Final Safety Evaluation Report for the Early Site Permit Application for the Clinch River Nuclear Site

U. S. Nuclear Regulatory Commission
Office of New Reactors
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ABSTRACT

This final safety evaluation report[1] (FSER) documents the U.S. Nuclear Regulatory Commission (NRC) staff's safety review of the early site permit (ESP) application submitted by the Tennessee Valley Authority (TVA or the applicant), for the proposed Clinch River Nuclear (CRN) Site, in Roane County, Tennessee.

In a May 12, 2016, letter, TVA submitted an ESP application (ESPA), Revision 0, for the CRN Site in accordance with Subpart A, "Early Site Permits," of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The proposed CRN Site, which hosted the former Clinch River Breeder Reactor Project, is a tract of land adjacent to the Clinch River arm of the Watts Bar Reservoir, located west of the Oak Ridge Reservation, within the city of Oak Ridge, Tennessee. The site is bounded on the east, south, and west by the Clinch River arm of the Watts Bar Reservoir and on the north by the Grassy Creek Habitat Protection Area. Communities located near the site include Kingston (approximately 6.8 mi west), Harriman (9.2 mi west-northwest), Lenoir City (approximately 8.8 mi southeast), and Knoxville (approximately 25.6 mi east-northeast). The CRN Site is approximately 935 ac within a 1,200 ac property owned by the United States of America and managed by TVA. The applicant revised the ESPA over the course of the review to capture its responses to staff requests for additional information and other information provided on the docket as the result of regulatory audits described in this FSER. TVA submitted Revision 1 of the ESPA on December 15, 2017, and submitted Revision 2, the final revision of the application supporting this FSER, on January 18, 2019.

TVA has not selected a specific reactor technology, but used a plant parameter envelope (PPE) in developing its application. TVA used technical information from various reactor designs to develop bounding parameters (i.e., PPE) that are used to evaluate the suitability of the site for future construction and operation of a nuclear power plant. The PPE is based on construction and operation at the CRN Site of two or more small modular reactors (SMRs) with a maximum rated thermal power for a single unit of 800 MWt (reactor core). The combined nuclear generating capacity from the site is not to exceed 2,420 MWt (800 MWe). A future set of reactor modules on the CRN Site is proposed to be built in the "power block area" location identified in TVA's application.

In its application, TVA seeks an ESP that could be referenced as part of a future application to construct and operate a nuclear plant at the CRN Site. If the design that is referenced or included in the future application is bounded by the PPE, then the applicant would not have to revisit safety issues resolved in the ESP proceeding that depend on the PPE values. To the extent the PPE is not bounding, however, the COL applicant would have to show that the proposed facility may be safely located at the CRN Site notwithstanding the variance from the PPE.

Appendix A to this FSER identifies the proposed Permit Conditions, site characteristics, and bounding design parameters that the staff recommends be imposed, if an ESP is issued to the applicant. It also includes certain site-related items (combined license [COL] Action Items) that

[1] This FSER documents the NRC staff's position on all safety issues associated with the early site permit application. The relevant SER chapters and sections of this FSER have undergone a final review by the Advisory Committee on Reactor Safeguards (ACRS), and the results of the ACRS review are in a final report provided by the ACRS (ACRS 2019 - ML19009A286). This report, as well as a response letter from the NRC staff (NRC 2019 – ML19022A306), are included in Appendix E to this FSER.

will need to be addressed in a COL or construction permit (CP) application that references the CRN Site ESP. The staff concluded that addressing these items is not required for the staff to make its regulatory findings on the ESPA and that, for reasons specified in this FSER, the COL Action Items are more appropriately addressed when the applicant has applied for a COL or CP.

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The chapter and section layout of this final safety evaluation report is consistent with the format of (1) NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants; LWR Edition," (2) Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants," Revision 1, and (3) the applicant's site safety analysis report (SSAR). Numerous chapters and sections in NUREG-0800 are not within the scope of, or addressed in, an early site permit (ESP) proceeding. The reader will, therefore, note these chapters and sections are not included in this document. The subjects of chapters and sections in NUREG-0800 not addressed herein will be addressed, as appropriate and applicable, in other applications (design certification, construction permit, or combined license) for a plant that might be constructed on the CRN Site.

APPENDICES

FIGURES

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EXECUTIVE SUMMARY

The regulations in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," contain requirements for licensing new nuclear power plants (NPPs).[2] These regulations include the U.S. Nuclear Regulatory Commission (NRC) requirements for early site permits (ESPs), design certifications, and combined licenses (COLs). The ESP process discussed in 10 CFR Part 52, Subpart A, "Early Site Permits," is intended to address and resolve site-related issues. The DC process (10 CFR Part 52, Subpart B, "Standard Design Certifications") provides a means for a vendor to obtain NRC certification of a particular reactor design. Finally, the COL process (10 CFR Part 52, Subpart C, "Combined Licenses") allows an applicant to seek NRC authorization to construct and operate a new NPP. A COL applicant may reference an ESP, a certified design, both, or neither. A COL applicant referencing an ESP or certified design must resolve licensing issues that were not resolved as part of the referenced ESP or design certification proceeding before the NRC can issue a COL.

This final safety evaluation report (FSER) describes the results of a review by the NRC staff (the staff) of an ESP application (ESPA) submitted by the Tennessee Valley Authority (TVA) for the proposed Clinch River Nuclear (CRN) Site. The staff's review verified the applicant's compliance with the requirements of 10 CFR Part 52, Subpart A, and other requirements referenced therein. This FSER documents the staff's conclusions with respect to the ESP safety review and identifies items to be addressed by a future COL or construction permit (CP) applicant referencing the CRN Site ESP.

The NRC regulations also contain requirements for an applicant to submit an environmental report pursuant to 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions." The staff reviews the environmental report as part of its responsibilities under the National Environmental Policy Act of 1969, as amended. The staff presents the results of that review in a final environmental impact statement (Final EIS), which is a report separate from this FSER. The Final EIS is provided to the U.S. Environmental Protection Agency (EPA). The staff's Final EIS for the ESPA, NUREG-2226, "Final Environmental Impact Statement for an Early Site Permit (ESP) at the CRN Site," can be accessed through the Agencywide Documents Access and Management System (ADAMS)[3] at Accession No. ML19087A266.

In a May 12, 2016 letter, TVA submitted an ESPA, Revision 0 (ADAMS Accession No. ML16139A752) for the CRN Site. The proposed CRN Site, which hosted the former Clinch River Breeder Reactor Project, is a tract of land adjacent to the Clinch River arm of the Watts Bar Reservoir, located west of the Oak Ridge Reservation, within the city of Oak Ridge, Tennessee. The site is bounded on the east, south, and west by the Clinch River arm of the

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[2] Applicants may also choose to seek a CP and operating license in accordance with 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" instead of using the 10 CFR Part 52 process.

[3] ADAMS is the NRC information system that provides access to all image and text documents that the NRC has made public since November 1, 1999, as well as bibliographic records (some with abstracts and full text) that the NRC made public before November 1999. Documents available to the public may be accessed via the Internet at http://www.nrc.gov/reading-rm/adams.html. Documents may also be viewed by visiting the NRC Public Document Room at One White Flint North, 11555 Rockville Pike, Rockville, Maryland. Telephone assistance for using web-based ADAMS is available at (800) 397-4209 between 8:30 a.m. and 4:15 p.m., Eastern Time, Monday through Friday, except Federal holidays. The staff is also making this FSER available on the NRC new reactor licensing public Web site at http://www.nrc.gov/reactors/new-reactors/esp/clinch-river.html.

Watts Bar Reservoir and on the north by the Grassy Creek Habitat Protection Area. Communities located near the site include Kingston (approximately 11.58 km [7.2 mi] west), Harriman (16.41 km [10.2 mi] west-northwest), Lenoir City (approximately 14.32 km [8.9 mi] southeast), and Knoxville (approximately 40.55 km [25.2 mi] east-northeast). The CRN Site is approximately 935 ac within a 1,200 ac property owned by the United States of America and managed by TVA. The applicant revised the ESPA over the course of the review to capture its responses to staff requests for additional information and other information provided on the docket as the result of regulatory audits described in this FSER. TVA submitted Revision 1 of the ESPA on December 15, 2017, and submitted Revision 2, the final revision of the application supporting this FSER, on January 18, 2019.

In accordance with 10 CFR Part 52, the CRN Site ESPA includes, among other information, the following:

- a description of the site and nearby areas that could affect or be affected by a NPP(s) located at the site;
- a safety assessment of the site on which the facility would be located, including an assessment of the major structures, systems, and components that bear significantly on the acceptability of the site;
- an assessment of whether any physical characteristics of the site could pose a significant impediment to the development of emergency plans;
- a major features emergency plan; and
- the quality assurance program under which ESP-related activities were performed.

Unique aspects of the application were the inclusion of two distinct major features emergency plans; requests for exemptions from emergency planning requirements, including requirements for the plume exposure pathway (PEP) emergency planning zone (EPZ); and a proposed methodology that a COL applicant could use to determine the PEP EPZ size. The ESPA describes how the site complies with the applicable requirements of 10 CFR Part 50, 10 CFR Part 52, and the siting criteria of 10 CFR Part 100, “Reactor Site Criteria.”

The applicant has not selected a particular reactor design for construction at the CRN Site. To provide sufficient facility design information for the proposed site, the applicant used the plant parameter envelope (PPE) approach, selecting a set of bounding parameters to represent a surrogate plant, and included these parameters in the ESPA along with the site characteristics that form the basis for an ESP. The PPE approach has been accepted by the NRC in previous ESPAs.

This FSER presents the conclusions of the staff’s review of the application, including supplemental information submitted by the applicant to staff in support of the ESPA. Supplemental information was provided by the applicant as a result of NRC staff observations shared and documented through NRC public meetings, audits, inspections, and requests for additional information (RAIs) transmitted to the applicant. The staff conducted a four-phase review of the application. The staff identified several open items during the first phase (i.e., Phase A, which included RAIs and supplemental RAIs). During the second phase (i.e., Phase B), the staff received and reviewed the applicant’s responses to all RAIs and all supplemental RAIs. In consideration of the applicant’s responses to the RAIs and the results of the audits and inspections conducted during Phases A and B, the staff issued chapter-specific Advanced Safety Evaluations (ASEs) with no open items at the end of Phase B. The staff

presented the ASEs to the NRC Advisory Committee on Reactor Safeguards (ACRS) as part of Phase C of the review. Phase D is the issuance of the final safety evaluation report (FSER). Section 1.6 of this FSER provides a brief summary of the process used to resolve issues that arose during the review; specific details about the resolution of these issues are presented in the corresponding sections of this report.

Appendix A of this FSER identifies the proposed Permit Conditions, site characteristics, and bounding design parameters that the staff recommends be imposed, if an ESP is issued to the applicant. Appendix A also includes certain site-related items (COL Action Items) that will need to be addressed in a COL or CP application that references the CRN Site ESP. The staff concluded that addressing these items is not required for the staff to make its regulatory findings on the ESPA and that, for reasons specified in this FSER, the COL Action Items are more appropriately addressed when the applicant has applied for a CP or COL.

Inspections, site visits, and regulatory audits conducted by the staff have verified, where appropriate, information supporting the conclusions in this FSER. The inspections and audits focused on selected information in the ESPA and its references and are cited and discussed in the applicable sections of this FSER.

The ACRS also reviewed the bases for the conclusions in this report, as required by 10 CFR 52.23, "Referral to the ACRS." The ACRS independently reviewed the aspects of the application that concern safety, as well as the relevant SER chapter sections, and provided the results of its review to the Commission in a January 9, 2019, report. Appendix E of this FSER includes a copy of the ACRS letter about the relevant SER chapter sections (ADAMS Accession No. ML19009A286) as well as a response letter from the NRC staff (ADAMS Accession No. ML19022A306).

ABBREVIATIONS

ΔP	pressure drop
$\Delta T/\Delta Z$	temperature change with height
°C	degree Celsius (Centigrade)
°F	degree Fahrenheit
Pb	bulk density
σ_{ci}	unconfined compressive strength
σy	lateral plume spread
σz	vertical plume spread
ABWR	Advanced Boiling-Water Reactor
ac	acre(s)
ac-ft	acre-feet
ACI	American Concrete Institute
ACRS	Advisory Committee on Reactor Safeguards
AQCR	Air Quality Control Region
ADAMS	Agencywide Documents Access and Management System
ALARA	As Low As Reasonably Achievable
ALI	Annual Limit on Intake
ANSI/ANS	American National Standards Institute/American Nuclear Society
ANS	alert and notification system
AOO	anticipated operational occurrence
AP1000	Advanced Passive 1000
API	Antecedent Precipitation Index
Ar	argon
ASCE	American Society of Civil Engineers
ASE	Advanced Safety Evaluation
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASLB	Atomic Safety Licensing Board
ASME	American Society of Mechanical Engineers
ASTM	ASTM International
ATV	acoustic televiewer
BFN	Browns Ferry Nuclear
bgs	below ground surface
bpf	blow(s) per foot
BTP	Branch Technical Position
BWXT	BWX Technologies, Inc.
µCi	microcurie(s)
C	carbon

CALPUFF	atmospheric dispersion modeling system
CDF	core damage frequency
CECC	Central Emergency Control Center
CEMP	Comprehensive Emergency Management Plan
CEUS	Central and Eastern United States
cfs	cubic feet per second
CH	classified as high
Ci	curie(s)
cm	centimeter(s)
Co	cobalt
COC	Chattanooga Office Complex
COL	combined license
COLA	combined license application
CP	construction permit
CRBRP	Clinch River Breeder Reactor Project
CRN	Clinch River Nuclear
CRREL	Cold Region Research and Engineering Laboratory
Cs	cesium
CU	consolidated undrained
CWS	circulating water system
1D	one-dimensional
2D	two-dimensional
3D	three-dimensional
d	day(s)
D	disturbance factor
DAC	Derived Air Concentration
DAD	depth-area-duration
DBA	design basis accident
DBE	design basis event
DBF	design basis flood
DHS	Department of Homeland Security
DL	dilution factor
DOE	U.S. Department of Energy
D/Q	deposition factor
DTM	Digital Terrain Model
EAB	exclusion area boundary
EAL	emergency action level
ECL	effluent concentration limit
EDO	Emergency Duty Officer
EL	elevation
EMT	Emergency Medical Technician
ENE	east-northeast

