effects, support system performance, and the influence of a disturbed rock zone due to blasting. The NRC staff reviewed the results as documented in PSAR Section 2.5.4.13 and found that the applicant demonstrated acceptable performance of the excavation support system and surrounding ground. The analysis showed that the support system maintained stability throughout excavation and that displacements and stresses remained within acceptable limits. The NRC staff determined that the integration of seepage and stress-deformation modeling provided a reasonable basis for assessing excavation stability and foundation integrity.

The NRC staff also reviewed Section 2.5.4.12, which describes the applicant's proposed monitoring program. The staff confirmed that the program includes piezometers for pore pressure monitoring, inclinometers and extensometers for lateral and vertical displacement monitoring, and settlement monitors to track vertical movement during and after construction. The staff found that these monitoring activities are consistent with the requirements of LTR NEDO-33914-A (GE Hitachi 2022-TN13022) and will be subject to inspection and oversight under the 10 CFR Part 50 licensing framework, including Appendix B quality assurance requirements and defect reporting under 10 CFR 50.55(e).

Based on its review of the PSAR, including site-specific groundwater data, the seepage analysis, and the detailed numerical modeling of excavation, as well as dewatering effects and the applicant's commitments, the NRC staff concludes that the applicant has provided sufficient technical information to adequately address COL Action Item 2.5-9.

- COL Action Item 2.5-10

The NRC staff reviewed PSAR Sections 2.5.4.5.3 and 2.5.4.6.3 to evaluate the applicant's response to COL Action Item 2.5-10, which requires a detailed design of foundation protection based on the chemical characteristics of groundwater and foundation and fill materials, consistent with applicable industrial standards. In PSAR Section 2.5.4.5.3, the applicant discusses the evaluation of granular backfill sources, including the potential use of onsite excavated rock. As part of the 2023 supplemental site investigation, the applicant conducted laboratory testing to assess the chemical properties of the Benbolt Formation, including soundness and abrasion characteristics (i.e., chloride content, sulfate content, PH, resistivity, and calcium carbonate). The applicant stated that these results will inform decisions on the suitability of excavated rock for use as backfill. The applicant also stated that a detailed field and laboratory testing program will be conducted during the design stage to evaluate backfill sources and their engineering properties, including chemical compatibility with concrete.

PSAR Section 2.5.2.4.1 indicates that the V_s model for backfill has been estimated empirically from literature reported or other site response analysis studies. In PSAR Section 2.5.4.6.3, the applicant indicated that the detailed design for foundation protection based on the chemical characteristics of the groundwater and foundation and fill materials will be described in the FSAR. Additionally, the applicant notes that the testing program during the final design stage will ensure compliance with applicable standards, including Tennessee Department of Transportation Section 903 and ASTM D1557.

Based on the information provided, the NRC staff concludes that the applicant has provided sufficient preliminary information for the CP stage in accordance with 10 CFR 50.34(a)(1)(ii) . In addition, the staff acknowledges that backfill sourcing, placement, and verification activities will be subject to inspection and oversight under the 10 CFR Part 50 licensing framework, including quality assurance requirements in Appendix B to 10 CFR Part 50 and defect reporting under 10 CFR 50.55(e). However, because the final design will be submitted in a future FSAR application, COL Action Item 2.5-10 remains open, pending resolution at the OLA stage.

- COL Action Item 2.5-11

The NRC staff reviewed PSAR Section 2.5.4.7 to assess the applicant's response to COL Action Item 2.5-11, which requires the development of seismic wave velocity profiles for safety-related structure locations based on detailed site investigation data, with consideration of uncertainties and variability, and the determination of appropriate damping and shear modulus reduction properties for in situ subsurface materials. In its review of PSAR Section 2.5.4.7, the staff noted that the applicant conducted extensive geophysical investigations during both the 2013 and 2023 site investigations, including downhole seismic testing and SASW, to develop V_s and V_p velocity profiles. The staff confirmed that the applicant developed site-specific V_s profiles for Location A adopted for the proposed CRN-1 layout, and accounted for epistemic uncertainty by providing BE, UB, and LB profiles. The staff also noted that the applicant used normalized borehole data and lognormal averaging to characterize variability in V_s, and supplemented site-specific data with adjusted regional data for deeper geologic units where direct measurements were limited.