ENS	Emergency Notification System
EOC	emergency operation center
EOF	Emergency Operations Facility
EP	emergency planning
EPA	U.S. Environmental Protection Agency
EPIP	Emergency Plan Implementing Procedure
EPRI	Electric Power Research Institute
EPZ	Emergency Planning Zone
ER	Environmental Report
ERB	effluent release boundary
ERDS	Emergency Response Data System
ERO	emergency response organization
ERR	electronic reading room
ESE	east-southeast
ESP	early site permit
ESPA	early site permit application
ETTP	East Tennessee Technology Park
ETE	evacuation time estimate
ETS	Emergency Telecommunications System
ETSZ	Eastern Tennessee Seismic Zone
FEM	finite element method
FEMA	Federal Emergency Management Agency
fps	foot(feet) per second
FS	factor of safety
FSAR	Final Safety Analysis Report
FSER	Final Safety Evaluation Report
ft	foot(feet)
ft^2	square foot(feet)
FTS	Federal Telecommunications System
g	gram(s)
G	shear modulus
G/G_{max}	shear modulus degradation curve
Ga	Grenville-aged or billion year old
GI-LLI	gastrointestinal lower large intestine
GIS	geographic information system
GMM	Ground Motion Model
GMPE	ground motion prediction equation
GMRS	ground motion response spectrum
gpm	gallon(s) per minute
GSI	Geological Strength Index
H-3	tritium

HEC-HMS	Hydrologic Engineering Center-Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center-River Analysis System
HF	high-frequency
HIRAT	High-Resolution Acoustic Televiewer
HMR	hydrometeorological report
HPN	Health Physics Network
hr	hour(s)
HSA	Historical Site Assessment
Hz	hertz
I	iodine
IDLH	Immediately Dangerous to Life and Health
in.	inch(es)
iPWR	integral pressurized-water reactor
ISG	Interim Staff Guidance
ITAAC	Inspections, Tests, Analyses, and Acceptance Criteria
JFD	joint frequency distribution
JIC	Joint Information Center
K_d	distribution coefficient
kg	kilogram(s)
km	kilometer(s)
kN	kilonewton
kPa	kilopascal(s)
Kr	krypton
ksf	kip(s) per square foot
ksi	kip(s) per square inch
L	liter(s)
lb	pound(s)
LCD	Local Climatological Data
LF	low-frequency
LFL	lower flammability limit
LiDAR	light-detection and ranging
LIP	local intense precipitation
LLC	limited liability company
LLWR	large light water reactor
LOCA	loss of coolant accident
LPZ	low-population zone
LRC	Local Recovery Center
LRF	large release frequency
LWA	Limited Work Authorization
LWMS	Liquid Waste Management System

LWR	light-water reactor
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
M	magnitude
M1	model 1
M2	model 2
M	moment magnitude
Ma	million years ago
MACCS	MELCOR Accident Consequence Code System
mb	millibar(s)
mg	milligram(s)
M_{max}	maximum magnitude (earthquake)
MEI	maximally exposed individual
MERT	Medical Emergency Response Team
mg	milligram(s)
Mgd	million gallons per day
mg/L	milligram(s) per liter
mi	mile(s)
min	minute(s)
MJERP	Multi-Jurisdictional Emergency Response Plan
mL	milliliter(s) NI
m/s	meter(s) per second
m^3	cubic meter(s)
MOA	military operation area
MPa	megapascal(s)
mph	mile(s) per hour
mrad	millirad
mrem	millirem
MSWFE	maximum stillwater flood elevation
msl	mean sea level
MWe	megawatt(s) electric
MWt	megawatt(s) thermal
NAAQS	National Ambient Air Quality Standard
NAVD88	North American Vertical Datum of 1988
NCDC	National Climatic Data Center
Nb	niobium
NCDC	National Climatic Data Center
NCEI	National Centers for Environmental Information (formerly NCDC)
NE	northeast
NEI	Nuclear Energy Institute
NGVD29	National Geodetic Vertical Datum of 1929

NID	National Inventory of Dams
NIRMA	Nuclear Information and Records Management Association
NNW	north-northwest
NOAA	National Oceanic and Atmospheric Administration
NOUE	notification of unusual event
NPP	nuclear power plant
NP-REP	Nuclear Power Radiological Emergency Plan
NQA	Nuclear Quality Assurance
NQAP	Nuclear Quality Assurance Plan
NRC	U.S. Nuclear Regulatory Commission
NRF	National Response Framework
NRIA	Nuclear/Radiological Incident Annex
NSSS	Nuclear Steam Supply System
NTTF	Near-Term Task Force
NUREG	NRC technical report
NWS	National Weather Service
OCA	owner-controlled area
ODCM	Offsite Dose Calculation Manual
ODS	Operations Duty Specialist
ONT	other new technology
ORNL	Oak Ridge National Laboratory
ORO	offsite response organization
ORR	Oak Ridge Reservation
OSC	Operations Support Center
Pa	pascal(s)
PA	protected area
PAG	protective action guide
PAR	protective action recommendation
PAVAN	an atmospheric dispersion model
pcf	pound force per cubic foot
PEP	plume exposure pathway
PF	annual target performance goal
PGA	peak horizontal ground acceleration
P1	Profile 1
P2	Profile 2
P3	Profile 3
PI	Plasticity Index
$PM_{2.5}$	particulate matter less than 2.5 microns in aerodynamic diameter
PM_{10}	particulate matter less than 10 microns in aerodynamic diameter
PMF	probable maximum flood
PMH	probable maximum hurricane
PMP	probable maximum precipitation

PMSS	probable maximum storm surge
PMT	probable maximum tsunami
PMWP	probable maximum winter precipitation
PMWS	probable maximum wind storm
POR	period of record
PPE	plant parameter envelope
PRA	probabilistic risk assessment
PSAR	Preliminary Safety Analysis Report
PSEG	Public Service Enterprise Group
psf	pound(s) per square foot
PSHA	probabilistic seismic hazard analysis
psi	pound(s) per square inch
PWR	pressurized-water reactor
q_a	allowable bearing capacity
QA	quality assurance
QAP	Quality Assurance Plan
QC	quality control
RAI	request for additional information
RAM	Radiological Assessment Manager
RCP	reactor coolant pump
RCTS	Resonant Column and Torsional Shear
rem	roentgen equivalent man
REMP	Radiological Environmental Monitoring Program
REP	Radiological Emergency Preparedness; Radiological Emergency Plan
RG	Regulatory Guide
RLME	repeated large magnitude earthquake
RMCC	Radiological Monitoring Control Center
ROS	Reservoir Operations Study
RQD	Rock Quality Designation
RS	Review Standard
RVT	random vibration theory
rx-yr	reactor-year
s	second(s)
SACTI	Seasonal/Annual Cooling Tower Impact
SAR	safety analysis report
SASW	spectral analysis of surface wave
SCRAM	Support Center for Regulatory Atmospheric Modeling
sec	second(s)
SED	Site Emergency Director
SEI	Structural Engineering Institute
SEOC	State Emergency Operations Center

SER	safety evaluation report
SERTA	Safety and Emergency Response Training Academy
SESA	South Eastern Supplemental Adjustment
SM	Shift Manager
SMR	small modular reactor
SPDS	Safety Parameter Display System
SPT	Standard Penetration Test
SQN	Sequoyah Nuclear Plant
SRM	Staff Requirements Memorandum
SRP	Standard Review Plan
SSAR	site safety analysis report
SSC	Seismic Source Characterization
SSCs	structures, systems, and components
SSE	safe shutdown earthquake (ground motion)
SSHAC	Senior Seismic Hazard Analysis Committee
Sv	sievert(s)
SW	southwest
TAF	Terrain Adjustment Factor
Tc	technetium
Te	tellurium
TDEC	Tennessee Department of Environment and Conservation
TDS	total dissolved solids
TEDE	total effective dose equivalent
TEENS	TVA Enterprise Emergency Notification System
TEMA	Tennessee Emergency Management Agency
TI	Technical Integration (team)
TIN	triangulated irregular network
TMI	Three Mile Island
TSC	Technical Support Center
TVA	Tennessee Valley Authority
UHRS	Uniform Hazard Response Spectra
UHS	ultimate heat sink
UPS	Uninterruptible Power Supply
USACE	U.S. Army Corps of Engineers
USCB	U.S. Census Bureau
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
USGCRP	U.S. Global Change Research Program
UTM	Universal Transverse Mercator
VA	vital area
V/H	vertical to horizontal

VHF	very high frequency
V_p	compression wave (p-wave) velocity
V_s	shear wave (s-wave) velocity
WARL	Western Area Radiological Laboratory
WBN	Watts Bar Nuclear
WEWTP	West End Water Treatment Plant
WNW	west-northwest
WSE	water-surface elevation
WSW	west-southwest
WTP	Water Treatment Plant
χ/Q	atmospheric dispersion
Xe	xenon
XOQDOQ	computer code used to evaluate routine or anticipated, intermittent releases of radionuclides at nuclear power plants
yr	year(s)

1.0 INTRODUCTION AND GENERAL DESCRIPTION

In a May 12, 2016 letter, Tennessee Valley Authority (TVA or the applicant) submitted an early site permit (ESP) application, Revision 0, (TVA 2016-TN5002) to the U.S. Nuclear Regulatory Commission (NRC) for the proposed Clinch River Nuclear (CRN) Site. The applicant revised the ESP application over the course of the review to capture its responses to staff requests for additional information and other information provided on the docket as the result of regulatory audits described in this FSER. TVA submitted Revision 1 of the ESPA on December 15, 2017, and submitted Revision 2, the final revision of the application supporting this FSER, on January 18, 2019.

The proposed site, which hosted the former Clinch River Breeder Reactor Project, is located on a tract of land adjacent to the Clinch River arm of the Watts Bar Reservoir. The NRC docketed the application on December 30, 2016. Pursuant to 10 CFR Part 52, Subpart A (TN251), TVA requested an ESP with a permit duration of 20 years from the date of issuance.

The NRC staff (the staff) completed its review of the information presented in the CRN Site ESP application (ESPA) concerning the site's meteorology, hydrology, geology, and seismology, as well as the potential hazards to a nuclear power plant that could result from manmade facilities and activities on or in the vicinity of the site. The staff also assessed the risks of potential accidents that could occur as a result of the operation of a nuclear plant at the site and evaluated whether the site would support adequate physical security measures for a nuclear power plant (NPP). The staff evaluated whether the applicant's quality assurance measures were in accordance with the measures discussed in 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants" (TN249). The staff reviewed the two major features emergency plans that TVA would use to support the development for a combined license (COL) application of complete and integrated emergency plans that would be implemented if a NPP is eventually constructed at the CRN Site. Associated with these two major features emergency plans were two sets of exemption requests pertaining to emergency planning zone (EPZ) sizing that were evaluated and processed by the staff following the established agency guidance for exemption requests.

The CRN Site ESPA includes the site safety analysis report (SSAR), which describes a safety assessment of the site, as required by 10 CFR 52.17, "Contents of applications; technical information" (TN251). The public may inspect the final revision (Revision 2) of the entire ESPA at ADAMS Accession Nos. ML19030A485 [Cover Letter], ML18003A298 [Administrative Information], ML19030A358 [Site Safety Analysis Report; TVA 2019-TN5855], ML19030A478 [Environmental Report], ML18003A485 [Emergency Plan; TVA 2019-TN5857], ML19030A479 [Exemptions and Departures; TVA 2019-TN5856] and ML19030A568 [Enclosures; TVA 2019-TN6134]. The application is also available for public inspection at the NRC Public Document Room at One White Flint North, 11555 Rockville Pike, Rockville, MD 20852, at the Kingston Public Library, 1004 Bradford Way, Kingston, TN 37763, and at the Oak Ridge Public Library, 1401 Oak Ridge Turnpike, Oak Ridge, TN 37830.

This final safety evaluation report (FSER)[4] documents the staff's technical evaluation of the suitability of the proposed CRN Site for construction and operation of a NPP falling within the plant parameter envelope (PPE) that TVA specified in its application—specifically, two or more SMRs with a maximum rated thermal power for a single unit of 800 MWt (reactor core). The combined nuclear generating capacity for the site is not to exceed 2,420 MWt (800 MWe).

This FSER delineates the scope of the technical matters that the staff considered when evaluating the suitability of the proposed NPP site in accordance with NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants; LWR Edition," (NRC 2018-TN5898; hereafter referred to as the SRP). The SRP reflects the staff's many years of experience in establishing guidance to enhance the safety of nuclear facilities, as well as in performing safety assessments and evaluations.

The applicant also filed an environmental report for the CRN Site in which it evaluated matters related to the environmental impact assessment that can be reasonably reviewed at this time. The staff discussed the results of its evaluation of the environmental report for the CRN Site in a final environmental impact statement (Final EIS) NUREG-2226 (NRC 2019-TN6136).

Appendix A of this FSER lists the site characteristics, Permit Conditions, COL Action Items, and the bounding design parameters, that the staff recommends the Commission include in any ESP that might be issued for the proposed site. Appendix B of this FSER presents a chronology of the principal actions and correspondence related to the staff's review of the ESPA for the CRN Site. Appendix C lists the references for this FSER, Appendix D lists the principal contributors to this report, and Appendix E includes a copy of the letter by the ACRS and a follow-up clarification letter by NRC staff.