The NRC staff evaluated the applicant's approach to determining dynamic soil and rock properties, including damping and shear modulus reduction curves, as described in PSAR Sections 2.5.4.7.3 and 2.5.4.7.4.1. The staff confirmed that the applicant performed resonant column torsional shear testing on rock samples collected during the 2023 investigation to evaluate shear modulus and damping behavior under varying strain levels and confining pressures. The damping and shear modulus reduction curves were developed for engineered fill, residual soils, weathered rock, and unweathered rock, and were used in the site response analysis. The staff found that the use of both laboratory test data and justifiable generic curves, where appropriate, provided a reasonable basis for characterizing the dynamic behavior of subsurface materials.

Based on its review of the PSAR, including the site-specific geophysical and laboratory data, the development of seismic velocity profiles, and the characterization of dynamic properties with consideration of uncertainty and variability, the NRC staff concludes that the applicant has provided sufficient technical information to adequately address COL Action Item 2.5-11.

- COL Action Item 2.5-12

The NRC staff reviewed PSAR Section 2.5.4.10.1 to evaluate the applicant's response to COL Action Item 2.5-12, which requires assessment of foundation bearing capacity for safety-related structures under site-specific geologic conditions and anticipated static and seismic loadings. The applicant performed both analytical and advanced numerical evaluations for the RB, the only Seismic Category I structure, embedded in competent Benbolt Formation rock. Using U.S. Army Corps of Engineers guidance and a 3-D FE FIA developed in Midas GTS-NX, the applicant demonstrated that the RB foundation remains elastic under loads up to 11 times the service level, with no plastic strain development. The calculated allowable static bearing capacity of 76 ksf, though lower than the PPE minimum of 110 ksf, includes a factor of safety of 3 and is based on site-specific conditions, providing adequate margin given the relatively low applied structural load (8.4 ksf). In addition, the NRC staff noted that PSAR Section 2.5.4.2 identifies a bounding minimum static and dynamic bearing capacity of 33.4 ksf for the CRN Site. This value is used in the geotechnical characterization and design basis for Seismic Category I structures to ensure conservatism and consistency with the ESP. The staff notes that the use of both bounding and refined site-specific values (76 ksf static and 168 ksf dynamic for the RB) provides adequate margin and supports the safety and performance of safety-related foundations. The applicant also evaluated dynamic bearing capacity using Soubra's method, resulting in an allowable pseudo-static capacity of 168 ksf, exceeding the PPE minimum of 110 ksf.

For surface-founded, non-Seismic Category I structures, parametric studies using 2-D FE models indicated low bearing capacities due to residual soils, leading the applicant to propose drilled shafts into unweathered rock for final design. Sections 3.7.2.3.4 and 3.7.2.3.9 of this SER evaluate the interaction between the RB and adjacent Power Block structures through bounding SSI and SSSI analyses using integrated finite element models and engineered fill assumptions. Sensitivity studies addressed variations in subgrade and seismic parameters, confirming that seismic demands remained within acceptable limits. These analyses demonstrate that the design approach provides adequate foundation stability and seismic performance in conformance with GDC 2 and applicable codes (American Concrete Institute [ACI] 349-13, International Building Code [IBC] 2021, ACI 318-19/22, ASCE 7-16), and is acceptable for the CP stage.

Based on its review of the geotechnical data, modeling results, and design approach, the NRC staff concludes that the applicant has provided sufficient technical information to support reasonable assurance of foundation safety and performance required for the CPA. Therefore, COL Action Item 2.5-12 is resolved, with final confirmation of foundation design to be completed pursuant to COL Action Item 2.5-15, as further discussed below.

- COL Action Item 2.5-13

The NRC staff reviewed PSAR Sections 2.5.4.10.2 and 2.5.4.13 to evaluate the applicant's response to COL Action Item 2.5-12, which requires the assessment of foundation settlement and heave for safety-related structures based on selected plant structure and foundation designs, actual geologic conditions at the CRN-1 site, and anticipated excavation depths and static and dynamic loadings. The staff noted that the applicant performed both analytical and numerical evaluations of settlement and heave, including a detailed 3-D FE model developed using Midas GTS-NX software. The model incorporated site-specific stratigraphy, rock mass properties derived from GSI-based methods, construction sequences, groundwater conditions, and structural loading for the deeply embedded RB and surrounding surface-founded structures.

The staff reviewed PSAR Table 2.5.4-33R and confirmed that the RB foundation, embedded up to 115 ft into competent bedrock, experiences minimal deformation under service loads, with estimated settlement less than 0.05 in. and excavation-induced heave less than 0.022 in. For surface-founded structures, the applicant evaluated both a base case and an alternative case incorporating equivalent stiffness to simulate 36 in. drilled shafts socketed into unweathered rock. The base case resulted in excessive differential settlement, while the alternative case reduced differential settlement to within acceptable limits (less than 0.5 in. over 50 ft).

The staff also reviewed the applicant's evaluation of lateral pressures, bearing stresses, and the potential impact of undetected karst features. The model included two hypothetical 15 ft diameter cavities embedded within a 25 ft thick disturbed rock zone beneath and adjacent to the RB shaft. The simulation results showed no significant impact on foundation stability. The staff confirmed that the model appropriately incorporated the revised finished grade elevation of 814.5 ft, as requested in Variance CRN-1 ESP VAR 2.0-1, and that this change does not compromise the safety of the foundation system.

The staff finds that the Foundation Assessment Model is consistent with the guidance provided in LTR NEDO-33914-A for FIA. In accordance with 10 CFR 50.34(a)(1)(ii), the modeling approach, assumptions, and results are acceptable for the CP stage. The staff notes that the model will be updated at the final design stage to reflect any changes in layout, foundation geometry, or subsurface conditions. Based on its review, the NRC staff concludes that the applicant has adequately evaluated foundation settlement and heave for safety-related structures at the CRN-1 site, consistent with the requirements for CPA referencing the ESP. Therefore, COL Action Item 2.5-13 is resolved. However, final confirmation of settlement and heave parameters, including any updates to foundation geometry or subsurface conditions, will be addressed under COL Action Item 2.5.4-15, which covers geotechnical design criteria and structural performance evaluations during final design.

- COL Action Item 2.5-14

The NRC staff reviewed PSAR Sections 2.5.4.10.3 and 2.5.4.13.1 to assess the applicant's response to COL Action Item 2.5-14, which requires the evaluation of maximum lateral earth pressure and its distribution along foundation and structure walls below ground. This includes contributions from static soil pressure, hydrostatic pressure, surcharge-induced pressure from equipment and adjacent structures, and seismic lateral earth pressure under anticipated maximum static and dynamic/seismic loadings.

In its review of PSAR Section 2.5.4.10.3, the staff noted that the applicant described the methodology for evaluating lateral earth pressures, including the use of at-rest earth pressure coefficients for static conditions and the incorporation of site-specific FIRS into FE modeling to assess seismic lateral earth pressures. However, the staff also noted that the applicant deferred the evaluation of lateral earth pressures with the seismic component to the OLA stage.

The staff confirmed that the applicant performed a 3-D FE analysis to evaluate static lateral pressures and deformations on the RB shaft walls under service loads, as documented in PSAR Section 2.5.4.13.1. The staff reviewed PSAR Figures 2.5.4-33 and 2.5.4-34 that illustrate the distribution of lateral pressures and corresponding deformations, showing that the RB shaft remains stable under static loading conditions. The applicant also modeled surcharge effects from adjacent structures and hydrostatic pressures due to groundwater.