1.1 General Site Description

The CRN Site is within the city limits of Oak Ridge, Tennessee, and is approximately 11.58 km (7.2 mi) east of Kingston, approximately 16.41 km (10.2 mi) east-southeast of Harriman, , approximately 14.32 km (8.9 mi) northwest of Lenoir City, and approximately 40.55 km (25.2 mi) west-southwest of Knoxville—all in Tennessee. The site location is shown in SSAR Figures 2.1-3 and 2.1-4 (TVA 2016-TN5018), which identify major towns, roads, and other prominent features within 8 km (5 mi) and 80 km (50 mi), respectively, of the CRN Site. The existing 3.79 km^2 (935 ac) TVA-managed property is on a tract of land adjacent to the Clinch River arm of the Watts Bar Reservoir, located west of the Oak Ridge Reservation, within the city of Oak Ridge, Tennessee. The site is bounded on the east, south, and west by the Clinch River arm of the Watts Bar Reservoir and on the north by the Grassy Creek Habitat Protection Area.

According to the U.S. Census Bureau (USCB), the city of Oak Ridge had a 2010 population of 29,330 and is the largest city within 10 mi of the site. Lenoir City, the second largest city within 10 mi, had a population of 8,642 persons (USCB 2013-TN6084). The major transportation route in the vicinity of the site is U.S. Interstate 40 (I-40), which passes approximately 0.96 km (0.6 mi) to the southeast and serves as the primary east to west thoroughfare. At the closest

[4] This FSER documents the NRC staff's position on all safety issues associated with the ESPA. The relevant SER chapters and sections of this FSER have undergone a final review by the Advisory Committee on Reactor Safeguards (ACRS), and the results of the ACRS review are in a letter provided to the Commission by the ACRS (NRC 2019-TN6135). This letter, as well as a reponse letter from the NRC staff (NRC 2019 – ML19022A306), are included in Appendix E to this FSER.

approach, Tennessee State Route 58 (TN 58) is located about 1.45 km (0.9 mi) northwest of the site, and TN 95 is located about 4.18 km (2.6 mi) east of the site.

The location selected for a new NPP on the CRN Site is situated on the historical Clinch River Breeder Reactor Project site, and the bounding plant area, associated infrastructure, and proposed water intake and discharge locations are shown on the applicant's Site Map (Figure 2.1-1 of the SSAR [TVA 2016-TN5018]). The site is traversed by two power lines, the northeast-southwest Bull Run FP–Watts Bar NP 500 kV transmission line, and the northwest-southeast Bear Creek 161 kV No.1 transmission line.

1.2 <u>Plant Parameter Envelope</u>

The regulations in 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (TN251), and 10 CFR Part 100, "Reactor Site Criteria" (TN282), that apply to an ESP do not require an ESP applicant to provide detailed facility design information. However, some facility design information is required by 10 CFR 52.17(a)(1) (TN251), including 10 CFR 52.17(a)(1)(ix) (TN251), which requires "an analysis and evaluation of the major structures, systems, and components of the facility that bear significantly on the acceptability of the site under the radiological consequence evaluation factors identified in paragraphs (a)(1)(ix)(A) and (a)(1)(ix)(B) of this section."

In SSAR Section 2.0, "Plant Parameter Envelope," the applicant stated that it is currently evaluating four light-water-cooled SMR technologies for deployment at the CRN Site (TVA 2016-TN5018). Because a reactor technology has not been selected for deployment at the CRN Site, the plant-site interface is defined through a collection of site-related design parameters known as the PPE. The PPE is a set of postulated parameters furnished by the applicant that bound the parameters of a reactor or reactors that might be deployed at the CRN Site, and provide sufficient design detail to support both the NRC safety and environmental review of the ESPA Table 2.0-2 of the SSAR defines and describes each plant parameter, and references the location in the SSAR where additional information may be found (TVA 2016-TN5018). In SSAR Section 1.11, "Overview of Reactor Types" (TVA 2016-TN5018), the applicant identified the four conceptual, light-water cooled, SMR designs that were used to create a "surrogate plant" as defined in NEI 10-01, *Industry Guideline for Developing a Plant Parameter Envelope in Support of an Early Site Permit* (NEI 2012-TN5979). Available information from the following reactor designs was used in developing both the surrogate plant and the site-related PPE values:

- BWX Technologies, Inc. (BWXT) mPower™ (Generation mPower LLC design)
- NuScale (NuScale Power, LLC, design)
- SMR-160 (Holtec SMR, LLC, design)
- Westinghouse SMR (Westinghouse Electric Company, LLC, design).

The staff evaluated the PPE values in the context of the applicable SSAR sections of the ESPA. All questions and issues associated with the PPE values that the staff identified during the review as well as their resolution, are discussed in individual sections of this FSER.

The applicant provided, through its PPE, sufficient design information to allow it to perform the analysis required by 10 CFR 52.17(a)(1) (TN251) to determine the adequacy of the proposed exclusion area boundary (EAB) and low-population zone (LPZ) for the site. SSAR Chapter 15, "Accident Analysis," documents the results of this analysis (TVA 2016-TN5018). As described in SSAR Section 15.1, "Accident Selection," the applicant performed the analysis for a broad

spectrum of representative postulated design basis accidents (DBAs) to determine the bounding radiological consequences that affect the safe design and siting of an advanced light-water reactor (LWR) (TVA 2016-TN5018). The applicant selected accidents based on the LWR technologies being considered for development and the regulatory guidance for performing DBA analysis.

In addition to the information supporting the radiological dose consequence evaluation, the applicant provided other design information in its PPE. Because the applicant is not requesting that an ESP be issued referencing a specific reactor design, the staff's review criterion for the PPE is that the PPE values should not be unreasonable for a reactor that might be constructed on the ESP site.

The PPE, along with a summary of site characteristics provided in Table 2.0-1 of the SSAR (TVA 2016-TN5018), compose the ESP bases that will be the focus for comparison if a COL or construction permit (CP) application is submitted for the CRN Site. Appendix A to this FSER lists the site characteristics and bounding design parameters identified for the CRN Site.

If an ESP is issued for the CRN Site, an entity might wish to reference that ESP, as well as a certified design, in a COL or CP application. Such a COL or CP applicant must demonstrate that the site characteristics established in the ESP are bounded by the postulated site parameters established for the chosen design, and that the design characteristics of the chosen design fall within the bounding parameter values specified in the ESP. Otherwise, the COL or CP applicant must demonstrate that the design may be safely located on the site, notwithstanding the variance from a given ESP design parameter or site characteristic.

1.3 Identification of Agents and Contractors

In Part 2, Chapter 1 "Identification of Agents and Contractors," of the ESPA, the applicant provided information about the agents and contractors used in the development and preparation of the ESPA (TVA 2016-TN6151). Section 3.1, "Name of Applicant and Owner" of Part 1 (TVA 2016-TN6151) identifies TVA as the applicant for the CRN Site. The CRN Site is owned by the United States of America and managed by TVA as an agent of the Federal government. In Section 3.3, "Description of Business or Occupation of Applicant and Owner" of Part 1 (TVA 2016-TN6151), the applicant stated that TVA, a corporate agency and instrumentality of the United States, was created in 1933 by the U.S. Congress by virtue of the Tennessee Valley Authority Act of 1933, as amended ("TVA Act") (16 U.S.C. §§ 831-831ee [as amended [TN5024]). The applicant, being an agency of the United States, is not prohibited by 10 CFR 50.38 (TN249) from applying for or obtaining an ESP.

TVA was created to, among other things, improve navigation on the Tennessee River, reduce the damage from destructive floodwaters within the Tennessee River system and downstream on the lower Ohio and Mississippi Rivers, further the economic development of TVA's service area in the southeastern United States, and sell the electricity generated at the facilities TVA operates. TVA's service territory, which includes most of Tennessee and parts of Alabama, Georgia, Kentucky, Mississippi, North Carolina, and Virginia, serves more than nine million people. TVA sells electricity to 155 local power company customers and directly serves approximately 52 large industrial facilities and 8 Federal facilities. TVA has complete authority to regulate any and all access to, and activity within, the plant EAB, and authority to act as the agent of the site owner.

For the development of the ESPA, TVA used the services of the following three principal contractors and other participants:

- BWX Technologies, Inc. – TVA had a contract with BWXT to provide technical information to TVA in support of the ESPA.
- Generation mPower LLC – BWXT contracted Generation mPower to manage development of portions of the ESPA.
- Bechtel Power Corporation – Bechtel Power Corporation assisted in developing portions of the SSAR and conducted various analyses and investigations, including:
  - geotechnical field investigations, with contracted support from Amec Foster Wheeler
  - identification and characterization of seismic source zones, with contracted support from Lettis Consultants International
  - determination of site-specific distribution coefficients, with contracted support from Argonne National Laboratory.

TVA also retained the services of other contractors and specialized consulting firms to assist in preparation of the ESPA for the CRN Site because of their expertise related to technical areas, as described below:

- Barge Waggoner Sumner & Cannon, Inc. – contracted by TVA to perform evaluations and studies in the area of hydrology.
- Enercon Services, Inc. – contracted by TVA to prepare portions of the SSAR related to demography and meteorology and to develop the Emergency Plans.
- AECOM Technical Services Inc. – contracted by TVA to perform a portion of the seismic analyses.

With respect to the activities necessary to prepare the ESP application, the applicant demonstrated its technical qualifications. In Chapter 17 of this FSER, the staff concluded that the Applicant's Quality Assurance Program Description satisfies all applicable NRC requirements regarding preparation of the application. In addition, the applicant has extensive experience as a nuclear plant owner and operator of the TVA nuclear fleet (Sequoyah, Watts Barr and Browns Ferry nuclear generating stations). For all these reasons, the applicant is technically qualified under 10 CFR 52.24(a)(4).

1.4 <u>Summary of Principal Review Matters</u>

This FSER documents the staff's safety evaluation of the CRN Site ESPA. The staff's evaluation included a technical review of the information and data the applicant submitted, with emphasis on the following principal matters:

- the population density and land use characteristics of the site environs and the physical characteristics of the site, including meteorology, hydrology, geology, and seismology, to evaluate whether these characteristics were adequately described and appropriately considered when determining whether the site characteristics are in accordance with the Commission's siting criteria (10 CFR Part 100, Subpart B, "Evaluation Factors for Stationary Power Reactor Site Applications on or After January 10, 1997" [TN282]);
- the potential hazards from manmade facilities and activities to a NPP that might be constructed on the ESP site (e.g., mishaps involving storage of hazardous materials [toxic

chemicals, explosives], and transportation accidents [aircraft, marine traffic, railways, pipelines]);

- the potential capability of the site to support the construction and operation of a NPP with design parameters falling within those specified in the application under the requirements of 10 CFR Part 52 (TN251) and 10 CFR Part 100 (TN282);
- the suitability of the site for development of adequate physical security plans and measures for a NPP;
- two major features emergency plans, as well as exemption requests pertaining to plume exposure pathway EPZ sizing, if TVA applies for a CP or COL referencing the CRN Site ESP; any significant impediments to the development of emergency plans for the CRN Site; and a description of contacts and arrangements made with Federal, State, and local government agencies with emergency planning responsibilities;
- the nuclear quality assurance plan in accordance with the requirements of 10 CFR 52.17(a)(1)(xi) (TN251); and Appendix B to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" (TN249); and
- the acceptability of the applicant's proposed exclusion area and LPZ under the dose consequence evaluation factors of 10 CFR 50.34(a)(1) (TN249).

During its review, the staff held several meetings with representatives of TVA and its contractors and consultants to discuss various technical matters related to the staff's review of the CRN Site (refer to Appendix B of this FSER). The staff also visited the site to evaluate safety features and matters.

Appendix A of this FSER includes a list of the site characteristics, bounding design parameters, COL Action Items, and Permit Conditions that the staff recommends be included in an ESP for the CRN Site. The site characteristics are based on site investigation, exploration, analysis, and testing performed by the applicant and are specific physical attributes of the site, whether natural or manmade. Bounding design parameters set forth the postulated design parameters that support the staff's review. An explanation of COL Action Items and Permit Conditions is provided in Sections 1.6 and 1.7, respectively.

1.5 Summary of Open Items and Confirmatory Items

The staff conducted a four-phase review of the CRN Site ESPA. The staff identified several open items during the first phase (i.e., Phase A, which included requests for additional information [RAIs] and supplemental RAIs). For this phase, the staff considered an item to be open if the applicant had not yet provided the requested information and the staff did not know what would ultimately be included in the applicant's response. During the second phase (i.e., Phase B), the staff received and reviewed the applicant's responses to all RAIs and all supplemental RAIs. In consideration of the applicant's responses to the RAIs and the results of the regulatory audits conducted in Phases A and B, the staff developed Advanced Safety Evaluations (ASEs) with no open items at the end of Phase B. The staff presented the ASEs with no open items to the Advisory Committee on Reactor Safeguards (ACRS) as part of Phase C of the review. Phase D is the issuance of this FSER.

The staff identified confirmatory items to verify that the applicant incorporated all the necessary changes to which it had committed in RAI responses. An item was identified as confirmatory if

the staff and the applicant agreed on a resolution of a particular item, but the resolution had not yet been formally documented in the subsequent revision of the application.

The staff has completed its review of Revision 2 of the CRN Site ESPA, submitted by the applicant on January 18, 2019 (TVA 2019-TN6195), and has verified that the applicant did incorporate the changes, to which it had committed in RAI responses, in Revision 2. The staff documented the incorporation of these changes in this FSER and all confirmatory items are now closed.

1.6 Summary of Combined License Action Items

The staff also identified certain site-related items that will need to be addressed in a COL or CP application that references the CRN Site ESP. This report refers to these items as COL Action Items. The COL Action Items relate to issues that are outside the scope of the ESP review. The COL Action Items do not establish requirements; rather, they identify information that should be included in the site-specific portion of the SSAR submitted by a COL applicant or CP applicant referencing the CRN Site ESP. An applicant for a COL or CP referencing the CRN Site ESP will need to address each of these items in its application. The applicant may deviate from or omit these items provided that the COL or CP application identifies and justifies the deviation or omission. The staff determined that the COL Action Items are not required for the staff to make its regulatory findings on the ESP and for reasons specified in this FSER for each item, the COL Action Items are more appropriately addressed when the applicant has applied for a CP or COL.