Based on its review of the PSAR, the NRC staff concludes that in accordance with 10 CFR 50.34(a)(1)(ii) the applicant has outlined an acceptable methodology for evaluating lateral earth pressures and conducted an evaluation that shows that the RB shaft remains stable under static loading conditions in support of COL Action Item 2.5-14. However, the staff notes that the applicant deferred the final assessment of seismic lateral earth pressures, including detailed analysis using site-specific FIRS and finite element modeling, to the OLA stage. The commitment to perform the final seismic analysis at the OLA stage is consistent with regulatory practice under 10 CFR 50.34(a)(1)(ii), as the CP stage focuses on site suitability, general design criteria, and preliminary safety analyses. As such, COL Action Item 2.5-14 remains open.

- COL Action Item 2.5-15

The NRC staff reviewed PSAR Section 2.5.4.11 to assess the applicant's response to COL Action Item 2.5-15, which requires the identification and reevaluation of geotechnical engineering-related design criteria to meet applicable industrial standards and NRC regulations. In PSAR Section 2.5.4.11, the applicant summarized the geotechnical design criteria, including liquefaction, bearing capacity, settlement, slope stability, and structural performance considerations. The applicant stated that these criteria were initially addressed in the 2013 site analysis, re-evaluated using data from the 2023 supplemental site investigation, and will be further evaluated at the final design stage. The applicant's evaluation of liquefaction potential is consistent with the conclusions reached in the ESP, reaffirming that the residual soils and compacted granular backfill at the CRN Site are not susceptible to liquefaction. Based on the properties of the soil and rock at the site, the staff concurs with the applicant's conclusion that there is no liquefaction potential at the CRN Site.

The staff confirmed that the applicant performed updated analyses of bearing capacity and settlement using both empirical methods and 3-D FE modeling, as documented in PSAR Sections 2.5.4.10 and 2.5.4.13. The 3-D FE model incorporated site-specific stratigraphy, rock mass properties based on the GSI, and disturbance factors to simulate excavation effects. The applicant also evaluated the impact of potential karst features and confirmed that the foundation system remains stable under both static and dynamic loading conditions. In addition, stability of the Power Block foundations against sliding and overturning is addressed in PSAR Section 3.8.5.4.3 and evaluated in accordance with SRP Section 3.8.5, Section II.4. Required safety factors for these foundations, as provided in PSAR Table 3.8-10, include a minimum factor of safety of 1.5 for sliding and overturning under normal/static conditions and 1.1 under extreme/seismic conditions, as well as a factor of safety of at least 3.0 for ultimate bearing capacity. In accordance with PSAR Section 2.5.4.11, bearing capacity and settlement criteria for the selected reactor technology and associated structures along with geotechnical performance criteria such as wall rotation, sliding, and overturning have not been finalized by the manufacturer and will be addressed at the final design stage. The NRC staff acknowledges that these final foundation design parameters will be developed by the applicant in accordance with the structural design of the selected reactor and will be subject to NRC review and oversight under the 10 CFR Part 50 licensing framework.

Based on its review of the PSAR, the NRC staff concludes that the applicant has identified and re-evaluated the geotechnical engineering-related design criteria in support of COL Action Item 2.5-15. The methodologies used are consistent with NRC guidance, specifically with RG 1.132, RG 1.138, and NUREG-0800, SRP Section 2.5.4; and are consistent with industry practice. However, because the final bearing capacity and settlement criteria for the selected reactor technology and associated structures, as well as geotechnical-related structural performance criteria such as wall rotation, sliding, and overturning are deferred to the final design stage, COL Action Item 2.5-15 remains open pending completion of those assessments for confirmation at the OLA stage.

- COL Action Item 2.5-16

The NRC staff reviewed PSAR Sections 2.5.4.12, 2.5.4.13, and 2.5.4.13.1 to evaluate the applicant's response to COL Action Item 2.5-16, which requires improvement of subsurface conditions in the influence zone of foundations for safety-related structures when karst or other geologic hazard features are discovered.