The staff identified 43 COL Action Items, which are listed in Appendix A of this FSER. These COL Action Items are documented in Appendix A of this FSER to ensure that particular significant issues are tracked and considered during the COL or CP application review. Usually, COL Action Items are not necessary for issues covered by Permit Conditions or explicitly covered by the bounding parameters. The list of COL Action Items is not exhaustive with respect to the information required to meet the requirements for a CP or COL.

1.7 Summary of Permit Conditions

The staff identified certain Permit Conditions that it will recommend be imposed if an ESP is issued to the applicant. Of the seven Permit Conditions identified, two are associated with Section 2.2 of the application, two are associated with Section 2.5 of the application, two are associated with Section 13.3 of the application, and one is discussed in the following paragraph.

As explained above, if a CRN Site ESP is issued, the ESP could be referenced in a later CP or COL application. This possibility is also discussed in ESPA, Part 1, "Administrative Information," Section 2.1. However, the SSAR does not consistently reflect the possibility that a CP applicant could reference the ESP. For example, the SSAR Section 13.3 discussion of the plume exposure pathway EPZ sizing methodology only mentions COL applicants, not CP applicants. Therefore, to appropriately account for the possibility that a CP application references the ESP, the staff proposes the following Permit Condition:

- Permit Condition 1.7-1 (7): If an applicant for a CP references this ESP, then references in the ESP SSAR to COL, COL applicant, or COL application will include and apply to a CP, CP applicant, and CP application, respectively, unless the context indicates otherwise.

Appendix A of this FSER summarizes the Permit Conditions. Each Permit Condition has been assigned numbers based on the corresponding sections of this FSER in which they appear as well as a sequential number (i.e., one through seven). The staff has provided an explanation of each Permit Condition in the applicable section of this report. The Permit Conditions are imposed pursuant to 10 CFR 52.24, “Issuance of early site permit” (TN251).

1.8 Summary of Inspections, Tests, Analyses, and Acceptance Criteria

The ESPA did not include any emergency planning inspections, tests, analyses, and acceptance criteria, as permitted by 10 CFR 52.17(b)(3) (TN251) for the major features emergency plan submitted by the applicant.

2.0 SITE CHARACTERISTICS

2.1 Geography and Demography

2.1.1 Site Location and Description

The descriptions of the Clinch River Nuclear (CRN) Site area and small modular reactor (SMR) locations are used to assess the acceptability of a nuclear reactor site. The U.S. Nuclear Regulatory Commission (NRC) staff's review covers the following specific areas: (1) the specification of SMR location with respect to latitude and longitude, political subdivisions, and prominent natural and manmade features of the area; (2) a map of the site area to determine the distance from the CRN power block area to the boundary lines of the exclusion area, including consideration of the location, distance, and orientation of plant structures with respect to highways, railroads, and waterways that traverse or lie adjacent to the exclusion area; and (3) any additional information requirements prescribed in the applicable subparts of Title 10 of the *Code of Federal Regulations* (10 CFR) 52.17, "Contents of Applications; Technical Information" (TN251). The purpose of the review is to ascertain the accuracy of the applicant's description of the CRN Site for use in independent evaluations of the exclusion area authority and control, the surrounding population, and nearby manmade hazards.

2.1.1.1 *Summary of Application*

The applicant addressed the CRN Site location and description in Site Safety Analysis Report (SSAR) Section 2.1.1, "Site Location and Description" of the early site permit (ESP) application (ESPA) (TVA 2017-TN5387), in which the applicant provided site-specific information related to the CRN Site location and description, including political subdivisions, natural and manmade features, population, highways, railways, waterways, and other significant features of the area. In SSAR Figures 2.1.3, "Vicinity Map," consisting of the "5-Mile Radius," and Figure 2.1.4, "50-Mile Region," the applicant showed the CRN Site location and the surrounding area within 8 km (5 mi) and 80 km (50 mi), respectively, and identified the prominent natural and manmade features, including the Clinch River, towns, industrial, military facilities, and major transportation routes.

2.1.1.2 *Regulatory Basis*

The relevant requirements of NRC regulations for the site location and description and the associated acceptance criteria, are specified in Section 2.1.1 of NUREG‑0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants; LWR Edition" (hereafter the SRP) (NRC 2007/2018-TN5898).

The applicable regulatory requirements for identifying site location and description are as follows:

- 10 CFR 50.34(a)(1), "Contents of Applications; technical information" (TN249), 10 CFR 52.17(a)(1), "Contents of Applications; technical information" (TN251), and 10 CFR 52.79(a)(1), "Contents of Applications; technical information in final safety analysis report" (TN251), as they relate to the inclusion in the safety analysis report (SAR) of a detailed description and safety assessment of the site where the facility will be located, with appropriate attention given to features affecting facility design; and

- 10 CFR Part 100, "Reactor Site Criteria" (TN282), as it relates to the following: (1) defining an exclusion area and setting forth requirements regarding activities in that area (10 CFR 100.3, "Definitions" [TN282]); (2) addressing and evaluating factors that are used to determine the acceptability of the site as identified in 10 CFR 100.20, "Factors to be considered when evaluating sites," Subpart (b) (TN282); (3) determining an exclusion area such that certain dose limits would not be exceeded in the event of a postulated fission product release as identified in 10 CFR 50.34(a)(1) (TN249), as it relates to site evaluation factors identified in 10 CFR Part 100 (TN282); and (4) requiring that the site location and the engineered features included as safeguards against the hazardous consequences of an accident, if one occurred, would ensure a low risk of public exposure.

2.1.1.3 *Technical Evaluation*

SSAR Section 2.1.1 (TVA 2017-TN5387) describes the site and its location.

The CRN Site is in Roane County within the city limits of Oak Ridge, Tennessee. The CRN Site consists of approximately 3.79 km^2 (935 ac) and is located on a peninsula formed by a meandering Clinch River arm of the Watts Bar Reservoir where there is approximately 4.86 km^2 (1,200 ac) of Clinch River property. The property is bounded on the east, south, and west by the Clinch River arm of the Watts Bar Reservoir, and on the north by the U.S. Department of Energy's Oak Ridge Reservation and Wildlife Management Area. The site is situated on the site of the historical Clinch River Breeder Reactor Project (CRBRP).

Other communities located near the site include Kingston (west), Harriman (west-northwest), Lenoir City (southeast), and Knoxville (east-northeast), Tennessee, which are respectively located approximately 11.58 km (7.2 mi), 16.41 km (10.2 mi), 14.32 km (8.9 mi), and 40.55 km (25.2 mi) from the site center point. According to U.S. Census Bureau (USCB), the city of Oak Ridge had a 2010 population of 29,330 and is the largest city within 10 mi of the site. Lenoir City, the second largest city within 10 mi, had a population of 8,642 persons (USCB 2013-TN6084).

SSAR Figure 2.1-4 shows the CRN Site location and the surrounding area within 80 km (50 mi) (TVA 2017-TN5387). The site location, natural and manmade features, including rivers and major transportation routes within 8 km (5 mi), are shown in SSAR Figure 2.1-3 (TVA 2017-TN5387). The major transportation route in the vicinity of the site is U.S. Interstate 40 (I-40), which passes approximately 0.96 km (0.6 mi) to the southeast and serves as the primary east to west thoroughfare. At the closest approach, Tennessee State Route 58 (TN 58) is located about 1.45 km (0.9 mi) northwest of the site, and TN 95 is located about 4.18 km (2.6 mi) east of the site. No military facilities are located in the vicinity of the site. No regularly scheduled passenger transportation trains pass through or service any cities within the 80 km (50 mi) region. However, excursion trains provide entertainment in the region, and a rail line in the vicinity is used for commercial purposes.

The CRN property is illustrated in SSAR Figure 2.1-1 (TVA 2017-TN5387). The CRN property is the same as the owner-controlled area. No public access roads traverse the site and no commercial, institutional, recreational, or residential structures are located on the site. No mineral resources, including oil and natural gas, within or adjacent to the site are being exploited. The only known resource of value located within the property is limestone, and the U.S. Federal Government owns all of the mineral rights for the property. The topography of the property is characterized by a series of parallel ridges and valleys, generally oriented in a

northeast to southwest direction. Elevations on the site range from 225 m (740 ft) above mean sea level (msl) to a high of 341.4 m (1,120 ft) above msl.

The exclusion area boundary (EAB) is delineated by the boundaries of the CRN Site and is designated to be the CRN property line, as shown in SSAR Figure 2.1-5 (TVA 2017-TN5387). However, an analytical EAB based on the shortest distance between the effluent release point and boundary of analytical EAB for each of 16 compass sectors is used conservatively as 1,100 ft, and is used for atmospheric dispersion (χ/Q) modeling. This distance is established based on the minimum distance between the release point and the analytical EAB such that an individual located at any point on the EAB boundary would not receive a radiation dose in excess of 25 rem total effective dose equivalent over any 2-hour period following a postulated fission product release. The various analytical EABs can be encompassed by an ellipse fixed completely within the CRN property boundary. Because the radiological dose is directly proportional to the χ/Q value and the χ/Q value decreases as a function of distance from the release point to the boundary of EAB, the analytical EAB dose bounds the dose at the encompassed ellipse-shaped EAB and the actual EAB. A detailed discussion of the analytical EAB approach is presented in SSAR Sections 2.3.4 and 2.3.5.2 (TVA 2016-TN5018). The staff communicated to the applicant in a February 13, 2017 public meeting that an EAB designation should not be applied to various areas such as the site boundary, 1 mi CRN Site boundary, and 1,100 ft analytical EAB (NRC 2017-TN5864). These designations need to be identified discretely to clearly distinguish the EAB, analytical EAB, and site boundary designations. Therefore, during the public meeting, the applicant was asked to provide, and subsequently provided, supplemental information (TVA 2017-TN5865) that referred to the EAB as the area that is delineated by the boundaries of the CRN property, as shown in updated SSAR Figure 2.1-5 (TVA 2017-TN5387). The shortest distance between the effluent release point and boundary of 1,100 ft for each of the 16 compass sectors is used as the analytical EAB for short-term meteorological dispersion and radiological dose evaluation purposes.

The staff reviewed the SSAR Section 2.1.1 (TVA 2017-TN5387) description of the site and its location, including natural and manmade features, highways, railways, waterways, and other significant features of the area. The staff confirmed that the information in the application addresses the requirements for identifying the CRN Site location and description.

Using publicly available maps, the staff independently estimated and confirmed the latitude and longitude that the applicant supplied. The staff then converted the latitude and longitude to Universal Transverse Mercator (UTM) coordinates and verified the UTM coordinates of the CRN Site reference point in the SSAR (TVA 2017-TN5387).

The geodetic and UTM coordinates are as follows:

Geodetic		**UTM Coordinates (NAD83, Zone 16 [m])**	
Latitude	Longitude	Northing	Easting
N35° 53' 27.2"	W84° 22' 48.0"	3,974,815.26 m (13,040,732.48 ft)	736,407.14 m (2,416,033.924 ft)

The staff reviewed the site map in the SSAR (Figure 2.1-1) (TVA 2017-TN5387) for the proposed CRN Site to verify that the distance from the proposed power block to the boundary line of the exclusion area meets the guidance in SRP Section 2.1.1 (NRC 2007/2018-TN5898). Based on its review of the information in the SSAR, and confirmatory review of prominent, natural, and manmade features of the area as found in publicly available documentation, the

staff finds the information provided by the applicant with regard to the CRN Site location and description adequate and acceptable.

2.1.1.4 *Conclusion*

As discussed above, the applicant presented and described information to establish the CRN Site location and description, which includes the information submitted by the applicant in response to public meeting discussions and updates to the SSAR (TVA 2017-TN5387). The staff reviewed the information that the applicant submitted and, for the reasons given above, concludes that the applicant has established site characteristics and design parameters acceptable to meet the requirements of 10 CFR 52.17(a)(1) (TN251), 10 CFR 100.3 (TN282), and the radiological consequence evaluation factors in 10 CFR 50.34(a)(1) (TN249). The staff also affirms that the applicant provided sufficient details about the CRN Site location and site area, as documented in SSAR Sections 2.1.2, 2.1.3 and 13.3 and SSAR Chapter 15 (TVA 2017-TN5387). These details allowed the staff to conclude that the applicant met the requirements in 10 CFR 52.17(a)(1) (TN251) and 10 CFR Part 100 (TN282) regarding site location and description.

2.1.2 Exclusion Area Authority and Control

The descriptions of exclusion area authority and control are used to verify that the applicant's legal authority to determine and control activities within the designated EAB, as provided in the application, is sufficient to allow reviewers to assess the acceptability of the site. The staff's review includes the following specific areas:

- establishing the applicant's legal authority to determine all activities within the designated exclusion area;
- validating the applicant's authority and control to exclude or remove personnel and property from the area in the event of an emergency;
- establishing that proposed or permitted activities in the exclusion area that are unrelated to operation of the facility do not result in a significant hazard to public health and safety; and
- requesting any additional information prescribed in 10 CFR 52.17 (TN251).

2.1.2.1 *Summary of Application*

In the CRN Site SSAR (TVA 2017-TN5387), the applicant identified the EAB and addressed the authority and control of the area in the case of an emergency. The applicant addressed the information pertaining to ownership, activities, authority, and control, including arrangements for traffic control.

2.1.2.2 *Regulatory Basis*

The relevant requirements of NRC regulations for exclusion area authority and control and the associated acceptance criteria are specified in SRP Section 2.1.2, "Exclusion Area Authority and Control" (NRC 2007/2018-TN5898), and in Review Standard (RS) 002, "Processing Applications for Early Site Permits" (NRC 2004-TN2219).