To address the potential for undetected cavities, the applicant developed a karst mitigation plan as described in PSAR Section 2.5.4.12. The plan includes geologic mapping during excavation, ground-penetrating radar, and multi-frequency electromagnetic surveys at the base of excavation lifts to detect potential voids within the zone of influence. If anomalies are identified, the applicant committed to performing confirmatory core drilling and implementing remedial measures such as grouting, as necessary. A grouting program that meets regulatory requirements will be developed and implemented at the CRN Site, as stated in response to audit item CRN-1 A-2.5-9 (TVA 2025-TN13044). The applicant also committed to geologic mapping throughout excavation, consistent with ESP Permit Condition #3.

To evaluate the potential impact of undetected karst features, the applicant developed a 3-D FE model as part of the FIA, as documented in PSAR Sections 2.5.4.13 and 2.5.4.13.1. The model incorporated two hypothetical 15-foot diameter spherical cavities—one located 5 ft beneath the RB mat foundation and another adjacent to the RB shaft and 2 ft below the top of unweathered rock beneath the Radwaste Building. These locations were selected to represent bounding conditions for the most critical structures.

The staff reviewed the modeling approach and confirmed that the applicant incorporated site-specific geologic and geotechnical parameters, including rock mass properties derived from GSI) classifications, a disturbance factor (D = 0.7) to simulate blasting effects, and interface elements to represent bedding planes and potential discontinuities. The model also accounted for staged excavation, groundwater conditions, and construction sequencing. The applicant concluded that the presence of such cavities, even under conservative assumptions, did not result in unacceptable deformations or compromise the stability of the RB foundation or surrounding structures. The staff reviewed the results of the 3-D FE simulations, as documented in PSAR Table 2.5.4-33R, and found that the estimated settlement (<0.05 in.) and heave (<0.022 in.) were minimal and within acceptable limits. The use of LB material properties and conservative assumptions regarding the disturbed rock mass zone provided a reasonable basis for the analysis.

The staff reviewed the applicant's overall approach and found it to be consistent with industry practices for karst detection and mitigation. This includes real-time geologic mapping, targeted geophysical surveys during excavation, and a grouting program, as needed. The NRC staff notes that under the 10 CFR Part 50 licensing framework, these mitigation measures—particularly grouting—will be subject to NRC inspection and oversight during construction. This regulatory oversight ensures that foundation conditions for safety-related structures remain acceptable throughout the construction process. Furthermore, this oversight is reinforced by the quality assurance requirements in

Appendix B to 10 CFR Part 50, which include provisions for design control, control of special processes, inspection, and defect reporting under 10 CFR 50.55(e).

Based on its review, the NRC staff concludes that the applicant has provided sufficient site-specific geologic and geotechnical information, including an evaluation of potential undetected karstic cavities and a commitment to perform geophysical surveys and remediation during excavation, to support the conclusion that such features do not pose a hazard to the safe design and construction of safety-related structures. Therefore, the staff finds the applicant's approach acceptable and concludes that COL Action Item 2.5-16 is adequately addressed.

ESP Permit Condition

To address ESP Permit Condition #4, as established in the NRC staff's CRN Site ESP SER, the applicant submitted the CPA PSAR to demonstrate compliance with NRC regulations governing the issuance of a CP. ESP Permit Condition #4 requires that an applicant for a COL or CP referencing the ESP must remove material above elevation 741 ft NAVD 88 in areas where safety-related structures will be located. This is intended to minimize the adverse effects of discontinuities, weathered and shear-fracture zones, and karst features on the stability of subsurface materials and foundations. The condition also requires that additional geotechnical investigations be performed at the excavation level in accordance with RG 1.132, and that if adverse geologic features are identified, the applicant should excavate or improve the subsurface materials in accordance with COL Action Item 2.5-3.

In PSAR Section 2.5.4.5, the applicant confirms that the RB will be embedded to elevation 699.5 ft, which is significantly below the 741 ft threshold. This excavation depth ensures that all overburden materials, including potentially adverse geologic features, are removed. The applicant also conducted a supplemental geotechnical investigation in 2023, which included 16 geotechnical boreholes, borehole geophysical surveys (such as acoustic televiewer and seismic velocity logging), laboratory testing of soil and rock samples, and surface geophysical surveys using SASW. These investigations included 4 deep borings at the center and perimeter of the RB shaft and were performed in accordance with RG 1.132 and at a targeted excavation level to identify any geologic features that could impact foundation stability.

The PSAR further addresses the permit condition through detailed characterization of discontinuities, shear-fracture zones, weathered rock, and karst features in Sections 2.5.4.1.3.1 through 2.5.4.1.4. The applicant confirms that these features were identified and incorporated into the geologic and engineering models used for foundation design (i.e., GSI and Hoek-Brown criteria). In PSAR Section 2.5.4.12, the applicant outlines a plan for excavation mapping, instrumentation, and monitoring during construction. If adverse features are encountered, remediation measures such as grouting or additional excavation will be implemented, consistent with COL Action Item 2.5-3. Additionally, PSAR Section 2.5.4.13 describes a 3-D finite element model developed to simulate excavation and construction sequences, including the presence of potential karst features and disturbed rock zones. The model confirmed that the foundation remains stable even with postulated adverse geologic conditions.

The NRC staff previously concluded in the ESP SER that the applicant's proposed approach, removal of material above elevation 741 ft, supplemental investigations, and mitigation of adverse features was acceptable but required verification at the COL or CP stage. The PSAR now provides that verification, as explained above, demonstrating that the applicant has fulfilled the intent of ESP Permit Condition #4.

2.5.4.5 Conclusion

The NRC staff reviewed PSAR Section 2.5.4 and concludes that the applicant has adequately characterized the subsurface conditions at the CRN Site and provided sufficient site-specific geotechnical data, analyses, and design information for the CP stage. The applicant performed supplemental investigations in 2023, including deep borings, laboratory testing, and geophysical surveys, and incorporated the results into updated geologic models, stratigraphy, and finite element analyses.

The staff reviewed Variance CRN Site ESP VAR 2.0-1, which revised the finished grade elevation from 821 ft to 814.5 ft, and finds that the change is technically justified and consistently applied throughout the geotechnical and structural evaluations. The revised elevation does not adversely affect the safety conclusions of the ESPA.

The staff also reviewed the applicant's compliance with ESP Permit Condition #4 and finds that the commitment to embed the RB to elevation 699.5 ft NAVD88, along with supplemental investigations and excavation mapping, satisfies the condition's requirements. The applicant's modeling and monitoring plans provide reasonable assurance that adverse geologic features will be identified and mitigated during construction.

The staff evaluated the applicant's use of the NRC-approved LTR NEDO-33914-A and finds that the five associated limitations and conditions have been adequately addressed. This includes validation of interface properties, excavation stability, rock mass assumptions, hazard-consistent strain-compatible properties, and justification for not performing nonlinear SSI analysis.

The staff reviewed the applicant's responses to COL Action Items 2.5-1 through 2.5-16 and finds that all but four items (2.5-8, 2.5-10, 2.5-14, and 2.5-15) are resolved at the CP stage. The applicant deferred these remaining items to the OLA stage for final confirmation of backfill properties, seismic lateral earth pressures evaluation, and design specific geotechnical-related structural performance criteria.

Based on its review, the NRC staff concludes that the information provided in PSAR Section 2.5.4 is sufficient to meet the regulatory requirements of 10 CFR 50.34(a)(1)(ii); Appendix A (GDC 1 and 2), the applicable provisions of Appendix B to Part 50 (Criteria II, III, V, VI, and XVII, as they pertain to geotechnical investigations and analyses), and the applicable seismic and geologic provisions of Appendix S to 10 CFR Part 50 (Sections I-IV) related to site characterization and foundation performance; and 10 CFR 100.23. The staff finds that the applicant's geotechnical characterization and foundation design approach provides reasonable assurance of safety and supports the issuance of a CP. Final design confirmation will be performed during the evaluation of the CRN-1 FSAR at the OLA stage. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.