The applicable regulatory requirements for verifying exclusion area authority and control are as follows:

- 10 CFR 50.34(a)(1) (TN249) and 10 CFR 52.17(a)(1) (TN251), as they relate to the inclusion in the site SAR of a detailed description and safety assessment of the site on which the facility is to be located, with appropriate attention given to features affecting facility design; and
- 10 CFR Part 100 (TN282), as it relates to the following: (1) defining an exclusion area and setting forth requirements regarding activities in that area (10 CFR 100.3 [TN282]); (2) addressing and evaluating factors that are used to determine the acceptability of the site as identified in 10 CFR 100.20(b) (TN282); and (3) determining an exclusion area such that certain dose limits would not be exceeded in the event of a postulated fission product release as identified in 10 CFR 50.34(a)(1) (TN249) as it relates to site evaluation factors identified in 10 CFR Part 100 (TN282).

2.1.2.3 *Technical Evaluation*

The CRN Site consists of approximately 3.79 km^2 (935 ac) and is located on a peninsula formed by a meandering Clinch River arm of the Watts Bar Reservoir, within approximately 4.86 km^2 (1,200 ac) of Clinch River property owned by U.S. Federal Government and managed by the Tennessee Valley Authority (TVA). No public transportation routes cross the site. No mineral resources, including oil and natural gas within or adjacent to the site, are being exploited. The only resource of value located within the property is limestone, and the U.S. Federal Government owns all of the mineral rights for the property. The CRN property would be clearly posted with “no trespassing” signs along the property border and river shorelines. All road access points will be controlled. Once inside the owner-controlled area, access to the nuclear plant will be controlled with security check-points and barriers. The permanent population distribution within the EAB is zero. TVA controls all activities within the EAB including exclusion and removal of personnel and property from the area. TVA owns and maintains transmission lines and maintains access control of the transmission rights-of-way that traverse the site.

There are no residences or commercial activities within the EAB. Recreational activities and hunting within the owner-controlled area and the EAB are prohibited and are controlled by security personnel. No public highways or active railroads traverse the exclusion area. Barge traffic occurs adjacent to the EAB along the Clinch River arm of the Watts Bar Reservoir. One small family cemetery and one Native American burial mound are located on the site; however, access to them is controlled by security personnel. Arrangements for traffic control or abandonment or relocation of roads are not required because no public roads cross the EAB.

2.1.2.4 *Conclusion*

As discussed above, the applicant presented information pertaining to legal authority and control of all the activities within the designated EAB. The staff reviewed the information and, for the reasons stated above, concludes that the applicant’s designated exclusion area is reasonable and acceptable, and meets the requirements of 10 CFR 50.34(a)(1) (TN249), 10 CFR 52.17(a)(1) (TN251), 10 CFR Part 100 (TN282), and 10 CFR 100.3 (TN282) in determining the acceptability of the CRN Site. The staff based its conclusion on the determination that the applicant appropriately described the plant exclusion area and the authority under which all activities within the exclusion area can be controlled.

2.1.3 Population Distribution

The description of population distributions addresses the need for information about the following:

- the population in the site vicinity, including transient populations;
- the population in the exclusion area;
- whether appropriate protective measures could be taken on behalf of the populace in the specified low-population zone (LPZ) in the event of a serious accident;
- whether the nearest boundary of the closest population center having 25,000 or more residents is at least one and one-third times the distance from the reactor to the outer boundary of the LPZ;
- whether the population density in the site vicinity is consistent with the guidelines given in Regulatory Guide (RG) 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Regulatory Position C.4 (NRC 2014-TN3550); and
- any additional information requirements prescribed in the applicable subparts to 10 CFR 52.17, "Contents of Applications; Technical Information" (TN251).

2.1.3.1 *Summary of Application*

In the CRN Site SSAR (TVA 2017-TN5387), the applicant addressed the population distribution surrounding the CRN Site to an 80 km (50 mi) radius based on 2010 U.S. Census data, which were the most recent data at the time of submission of the ESPA. The population distribution was estimated in 15 concentric rings for 16 cardinal directional sectors. The population projections were derived from county estimates obtained from the States and based on cohort component (Kentucky and Tennessee) and cohort survey (North Carolina) methodologies. Using linear or polynomial regression, an equation was derived to analyze population growth for each county, and it was used in conjunction with 2010 Census data to produce a growth ratio. These growth ratios calculated for each county were then weighted by area and summed into sectors and used further to produce a sector-level population projection ratio set for the 80 km (50 mi) region. The years selected for the projection period represent the 2010 Census, calculation development year 2013, projected start of construction year 2021, and projected commencement of operation date of 2027 with an operational life of 40 years (until 2067). The projected permanent population for each sector out to 16 km (10 mi) and from 16 km (10 mi) out to 80 km (50 mi), for the years 2010, 2013, 2021, 2027, 2037, 2047, 2057, and 2067 was addressed along with the estimated transient population. For the CRN Site, the LPZ is defined as the area within the 1.6 km (1 mi) radius from the site center point. Based on the 2010 Census 149 people live in the LPZ. The distribution of people within the LPZ is presented in SSAR Table 2.1-7 (TVA 2017-TN5387). One special facility identified as Kingston Academy, a 52-bed coed psychiatric residential treatment facility for children, is within the LPZ. There are no hospitals, prisons, or jails within the LPZ. Population center distance and population density are also addressed. The information in the application is reviewed and evaluated by the staff and presented below in Section 2.1.3.4 of this chapter.

2.1.3.2 *Regulatory Basis*

The relevant requirements of NRC regulations for population distribution and the associated acceptance criteria are specified in SRP Section 2.1.3, "Population Distribution" (NRC 2007/2018-TN5898), and in RS-002 (NRC 2004-TN2219).

The applicable regulatory requirements pertinent to the review of population distribution are as follows:

- 10 CFR 50.34(a)(1) (TN249), as it relates to consideration of the site evaluation factors identified in 10 CFR 100.3 (TN282);
- 10 CFR Part 100 (TN282) (including consideration of population density) and 10 CFR 52.17 (TN251), as they relate to provision by the applicant in the SSAR of the existing and projected future population profile of the area surrounding the site;
- 10 CFR 100.20, "Factors to Be Considered When Evaluating Sites" (TN282); and
- 10 CFR 100.21, "Non-Seismic Site Criteria" (TN282) requirements, as they relate to determining the acceptability of a site. In 10 CFR 100.3, 10 CFR 100.20(a), and 10 CFR 100.21(b), the NRC provides definitions and other requirements for determining an exclusion area, LPZ, and the population center distance.

The related acceptance criteria from SRP Section 2.1.3 (NRC 2007/2018-TN5898) and RS-002 (NRC 2004-TN2219) are as follows:

- Population Data. The information about population data that the applicant supplied in the SSAR is acceptable if the SSAR (1) includes present and future population data for the life of the plant from the latest Census data and projected population data; (2) describes the methodology and sources used to obtain the population data, including the projections; and (3) includes information about transient populations in the site vicinity.
- Exclusion Area. The exclusion area should not have any residents or such residents should be subject to ready removal if necessary.
- Low-Population Zone. The specified LPZ is acceptable if it is determined that appropriate protective measures could be taken on behalf of the enclosed populace in the event of a serious accident.
- Nearest Population Center Boundary. The nearest boundary of the closest population center having 25,000 or more residents is at least one and one-third times the distance from the reactor facility to the outer boundary of the LPZ.
- Population Density: If the population density exceeds the guidelines given in RG 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Regulatory Position C.4 (NRC 2014-TN3550), the applicant must give special attention to considering alternative sites that have lower population densities.

2.1.3.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.1.3 (TVA 2017-TN5387) and confirmed that the application addressed the required information related to population distribution.

The staff reviewed the data on the population in the CRN Site environs, as presented in SSAR Sections 2.1.1, 2.1.2, and 2.1.3 (TVA 2017-TN5387), to determine whether the exclusion area, LPZ, and nearest population center distance for the proposed site comply with the requirements of 10 CFR Part 100 (TN282). The staff also evaluated whether, consistent with RG 4.7, Regulatory Position C.4 (NRC 2014-TN3550), the applicant should consider alternative sites that have lower population densities. Further, the staff reviewed whether appropriate protective measures could be taken on behalf of the enclosed populace within the Emergency Planning Zone (EPZ), which encompasses the LPZ in the event of a serious accident.

Based on the 2010 U.S. Census data, an estimated 67,203 residents are located within 16.1 km (10 mi) of the CRN Site. About 149 people are within 1.61 km (1 mi) of the CRN Site, within the LPZ. Based on population projections, the population within 16.1 km (10 mi) of the CRN Site is expected to increase from 77,889 in 2027 (first year of operation) to 93,470 in 2067 (end of plant operating life). The population projections for residents within 16.1 km (10 mi) of the CRN Site for the years 2010 through 2067 are presented in SSAR Table 2.1-2 (TVA 2017-TN5387). The transient population estimated within 16.1 km (10 mi) is presented in SSAR Tables 2.1-4 and 2.1-5 (TVA 2017-TN5387).

Based on the 2010 U.S. Census data, an estimated 1,090,823 residents are located within 16.1 to 80 km (10 to 50 mi) of the CRN Site. The population within 16.1 to 80 km (10 to 50 mi) of the CRN Site is projected to increase from 1,298,708 in 2027 to 1,678,800 in 2067. The population projections between 16.1 and 80 km (10 and 50 mi) from the CRN Site for the years 2010 through 2067 are presented in SSAR Table 2.1-3 (TVA 2017-TN5387). The transient population projections within 80 km (50 mi) are presented in SSAR Table 2.1-5 (TVA 2017-TN5387).

In addition to the permanent residents within 16.1 km (10 mi) of the CRN Site, people who are considered transient enter this area on a regular basis for employment, education, recreation, and medical care. SSAR Table 2.1-4 (TVA 2017-TN5387) provides the sources of transient populations within 16.1 km (10 mi) of the CRN Site.

The transient population within 16.1 and 80 km (10 and 50 mi) include people attending various events and contributors as listed, and peak daily visitors are listed in SSAR Table 2.1-4 (TVA 2017-TN5387). The projected transient population is presented in SSAR Table 2.1-5 (TVA 2017-TN5387).

The proposed LPZ consists of a 1.61 km (1 mi) radius around the center point of the CRN power block as shown in SSAR Figure 2.1-3 (TVA 2017-TN5387). The population projections within the LPZ are presented in SSAR Table 2.1-2 (TVA 2017-TN5387).

The 80 km (50 mi) radius from the center of the CRN Site includes a total of 33 counties, of which 2 are in the State of Kentucky, 3 are in the State of North Carolina, and 28 are in the State of Tennessee as presented in SSAR Table 2.1-1 (TVA 2017-TN5387). The staff obtained the U.S. Census population data for the years 2000 and 2010 for each of the above counties. The population within an 80 km (50 mi) radius of the center of CRN is independently estimated by the staff, using the fraction of each county within 80 km (50 mi) multiplied by the respective county population and summing this product over all the counties considered within 80 km (50 mi) for the years 2000 and 2010, respectively. The total population value within 80 km (50 mi) for the year 2010 estimated by the staff compared well with that of the applicant-generated population values in SSAR Tables 2.1-2 and 2.1-3 (TVA 2017-TN5387). The annual growth rate calculated for each of the counties considered based on the above Census data for the years 2000 and 2010 is also found to be comparable to the applicant-reported growth rate.

The CRN Site is located in Roane County, within the city limits of Oak Ridge, Tennessee. According to the USCB, the city of Oak Ridge had a 2010 population of 29,330 and was the largest city within 16.1 km (10 mi) of the site. It is an unusual situation for the consideration of addressing population center distance when assessing the application for compliance with NRC regulations. The population center distance, as defined in 10 CFR 100.3 (TN282), must be at least one and one-third times the distance from the reactor to the outer boundary of the LPZ. In this case, the site is within the officially designated political boundary of the city limit.

Nevertheless, the regulatory requirement states that the boundary of the population center shall be determined based upon consideration of the population distribution, and political boundaries are not controlling in the application of the criterion. Therefore, in this case, the population center, which has a denser population, is farther away from the reactor and its distance from the reactor meets the intent of the regulatory requirement, as well as the site suitability criterion for population center distance. The majority of the population of the city of Oak Ridge is to the north through the east of the CRN Site.

Based on the review of population distribution by sector and distance in these directions, out to 16.1 km (10 mi), it can be observed that the population contributing to more than 25,000 people is between 8 to 16.1 km (5 to 10 mi) from the site, and therefore, the staff finds that the population center distance of one and one-third times the distance of LPZ of 2.16 km (1.34 mi) is satisfied.

The regulatory requirement of 10 CFR 100. 21(b) (TN282) related to population center distance, which is defined in 10 CFR 100.3 (TN282) as the nearest population center having population of 25,000 or more people, requires it to be at least one and one-third times the distance from the reactor to the outer boundary of the LPZ. In meeting this requirement, the applicant used USCB Census-delineated urban areas in the region based on population density. The two urban areas identified are the Knoxville (4.8 mi southeast) urban area with the combination of smaller cities including Lafollette, Oak Ridge, Clinton, Loudon, Lenoir City, Alcoa, Maryville, Farragut, Rockwood, Seymour, and Knoxville; and the Cleveland (45 mi south-southwest) urban area with the combination of smaller cities including Calhoun, Charleston, Hopewell, and Cleveland, Tennessee. The Knoxville and Cleveland urban areas had 2010 populations of 558,696 and 66,777 persons, respectively (USCB 2013-TN6084). The applicant stated that the population center distance requirement in 10 CFR 100.21(b) (TN282) is being met, because the distances of these identified urban areas are much greater than the one and one-third times the distance from the site center point to the outer boundary of the LPZ. The applicant, however, followed an approach using the urban area designation with a combination of smaller cities for complying with the population center distance of one and one-third times the distance from the reactor to the outer boundary of LPZ. This approach differs from the regulatory requirement by considering and combining various small cities of less than 25,000 people. Therefore, the staff requested in request for additional information (RAI) eRAI-8857 (RAI No. 4) (TVA 2017-TN5896) that the applicant revise the evaluation methodology used to meet the 10 CFR 100.21(b) (TN282) regulatory requirement to base the evaluation methodology solely on consideration of the nearest city having a population of 25,000 or more people. The applicant provided a response to the RAI on August 24, 2017 (TVA 2017-TN5896), and subsequently updated information in the SSAR (TVA 2017-TN5387). The applicant stated that the city of Oak Ridge, with a 2010 population of 29,330, is the closest city to the CRN Site that exceeds 25,000 people, based on political boundaries. The CRN Site is located within the southern extent of the city of Oak Ridge, and the city's territory primarily extends to the northeast of the CRN Site. The densely populated portions of the city of Oak Ridge are located in these northeast portions. This is illustrated in SSAR Figures 2.1-6 and 2.1-9 (TVA 2017-TN5387), which portray the distribution of population by sector and distance from the CRN Site. In these figures, the sectors in the northeast directions have low populations within 0 to 6 mi. Therefore, densely populated portions of the city of Oak Ridge are located beyond the distance required by 10 CFR 100.21(b) (TN282). Accordingly, the staff finds the applicant's methodology acceptable because it is consistent with the regulatory requirement. Also, this is further supported by the USCB, which has delineated the densely populated portions of the city of Oak Ridge as part of the greater Knoxville urban area as being approximately 5.9 mi from the CRN Site.

The applicant determined the population density by using the estimated populations projected to the years 2021, 2027, and 2067. The relationship between population totals and distance from the site is presented SSAR Figure 2.1-8 (TVA 2017-TN5387). The respective estimated population densities within 32.2 km (20 mi) of the center of CRN Site for the years 2021, 2027, and 2067 are 295, 311, and 400 people per square mile, and are less than the guidance value of 500 people per square mile per RG 4.7 (NRC 2014-TN3550).

2.1.3.4 *Conclusion*

As discussed above, the applicant provided an acceptable description of current and projected population distribution, LPZ, population center distances, and population densities in and around the CRN Site. The staff reviewed the information provided and, for the reasons stated above, concludes that the applicant has provided acceptable population data that meet the requirements of 10 CFR 50.34(a)(1) (TN249), 10 CFR 52.17(a)(1)(viii) (TN251), 10 CFR 100.20(a) (TN282), 10 CFR 100.21(b) (TN282), 10 CFR Part 100 (TN282), and 10 CFR 100.3 (TN282). This conclusion is based on the applicant providing an acceptable description and safety assessment of the CRN Site. The site area contains present and projected population densities that conform to the guidelines of RG 4.7, Regulatory Position C.4 (NRC 2014-TN3550), and the applicant properly specified the LPZ and population center distance. Additionally, by assessing the population data independently, the staff reviewed and confirmed the applicant's estimates of the present and projected populations surrounding the CRN Site, including transients, and found them reasonable and acceptable. The applicant also calculated the radiological consequences of design basis accidents (DBAs) at the outer boundary of the LPZ (Chapter 15, Section 15.0.3) and has provided reasonable assurance that appropriate protective measures can be taken within the LPZ to protect the population in the event of a radiological emergency. Therefore, the staff finds that the CRN Site ESP applicant has provided adequate and acceptable information and description to comply with the requirements of 10 CFR 50.34(a)(1) (TN249), 10 CFR 52.17(a)(1)(viii) (TN251), and 10 CFR Part 100 (TN282).

2.2 Nearby Industrial, Transportation, and Military Facilities

2.2.1 Locations and Routes

In the identification of potential hazards in the site vicinity, the description of locations and routes refers to potential external hazards or hazardous materials that are present or may reasonably be expected to be present during the projected lifetime of the proposed plant. The purpose of the staff's review of this section is to determine the adequacy of information in meeting regulatory requirements concerning the presence and magnitude of potential external hazards so that the staff can perform its technical review and evaluation consistent with the guidance provided in SRP Sections 2.2.1, 2.2.2, 2.2.3, 3.5.1.5, and 3.5.1.6 (NRC 2007/2018-TN5898). The staff's review covers the following specific areas: (1) the locations of, and separation distances to, transportation facilities and routes, including airports and airways, roadways, railways, pipelines, and navigable bodies of water; (2) the presence of military and industrial facilities, such as fixed manufacturing, processing, and storage facilities; and (3) any additional information requirements prescribed in the applicable subparts to 10 CFR 52.17 (TN251).

2.2.1.1 *Summary of Application*

In the CRN Site SSAR, the applicant identified potential hazardous facilities and routes within the 8 km (5 mi) vicinity of the CRN Site and airports within 16.1 km (10 mi) of the CRN Site, along with significant facilities at greater distances (TVA 2017-TN5387). The applicant provided detailed descriptions of these facilities and routes for further consideration of hazards evaluation. There are five industrial facilities, one major highway, four major roads, two natural gas pipelines, one waterway, a railroad, five small airports, and two airways.

2.2.1.2 *Regulatory Basis*

The acceptance criteria for identification of potential hazards in the site vicinity are based on meeting the relevant requirements of 10 CFR Part 50 (TN249), 10 CFR 52.17 (TN251), and 10 CFR Part 100 (TN282), and the information provided in accordance with the following guidance:

- Regulatory Guide (RG) 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition) (NRC 2007-TN3035),"
- RG 1.91, "Evaluation of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants" (NRC 2013-TN5899),
- RG 4.7, "General Site Suitability Criteria for Nuclear Power Stations" (NRC 2014-TN3550), and
- RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release" (NRC 2001-TN5897).

The staff also considered the following regulatory requirements when reviewing the identification of potential hazards in the CRN Site vicinity:

- 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" (TN249);
- 10 CFR 52.17 (TN251), as it relates to the requirement that the application contain information about the location and description of any nearby industrial, military, or transportation facilities and routes;
- 10 CFR 100.20(b) (TN282), as it relates to the requirement that the nature and proximity of human-related hazards (e.g., airports, dams, transportation routes, and military and chemical facilities) 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) (TN282), 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 the site.

Both the SRP (NRC 2007/2018-TN5898) and RS-002 Sections 2.2.1 and 2.2.2 (NRC 2004-TN2219), specify that an applicant has submitted adequate information to meet the above requirements if the submitted information satisfies the following criteria:

- Data in the site safety assessment adequately describe the locations and distances of industrial, military, and transportation facilities in the vicinity of the plant, a nuclear power

plant (NPP) or NPPs of specified type that might be constructed on the proposed site, and agree with the data obtained from other sources, when available.

- Descriptions of the nature and extent of activities conducted at the site and nearby facilities, including the products and materials likely to be processed, stored, used, or transported, are adequate to permit identification of possible hazards.
- Sufficient statistical data related to hazardous materials are provided to establish a basis for evaluating the potential hazard to a NPP or NPPs of specified type that may be constructed on the proposed site.

2.2.1.3 *Technical Evaluation*

The staff reviewed the CRN Site SSAR (TVA 2017-TN5387) using the review procedures described in SRP Sections 2.2.1 and 2.2.2 (NRC 2007/2018-TN5898). This section identifies and provides information that would help in evaluating potential hazards due to industrial, transportation, and military installations in the CRN Site area that could have an impact on the safe operation of the proposed nuclear facility.

In the SSAR, the applicant identified the following potential hazard facilities and operations within 8 km (5 mi) of the CRN Site for further analysis (TVA 2017-TN5387).

- Industrial facilities
  - Oak Ridge National Laboratory (ORNL) (Battelle and URS)
  - TVA Kingston Fossil Plant
  - Oak Ridge Water Treatment Plant (WTP)
  - TVA Bull Run Fossil Plant
  - Hallsdale Powell Utility District Melton Hill WTP
- Transportation routes
  - Clinch River arm of Watts Bar Reservoir
  - I-40
  - Tennessee state roads TN 1/US 11-70, and TN 58, TN 95, and TN 327
  - Heritage Railroad Corporation Railway
  - East Tennessee Natural Gas Pipeline 1 (East) and Pipeline 2 (North)
- Airports and airways
  - Big T
  - Wolf Creek
  - Cox Farm
  - Will A Hildreth Farm
  - Riley Creek
  - Federal Airways V16 and J46.

The Oliver Springs and Fergusons Circus airports are within 16.1 to 24.1 km (10 to 15 mi) of the CRN Site.

2.2.2 Facility and Route Descriptions

The applicant provided detailed descriptions of the identified facilities and routes in SSAR Section 2.2.2 (TVA 2017-TN5387) in accordance with the SRP (NRC 2007/2018-TN5898), RS-002 (NRC 2004-TN2219), and RG 1.206 (NRC 2007-TN3035).

2.2.2.1 *Descriptions of Facilities*

The following five facilities were identified for further review for potential impact evaluation:

- ORNL (Battelle and URS)
- TVA Kingston Fossil Plant
- Oak Ridge WTP
- TVA Bull Run Fossil Plant
- Hallsdale Powell Utility District Melton Hill WTP.

CRN Site SSAR Table 2.2-1 provides a concise description of each facility, including its primary function and major products, as well as the number of persons employed, if available (TVA 2017-TN5387).

2.2.2.2 *Descriptions of Products and Materials*

A more detailed description of offsite chemicals associated with each of the above facilities is provided in the SSAR. The description includes information about the products and materials regularly manufactured, stored, used, or transported in the site vicinity. The chemicals stored at the offsite facilities identified in Section 2.2.2.1 are provided in detail in SSAR Tables 2.2-2 and 2.2-5 (TVA 2017-TN5387).

ORNL is located in Oak Ridge, Tennessee, approximately 6.1 km (3.8 mi) northeast of the CRN Site power block area. ORNL conducts research and development related to national energy and security issues and employs approximately 4,400 employees. The I-40 corridor is considered the most significant and the closest highway to the CRN Site and is evaluated as a potential transport route for chemical supplies shipped to ORNL and other facilities. The chemicals stored at ORNL identified for possible analysis are addressed in SSAR Section 2.2.3 (TVA 2017-TN5387).

The TVA Kingston Fossil Plant is located in Kingston, Tennessee, approximately 12.2 km (7.6 mi) west of the CRN Site power block area. The plant operates nine coal-fired generating units. The TVA Kingston Fossil Plant employs 248 employees. The facility uses anhydrous ammonia in the coal-burning process to remove nitrogen oxides that are produced during combustion in the course of producing electricity from coal.

The Oak Ridge WTP is located in Oak Ridge, Tennessee, approximately 16.6 km (10.3 mi) northeast of CRN Site power block area. The plant is owned and operated by the City of Oak Ridge Public Works Department, which employs 94 employees. The Oak Ridge WTP uses chlorine as a disinfectant in its water-treatment process. The plant receives chlorine from its supplier by truck.

The TVA Bull Run Fossil Plant is located in Clinton, Tennessee, approximately 24.1 km (15 mi) northeast of the CRN Site power block area. The plant uses anhydrous ammonia in the coal-burning process to remove nitrogen oxides that are produced during combustion in the course of producing electricity from coal. The TVA Bull Run Fossil Plant receives anhydrous ammonia from its supplier by truck.

Hallsdale Powell Utility District Melton Hill WTP is located approximately 29.3 km (18.2 mi) northeast of the CRN Site power block area in Knoxville, Tennessee. This plant uses chlorine as a disinfectant in its water-treatment process, and is supplied by truck.

2.2.2.3 *Description of Pipelines*

The East Tennessee Natural Gas Company operates two natural gas pipelines within 5 mi of the CRN Site power block area. Pipeline 1, located east of the CRN Site, has a 6 in. diameter and was constructed in 1957. Pipeline 2, located north of the CRN Site, has a 22 in. diameter and was constructed in 1950. Both pipelines operate at a maximum allowable operating pressure of 720 psig and are buried to a depth of 0.9 m (3 ft). The pipelines have various isolation valves located along the pipeline route, which can be reached and operated within 1 hour of notification. The closest branch of the pipeline originates at approximately the intersection of TN 58 and TN 327 and extends south toward the Clinch River. This pipeline crosses the Clinch River and its closest approach to the CRN Site power block area is approximately 1.8 km (1.1 mi) away from the site.

2.2.2.4 *Description of Waterways*

There are 802 stream miles in the lower Clinch River Watershed, which is located in East Tennessee and includes parts of Anderson, Campbell, Grainger, Know, Loudon, Morgan, Roane, and Union Counties. The Clinch River flows southwest from Tazewell, Virginia, through the Great Appalachian Valley to Kingston, just west of Knoxville, where it joins the Tennessee River. Significant waterborne transport in the CRN Site vicinity is possible on the Clinch River arm of the Watts Bar Reservoir. Annual waterborne commerce data compiled by the U.S. Army Corps of Engineers' Waterborne Commerce Statistics Center, for the period of 2007 through 2012, indicate that there was inconsequential shipping on the river, and that there was no transport of hazardous materials (e.g., chemicals and related products, petroleum, ordinance, etc.) that could pose a threat to operations at the CRN Site. Therefore, potential impacts due to water transport of hazardous materials were not considered.

2.2.2.5 *Description of Highways*

The most significant highway near the site is I-40, which runs roughly east-west on the opposite side of the Clinch River arm of the Watts Bar Reservoir relative to the CRN Site. At its closest point, I-40 is just over 1.61 km (1 mi) from the CRN Site power block area. Other larger roads near the site include TN 1/US 11-70, TN 58, TN 95 and TN 327 (all are farther away than I-40). I-40 was identified as a road within 8 km (5 mi) of the site on which chemicals may be transported. The analysis of chemical transport on I-40 bounds an analysis of other roads in the vicinity of the CRN Site because no closer roadway was identified on which chemicals may potentially be transported.

2.2.2.6 *Description of Railroads*

The nearest major rail line to the CRN Site is operated by Norfolk Southern and runs roughly northeast from Harriman, Tennessee, parallel to TN 61 toward Oliver Springs, Tennessee. At the closest approach, this line is approximately 11.3 km (7 mi) from the site. A second major rail line operated by Norfolk Southern lies south of the site and also runs roughly northeast through Loudon, and Lenoir City, and on to Knoxville. At the closest approach this line is approximately 14.5 km (9 mi) from the site. Due to the large distance from these lines to the site and the complex intervening terrain, accident scenarios on these lines are not evaluated further. Another minor rail line is used for shipping solid and low-level radioactive wastes. The applicant considered that these wastes do not pose a significant threat. The staff independently evaluated the information provided by the applicant and finds this acceptable because the materials are mostly solids having vapor pressures that are sufficiently low to preclude vapor

cloud formation for dispersion and explosion. Therefore, accidents from the transport of these hazardous wastes in the vicinity of CRN Site by rail are not considered further.