2.5.5 Stability of Slopes

2.5.5.1 Introduction

In PSAR Section 2.5.5, “Stability of Slopes,” the applicant addresses the stability of natural and manmade earth slopes (e.g., cuts, fills, embankments) whose failure could adversely affect safety-related structures. The NRC staff reviewed this section to determine whether slope conditions at the CRN-1 site pose any hazard to the selected reactor technology. The applicant has selected the BWRX-300 reactor technology and indicates that no permanent safety-related (SC1) slopes are present and that temporary construction slopes will be managed appropriately. The applicant indicated that final excavation support and slope stabilization measures will be developed during the OLA stage.

As discussed below, the staff concludes that the applicant has provided sufficient information to characterize the slope conditions at the CRN Site.

2.5.5.2 Summary of Application

PSAR Section 2.5.5 provided updated site-specific information related to subsurface investigations conducted in 2013 and 2023 to evaluate the stability of natural and graded slopes at the CRN Site. The site is characterized by gently sloping terrain resulting from previous grading activities, with the finished grade for the Power Block area set at 814.5 ft (NAVD88). The proposed layout results in a flat, table-top configuration with no permanent SC1 slopes.

The applicant confirmed that no SC1 slopes are present within or near the Power Block area, and the nearest permanent slope is more than 900 ft from any SC1 structure. Temporary excavation cut slopes will be required during construction for foundation installation in soil, weathered rock, and hard rock. The applicant indicated that these temporary slopes will be backfilled after construction, and final excavation support and stabilization designs will be developed during the OLA stage.

The PSAR includes results from detailed geotechnical investigations, including material and rock mass characterization, which will inform the final design of excavation slopes.

ESP CP/COL Action Items

COL Action Item 2.5-17 states as follows:

“An applicant for a COL that references this early site permit should perform a slope stability analysis of any safety-related slopes, including dams and dikes, consistent with the selected reactor technology”

2.5.5.3 Regulatory Evaluation

The regulatory basis for the evaluation of slope stability at the CRN Site is established through applicable requirements of NRC’s regulations and associated guidance documents. These include:

- 10 CFR 50.34(a)(1)(ii) requires a description and safety assessment of the site on which the facility is to be located (TN249).
- 10 CFR 50.35, “Issuance of construction permits.”

- 10 CFR Part 50, Appendix A, GDC:
  - GDC 1, "Quality Standards and Records," which requires that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed
  - GDC 2, "Design Bases for Protection Against Natural Phenomena," which requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, without loss of capability to perform their safety functions.
- 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," which establishes quality assurance requirements for the design, construction, and operation of SSCs that prevent or mitigate the consequences of postulated accidents
- 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," which applies to the design of nuclear power plant SSCs important to safety to withstand the effects of earthquakes
- 10 CFR Part 100.23, "Geologic and Seismic Siting Criteria," which outlines the geologic and seismic sitting criteria and the investigations required to determine site suitability (TN282)

The NRC staff's review of PSAR Section 2.5.5 is guided by the acceptance criteria in NUREG-0800 (NRC 2021-TN8013), Section 2.5.5, "Stability of Slopes," which provides guidance for evaluating the stability of natural and graded slopes for which failure could adversely affect the safety of nuclear power plant SSCs. The staff also considers relevant guidance from the following RGs:

- RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Revision 3, December 2021 (NRC 2021-TN13247)
- RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," Revision 3, December 2021 (NRC 2014-TN5903)

2.5.5.4 Technical Evaluation

The NRC staff reviewed the information presented in Section 2.5.5 of the PSAR in accordance with the guidance in NUREG-0800, Section 2.5.5, to evaluate the adequacy of the applicant's assessment of slope stability at the CRN Site. The staff's review considered the results of the 2013 and 2023 site-specific subsurface investigations, which were conducted to support the siting of the proposed design.