2.2.2.7 *Description of Airports, Aircraft, and Airway Hazards*

Five small privately owned airports (Big T, Wolf Creek, Cox Farm, Will A Hildreth Farm, and Riley Creek) are located between 8 and 16.1 km (5 and 10 statute mi) of the CRN Site. The closest military operation area (MOA) is the Snowbird MOA located approximately 57.9 km (36 mi) from the CRN Site. There are two Federal airways, one Victor (V) and one Jet (J) route (V16 and J46), respectively, whose nearest edge lies within 3.2 km (2 statute mi) of the CRN Site. The details of the impacts addressed and evaluated are discussed and presented in Section 3.5.1.6 of this FSER.

2.2.2.8 *Projection of Industrial Growth*

The East Tennessee Technology Park (ETTP) has begun a major environmental site cleanup with the long-term goal of converting the ETTP into a private industrial park called Heritage Center Industrial Park. The cleanup activities are currently being conducted and, as cleanup is completed, the U.S. Department of Energy (DOE) will transfer ownership of the uncontaminated buildings to the community Reuse Organization of East Tennessee, which in turn will lease this property for immediate private industrial use. Many of the buildings will be slated for potential reuse and the remediated land will be available for new construction. Additionally, the Metropolitan Knoxville Airport Authority working with community partners and DOE, has slated the Heritage Center Industrial Park, approximately 9.6 km (6 mi) from the CRN Site, to be the potential site for a general aviation airport. Current site plans indicate future construction dates for the airport are approximately 2017–2022. No other projections of industrial growth within a 16.1 km (10 mi) radius of the CRN Site were identified. If this airport comes into operation by the combined license (COL) or construction permit (CP) stage, its impact evaluation should be included in the combined license application (COLA). The staff identifies this as Permit Condition 2.2-1 (Permit Condition 1) as described in Section 2.2.3.3.6 of this chapter.

2.2.2.9 *Conclusion*

As discussed above, the applicant presented detailed information to establish the identification of potential hazards in the CRN Site vicinity. The staff reviewed the information provided, and concludes that the applicant has provided reasonable and appropriate information with respect to identification of potential hazards in conformance with the guidance in the SRP (NRC 2007/2018-TN5898), as described in the “Regulatory Basis” section above, and in compliance with the requirements of 10 CFR 52.17(a)(1)(vii) (TN251) and 10 CFR 52.17(a)(1)(ix) (TN251), as well as 10 CFR 100.20(b) (TN282) and 10 CFR 100.21(e) (TN282). The nature and extent of activities involving potentially hazardous materials that are conducted at nearby industrial, military, and transportation facilities have also been evaluated to identify any such activities that have the potential for adversely affecting plant safety-related structures. On the basis of an evaluation of information in the SSAR (TVA 2017-TN5387), as well as information obtained independently, the staff concludes that all potentially hazardous activities onsite and in the vicinity of the plant have been identified. The hazards associated with these activities have been reviewed and are discussed in Sections 2.2.3 and 3.5.1.6 of this report.

2.2.3 Evaluation of Potential Accidents

The staff's evaluation of potential accidents considers the applicant's probability analyses of potential accidents involving hazardous materials or activities on the CRN Site and in the vicinity of the proposed CRN Site to confirm that appropriate data and analytical models have been used. The review covers the following specific areas: (1) hazards associated with nearby industrial activities, such as manufacturing, processing, or storage facilities; (2) hazards associated with nearby military activities, such as military bases, training areas, or aircraft flights; and (3) hazards associated with nearby transportation routes (aircraft routes, highways, railways, navigable waters, and pipelines). Each hazard review area includes consideration of the following principal types of hazards:

- toxic vapors or gases and their potential for incapacitating nuclear plant control room operators;
- overpressure resulting from explosions or detonations involving materials such as munitions, industrial explosives, or explosive vapor clouds resulting from the atmospheric release of gases (such as propane and natural gas or any other gas) that could ignite or explode;
- missile effects attributable to mechanical impacts, such as aircraft impacts, explosion debris, and impacts from waterborne items such as barges; and
- thermal effects attributable to fires.

2.2.3.1 *Summary of Application*

In the CRN Site SSAR (TVA 2017-TN5387), the applicant evaluated potential accidents based on the information compiled for the identified facilities in Sections 2.2.1 and 2.2.2, in accordance with regulatory requirements in 10 CFR 52.17 (TN251), 10 CFR 100.20 (TN282), and 10 CFR 100.21 (TN282) using the guidance in RG 1.78, Revision 1 (NRC 2001-TN5897), RG 1.91, Revision 2 (NRC 2013-TN5899), RG 4.7, Revision 3 (NRC 2014-TN3550), and RG 1.206, Revision 0 (NRC 2007-TN3035). The applicant performed an analysis of these accidents to determine whether any of them should be considered design basis events (DBEs). The DBEs are defined as those accidents that have a probability of occurrence on the order of the magnitude 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 (TN282) could be exceeded. The following accident categories are considered in selecting DBEs: explosions, flammable vapor clouds (delayed ignition), toxic chemicals, aircraft crashes, fires; collisions with intake structures, and liquid spills.

2.2.3.2 *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-TN5898).

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

- 10 CFR 52.17(a)(1)(vii) (TN251), as it relates to the requirement that the application contain information about the location and description of any nearby industrial, military, or transportation facilities and routes and the requirements of 10 CFR 52.17(a)(1)(ix) (TN251), as it applies to 10 CFR Part 100 (TN282);

- 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) (TN282), 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.

2.2.3.3 *Technical Evaluation*

The staff reviewed the information presented in SSAR Section 2.2.3 (TVA 2017-TN5387), pertaining to potential accidents, as discussed below. The staff's review confirmed that the information in the application addressed the required information related to the evaluation of potential accidents.

The staff reviewed SSAR Sections 2.2.1 and 2.2.2 (TVA 2017-TN5387), which contain information related to industrial, military, and transportation facilities and routes, to establish the presence and magnitude of potential external hazards that include accident categories, such as explosions, flammable vapor clouds (delayed ignition), toxic chemicals, fires, and airplane crashes addressed in SSAR Section 2.2.3 (TVA 2017-TN5387).

2.2.3.3.1 Explosions and Flammable Vapor Clouds

2.2.3.3.1.1 <u>Explosions</u>

The applicant considered hazards involving potential explosions that result in blast overpressure as a result of the detonation of explosives, munitions, chemicals, liquid fuels, and gaseous fuels that are processed, stored, used, or transported near the CRN Site. The allowable and actual distances of potential hazardous explosive chemicals transported or stored are determined based on using 1 pound per square inch (psi) overpressure as a criterion for adversely affecting plant operation or preventing safe shutdown of the plant. In accordance with RG 1.91 (NRC 2013-TN5899), peak positive incident overpressures below 1 psi are considered to cause no significant damage. The locations and quantities of chemicals that would be stored onsite at the CRN Site have not yet been determined, so the effects of potential explosion events caused by onsite storage should be evaluated in the COLA.

The nearby facilities' chemicals, natural gas transported by pipeline, and chemicals assumed to be transported by roadways near the CRN Site were evaluated by the applicant. Hazardous materials are stored at nearby facilities, transported on nearby roads, and by pipeline as shown in SSAR Tables 2.2-2, 2.2-3, and 2.2-4, respectively (TVA 2017-TN5387). The effects of limiting explosion events along with determined minimum safe distances are summarized in SSAR Table 2.2-9 (TVA 2017-TN5387).

The chemicals at the nearby offsite facilities identified for explosion analysis include 30,000 gal, 9,999 lb, and 999 lb of anhydrous ammonia; 4,249 lb of ethanol; 750 lb of gasoline blend A; and 999 lb of gasoline blend B. The applicant's analysis results indicate that the calculated safe distances are less than the actual distance from the source to the center of CRN Site and pose no adverse impact on the safe operation of the proposed plant.

The chemicals potentially transported on I-40 that were further evaluated by the applicant for potential explosion are butane (11,500 gal) in a tanker truck, gasoline (8,500 gal) in a tanker truck, and hydrogen (15,032 ft^3 per tube). The largest minimum safe distance of 1,130 m (3,708 ft) was calculated for butane transport and is less than the actual distance of 1,768 m (5,800 ft) from center of CRN Site to the closest distance to I-40.

Natural gas (methane) is transported by 6 in. and 22 in. pipelines with a potential release at the source of over 5 seconds of 1,960 lb and 26,400 lb, respectively, due to a postulated complete rupture of each pipe considered. The minimum safe distance to 1 psi overpressure was determined to be 381 m (1,250 ft) for the 6 in. pipeline, which is less than the actual distance of 1,768 m (5,800 ft) from the center of the CRN Site to the closest distance to the pipeline, and 905 m (2,970 ft) for the 22 in. pipeline, which is less than 4,816 m (15,800 ft) from the center of CRN Site to the closest distance to the 22 in. pipeline. Overpressure of 1 psi or greater is not expected at the CRN Site because the natural gas is transported via pipelines. Based on the review of the applicant's information and the staff's independent assessment, the staff considers the information provided in the SSAR (TVA 2017-TN5387) to be reasonable and acceptable because it satisfies the guidance in the SRP (NRC 2007/2018-TN5898).

2.2.3.3.1.2 *Flammable Vapor Clouds (Delayed Ignition)*

Flammable gases in the liquid or gaseous state can form an unconfined vapor cloud that could drift toward the plant before ignition occurs, and then could burn or explode when the vapor concentration is within flammable range. For chemicals that have an identified flammability range, an air dispersion model based on the methods and equations in RG 1.78 (NRC 2001-TN5897) and NUREG–0570, "Toxic Vapor Concentration in the Control Room Following a Postulated Accidental Release" (NRC 1979-TN5901), is used to determine the distance that the vapor cloud can travel before the concentration is less than the Lower Explosive Level. The analyzed effects of flammable vapor clouds and vapor cloud explosions from internal and external sources are summarized in SSAR Table 2.2-10 (TVA 2017-TN5387).

The chemicals at the nearby offsite facilities identified for flammable vapor clouds (delayed ignition) and vapor cloud explosion analysis include 30,000 gal, 9,999 lb, and 999 lb of anhydrous ammonia; 4,249 lb of ethanol; 750 lb of gasoline blend A; and 999 lb of gasoline blend B. The applicant's analysis results indicate that the calculated safe distance for each of the chemicals considered is less than the actual distance from the source to the center of the CRN Site and poses no adverse impact on the safe operation of the proposed plant. Based on its review of the applicant's information as well as the staff's independent assessment, the staff considers the information provided in the SSAR (TVA 2017-TN5387) to be reasonable and acceptable because it satisfies the guidance in the SRP (NRC 2007/2018-TN5898).

The chemicals potentially transported on I-40 that were further evaluated by the applicant for potential flammable vapor clouds (delayed ignition) and vapor cloud explosion were butane (11,500 gal) in a tanker truck and gasoline (8,500 gal) in a tanker truck. The largest minimum safe distance of 1,178 m (3,864 ft) was calculated for butane transport and is less than the actual distance of 1,768 m (5,800 ft) from center of the CRN Site to the closest distance to I-40.

The natural gas (methane) is transported by 6 in. and 22 in. pipelines with a potential total release over 1 hour of 683,023 lb and 9,866,045 lb, respectively, due to complete rupture of each pipeline with an unbroken end connected to an infinite source. The minimum safe distance to a 1 psi overpressure, a 1 psi vapor cloud explosion, a lower flammability limit (LFL), and a heat flux of 5 kW/m^2 was determined by the applicant for the 6 in. pipeline to be less than

the actual distance of 1,768 m (5,800 ft) from the center of the CRN Site to the closest distance to the 6 in. pipeline, and was also determined for the 22 in. pipeline to be less than the actual distance of 4,816 m (15,800 ft) from the center of CRN Site to the closest distance to the 22 in. pipeline. Therefore, potential adverse impacts on the proposed plant are not expected, due to potential flammable vapor clouds (delayed ignition), vapor cloud explosion, and heat flux. Based on its review of the applicant's information as well as the staff's independent assessment, the staff considers the information provided in the SSAR (TVA 2017-TN5387) to be reasonable and acceptable because it satisfies the guidance in the SRP(NRC 2007/2018-TN5898).

2.2.3.3.2 Toxic Chemicals

The hazards due to potential accidents involving the release of toxic or asphyxiating chemicals from nearby facilities and transportation sources that may have the potential to have an impact on the CRN Site were considered. These hazards include chemicals processed, stored, used, or transported near the CRN Site. The chemicals stored at nearby facilities (SSAR Table 2.2-2), potentially transported along I-40 (SSAR Table 2.2-3), and by pipelines (SSAR Table 2.2-4) were evaluated with respect to their potential to form a toxic or asphyxiating vapor cloud after an accidental release (TVA 2017-TN5387). However, the control room habitability was not evaluated for this ESPA because the ESPA does not specify a reactor design technology, and the control room characteristics are unknown. Each identified chemical is evaluated based upon the chemical's properties, quantities, and distance in relation to the power block area without consideration of plant design factors, such as control room ventilation. Because TVA has not selected a reactor technology, the control room characteristics (e.g., the control room volume and outside air infiltration and circulation rates) are unknown. Therefore, the potential chemical concentration at the point closest to the power block area of the CRN Site (power block boundary) was estimated for the purposes of this evaluation. The chemicals that lead to concentrations above the respective chemical Immediately Dangerous to Life and Health (IDLH) concentrations at the edge of CRN Site power block boundary are further evaluated at the COL stage as part of the COLA. The locations and quantities of chemicals that would be stored onsite at the CRN Site have not yet been determined. The effects of toxic chemical releases from onsite chemical storage will be evaluated by the applicant and provided to the staff at the COLA stage, as required by 10 CFR 52.79 (TN251), to provide a detailed control room habitability assessment.