The applicant incorporates by reference Section 2.5.5 of the CRN Site ESP SSAR, supplemented with updated information in the PSAR. The staff previously found the ESP SSAR acceptable, as documented in the CRNS ESP SER (Accession No. TVA 2017-TN5387), subject to resolution of COL/CP action items.

COL Action Item 2.5-17

The NRC staff reviewed PSAR Section 2.5.5 to assess the applicant's response to COL Action Item 2.5-17, which requires that an applicant referencing the ESP perform a slope stability analysis of any safety-related slopes, including dams and dikes, consistent with the selected reactor technology.

In its review, the staff noted that the applicant provided a description of the site topography and grading plan for the proposed design. The PSAR states that the existing ground surface at and around the power block area is generally gently sloping downward from northwest to southeast, ranging from approximately elevation 855 to 780 ft NAVD88 and the finished grade elevation for the power block area is set at 814.5 ft NAVD88. The applicant stated that the site grading results in a flat, table-top configuration with no permanent slopes in the vicinity of safety-related structures. The applicant confirmed that no SC1 slopes are present, and that the shortest distance between any permanent slope and an SC1 structure is more than 900 ft.

The NRC staff also noted that while temporary excavation cut slopes will be required during construction for foundation installation, these slopes will be backfilled upon completion of construction and will not remain as permanent features. The applicant indicated that the final design of excavation support and slope stabilization measures will be developed during the OLA stage.

Based on its review of the PSAR and the absence of permanent SC1 slopes, the NRC staff concludes that the applicant has adequately addressed COL Action Item 2.5-17 for the CP stage. No slope stability analysis is required at this time, as no safety-related slopes are identified. The staff will evaluate final excavation support measures during the OLA review.

2.5.5.5 Conclusion

The staff has reviewed the available information provided in the PSAR and the referenced CRN Site ESP SSAR and, for the reasons given above, concludes that the design analyses contain margins of safety which adequately demonstrate that natural and manmade slopes will remain stable under SSE, floods, tsunamis, and other potential adverse conditions and that safety-related earthwork will function reliably at the site to justify the soil and rock characteristics used in the design. The staff further concludes that the design analyses contain adequate margins of safety for construction and operation of the nuclear power plant and meets the requirements of 10 CFR Part 50, Appendix A (GDC 1 and 2), Appendix B, and Appendix S; and 10 CFR 100.23. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.34(a)(1)(ii) and 10 CFR 50.35.

The NRC staff reviewed PSAR Section 2.5.5 and finds that the applicant has adequately addressed the stability of slopes at the CRN Site. The applicant confirmed that no permanent SC1 slopes are present within or near the Power Block area and that the site grading plan results in a flat, table-top configuration with a finished grade elevation of 814.5 ft. The staff verified that the nearest permanent slope is located more than 900 ft from any SC1 structure, and that temporary excavation slopes required during construction will be backfilled and stabilized.

The staff also reviewed the results of the site-specific subsurface investigations and finds that the applicant has provided sufficient geotechnical data to support the conclusion that slope instability does not pose a hazard to safety-related structures. The applicant’s approach is consistent with the guidance in NUREG-0800 Section 2.5.5 and addresses COL Action Item 2.5-17. Therefore, the staff concludes that the application meets the applicable requirements of 10 CFR Part 50, Appendix A (GDC 1 and 2), Appendix B,

Appendix S, and 10 CFR 100.23 with respect to slope stability. Therefore, the NRC staff finds that the information provided by the applicant is sufficient and meets the regulatory requirements of 10 CFR 50.34(a)(1)(ii) and other regulatory requirements identified in this section and adequately supports the issuance of a CP pursuant to the regulations in 10 CFR 50.35.