The chemicals stored at nearby facilities that have toxicity potential include anhydrous ammonia at the TVA Bull Run Fossil Plant and TVA Kingston Fossil Plant; anhydrous ammonia, argon, carbon dioxide, chloroform, chromic chloride, ethanol, gasoline, hydrogen fluoride, nitrogen, and sulfur hexafluoride at ORNL (Battelle); nitric acid at ORNL (URS); and chlorine at the Hallsdale Power Utility District Melton Hill WTP and Oak Ridge WTP. The results of the analyses using the stored amounts of each chemical presented in SSAR Table 2.2-11 (TVA 2017-TN5387) indicate that the distance to reach the IDLH concentrations of each of the chemicals analyzed is less than the distance from the chemical source location to the CRN Site power block area. This confirms that the potential control room concentration of a given chemical does not reach the limiting IDLH concentration.

The chemicals transported on I-40 that are identified as having a toxicity potential include anhydrous ammonia (11,500 gal), butane (11,500 gal), chlorine (22 T or 44,000 lb), gasoline (8,500 gal), nitric acid (6,000 gal), and sulfur hexafluoride (50,000 lb). The results of the applicant's analysis indicated that, except for anhydrous ammonia and chlorine, the distances to the identified toxicity limit for any plausible vapor cloud that could form following an accidental

release at the closest distance from the transportation route (I-40) are less than the minimum distances from the CRN Site power block area to I-40 of 1,768m (5,800 ft). The staff's confirmatory analysis not only confirmed the exceedance of the toxicity limits for anhydrous ammonia and chlorine but also for nitric acid at the CRN Site power block area. A release of anhydrous ammonia reached its toxicity limit at a distance of 4,184 m (13,728 ft) from the source and a release of chlorine reached its toxicity limit at distance of 7,242 m (23,760 ft) from the source. The staff's analysis for a release of nitric acid resulted in a distance of 2,575 m (8,448 ft) to reach the toxicity limit. Because detailed design information about control room and operational characteristics is not available at the ESP stage, the main control room habitability will be evaluated at the COLA stage. The staff identifies this as Permit Condition 2.2-2 (Permit Condition 2), as described in Section 2.2.3.3.6 of this chapter.

The distances to the asphyxiating limit analyzed by the applicant for the East Tennessee Pipeline 1 and East Tennessee Natural Gas Pipeline 2 under worst-case meteorological conditions are 282 ft and 846 ft, respectively. These distances are less than the separation distance from either pipeline to the CRN Site power block area, and therefore have no adverse effect on control habitability.

2.2.3.3.3 Fires

The locations and quantities of chemicals that would be stored onsite at the CRN Site have not yet been evaluated. Therefore, the effects of fires from onsite chemical storage and brush or forest fires will be evaluated by the applicant and provided to the staff in the COLA, as required by 10 CFR 52.79 (TN251).

Chemicals stored at nearby facilities and transported by via I-40 were evaluated by the applicant for potential effects of accidental releases to cause a delayed ignition due to formation of a vapor cloud. The results indicate that the vapor cloud distance to reach to LFL is less than the actual distance from the source to the CRN Site power block area, thereby confirming no adverse effects from fires or heat fluxes on the proposed units at the CRN Site.

The applicant's results of evaluating heat flux due to jet fire in the pipelines led to the conclusion that the distance to 5 kW/m^2 for the 6 in. pipeline is 95.1 m (312 ft), which is less than the separation distance of 1,768 m (5,800 ft) between the CRN Site power block and the pipeline break; and for the 22 in. pipeline it is 367 m (1,203 ft), which is less than the separation distance of 4,816 m (15,800 ft). Therefore, the applicant concludes that no adverse effects would be expected on the proposed units at the CRN Site power block area. The staff finds the applicant's conclusion and approach acceptable, because a heat flux of 5 kW/m^2, independently verified by staff, would not extend to the CRN Site power block area.

2.2.3.3.4 Collisions with Intake Structure

Because the raw water makeup system intake structure for the CRN Site is neither safety related nor anticipated to be required for the mitigation of DBAs, an evaluation that considers the probability and potential effects of impacts on the plant cooling-water intake structure and enclosed pumps is not required.

2.2.3.3.5 Liquid Spills

The accidental release of oil or liquids that are corrosive, cryogenic, or coagulant was considered to determine whether they would be drawn into the plant's raw water system intake

structure and circulating water system or would otherwise affect the plant's safe operation or shutdown. If these liquids were to spill into the Clinch River, they would not only be diluted by the large quantity of river water, but the raw water makeup system intake is not necessary for the safe operation or shutdown of the plant, because the intake structure is a non-safety-related structure. Therefore, the applicant considers that any spill in the Clinch River would not affect the safe operation or shutdown of units at the CRN Site. The staff finds this approach reasonable and acceptable, because the intake structure is not safety related.

2.2.3.3.6 Permit Conditions

- Permit Condition 2.2-1 (Permit Condition 1): 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 Clinch River Nuclear (CRN) Site, as the potential site for a general aviation airport. An applicant for a combined license (COL) or construction permit (CP) referencing this ESP shall evaluate this planned airport, wherever it is to be located, for potential aircraft crash impact probability to determine whether or not it is a design basis event. If the aircraft crash is a design basis event, then the applicant shall demonstrate that the plant may nonetheless be safely operated.
- Permit Condition 2.2-2 (Permit Condition 2): An applicant for a COL or CP referencing this ESP shall evaluate and demonstrate compliance with NRC regulations regarding the potential effect onsite and offsite toxic chemicals may have on control room habitability. This evaluation shall account for the onsite storage of chemicals (to be identified in the COL or CP application) and the chemicals anhydrous ammonia, chlorine, and nitric acid transported on Interstate Highway I-40, when the concentration of these chemicals exceeds the respective IDLH (Immediately Dangerous to Life and Health) limit at the CRN Site power block area.

2.2.3.3.7 Conclusion

Based on the aforementioned discussions, and subject to Permit Conditions 2.2-1 and 2.2-2 (Permit Conditions 1 and 2), the staff finds that the CRN Site ESP applicant has identified and evaluated potential accidents related to the presence of hazardous materials or activities in the CRN Site vicinity that could affect a NPP or NPPs that might be constructed on the proposed site. The staff notes that of these potential accidents, the applicant has selected those that should be considered DBEs at the COLA stage. The staff reviewed the information provided and, for the reasons discussed above, subject to Permit Conditions 2.2-1 and 2.2-2 (Permit Conditions 1 and 2), concludes that the CRN Site ESP applicant has established site characteristics and design parameters acceptable to meet the requirements of 10 CFR 52.17(a)(1)(vii) (TN251), 10 CFR 52.17(a)(1)(ix) (TN251), 10 CFR 100.20(b) (TN282), and 10 CFR 100.21(e) (TN282) for determining the acceptability of the CRN Site.

2.3 Meteorology

To ensure that a NPP or NPPs can be designed, constructed, and operated on an applicant's proposed ESP site in compliance with NRC regulations, the 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 staff also reviews information about the χ/Q characteristics of a proposed NPP site to determine whether the radioactive effluents from postulated accidental releases, as well as from routine operational releases, comply with NRC regulations.

The staff prepared Sections 2.3.1 through 2.3.5 of this FSER in accordance with the review procedures described in the SRP (NRC 2007/2018-TN5898). Input to these FSER sections was developed based on the staff's evaluation of the information presented primarily in (1) Section 2.3 of the CRN Site ESP SSAR (Revision 0 and subsequent revisions up through Revision 2) (TVA 2016-TN5018, TVA 2017-TN5387, TVA 2019-TN5855); (2) the applicant's responses to NRC staff RAIs; (3) the staff's assessment of technical information and supporting analyses discussed during an audit conducted in May 2018 (NRC 2018-TN6152); and (4) generally available reference materials identified in applicable sections of the SRP (NRC 2007/2018-TN5898).

2.3.1 Regional Climatology

In SSAR Section 2.3.1, "Regional Climatology," the applicant provided information regarding regional climatic conditions and the occurrence of meteorological phenomena (including 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 NPP (TVA 2019-TN5855).

2.3.1.1 *Summary of Application*

In SSAR Section 2.3.1 (TVA 2019-TN5855), the applicant provided the following information:

- a description of the general climate of the region with respect to types of air masses, synoptic features (high- and low-pressure systems), general airflow patterns (wind direction and speed), temperature and humidity, precipitation (rain, snow, etc.), potential influences of regional topographic features, and relationships between synoptic-scale atmospheric processes and local (site) meteorological conditions;
- regional meteorological conditions relevant to the design and operating bases for the CRN Site (i.e., information summarized in Table 2.0-1, "Site Characteristics," of the SSAR [TVA 2019-TN5855]);
- frequencies and descriptions of severe weather phenomena that could reasonably be expected to impact the proposed site, including extreme wind, tornadoes, tropical cyclones, precipitation extremes, winter precipitation (snowstorms and ice storms), and thunderstorms (including hail and lightning);
- a description of design basis dry- and wet-bulb temperatures for the proposed site;
- a discussion of potential climate changes in the proposed site region; and
- a description of regional air-quality conditions, including a discussion of projected air quality as a result of electricity generation from two or more SMRs at the CRN Site.

Based on the above information, in SSAR Table 2.0-1 the applicant provided a list of characteristics that describe climatological conditions that might reasonably be expected to occur at the CRN Site (TVA 2019-TN5855). 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. The applicant proposed the following climatic site characteristics as minimum design and/or operating bases applicable to the proposed CRN Site:

- the weight of the 100-year return period ground-level snowpack and the weight of the 48-hour probable maximum winter precipitation (PMWP) for use in determining the weight of winter precipitation events on the roofs of safety-related structures;

- the design basis tornado parameters (including maximum wind speed, maximum rotational and translational wind speed, the radius of maximum rotational wind speed, maximum pressure drop, and maximum rate of pressure drop) to be used in establishing tornado loadings on SSCs important to safety;
- the 100-year return period (straight-line) and hurricane 3-second gust wind speeds to be used in establishing wind loading on plant structures; and
- ambient air temperature and atmospheric moisture statistics, including maximum dry-bulb (5 percent, 2 percent, 1 percent, 0.4 percent, and 0 percent annual exceedance with coincident wet-bulb temperatures; 100-year return period); minimum dry-bulb (5 percent, 2 percent, 1 percent, 0.4 percent, and 0 percent annual exceedance; 100-year return period); and maximum non-coincident wet-bulb (2 percent, 1 percent, 0.4 percent, and 0 percent annual exceedance; 100-year return period).

2.3.1.2 *Regulatory Basis*

The acceptance criteria for identifying regional climatological and meteorological information are based on meeting the relevant requirements of 10 CFR 52.17, "Contents of Applications; Technical Information" (TN251), and 10 CFR Part 100, "Reactor Site Criteria" (TN282). The staff considered the following regulatory requirements when reviewing the applicant's identification of regional climatological and meteorological information:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to the requirement that the application contain a description of the meteorological characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated;
- 10 CFR 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 the site; and
- 10 CFR 100.21(d) (TN282), 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 ESPA (in compliance with the above regulatory requirements) will be necessary to determine, in any COLA submitted for the site, whether a proposed facility complies with the following requirements in Appendix A, "General Design Criteria for Nuclear Power Plants," of 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" (TN249):

- 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 acceptance criteria from SRP Section 2.3.1, "Regional Climatology" (NRC 2007/2018-TN5898):

- 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 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, "Ultimate Heat Sink for Nuclear Power Plants," Revision 3 (NRC 2015-TN5907), 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 use 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 PMWP should be determined in accordance with hydrometeorological reports (HMRs) published by NOAA's Hydrometeorological Design Studies Center (NOAA 2017-TN6063).
- 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/COL Interim Staff Guidance – 007 (DC/COL/ISG-007), "Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures" (NRC 2008-TN5930), which clarifies the 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" (NRC 2011-TN5931), which provides criteria for selecting the design basis hurricane parameters.
- NUREG/CR-7005, "Technical Basis for Regulatory Guidance on Design-Basis Hurricane Wind Speeds for Nuclear Power Plants" (Vickery et al. 2011-TN5932).

When independently assessing the information presented by the applicant in SSAR Section 2.3.1 (TVA 2019-TN5855), the staff applied the same above-cited methodologies and techniques.

2.3.1.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.3.1 to ensure that the ESPA represents the complete scope of information related to the regional climatology (TVA 2019-TN5855). The staff's review confirmed the ESPA addresses the required information related to the preceding subject matter.

2.3.1.3.1 General Climate

The applicant described the site as being located in eastern Tennessee, set alongside the southern portion of the Appalachian mountain chain. The site lies in a valley between two mountainous regions, which positions the valley in a southwest to northeast configuration. The applicant stated that prevailing winds generally flow following the orientation of the valley, and wind speeds are normally low; the mean annual wind speed is 2.9 mph, based on National Climatic Data Center (NCDC, recently renamed the National Centers for Environmental Information or [NCEI]) information about Oak Ridge, Tennessee.

The site's most dominant climate and weather influence for the region is the Azores-Bermuda high, which is a pseudo-permanent subtropical high-pressure system located over the southern portion of the North Atlantic Ocean and characterized by fair, stable weather and stagnant air. This phenomenon is most pronounced in the summer and early fall, and pulls warm, moist air from the Gulf of Mexico over the region. During the winter and early spring, alternating cold and warm air masses bring changes to this weather pattern.

In addition, the applicant stated that air temperatures show typically warm summers and mild winters, and precipitation averages about 51 in. annually, with January through March being the wettest period of the year and August through October being the driest. According to the applicant, snowfall is normally light and usually occurs from November through March; severe storms occur relatively infrequently, because the region is situated east of maximum tornado activity and more inland away from tropical cyclone impacts.

The staff reviewed the Local Climatological Data (LCD) publications, provided by NCEI, for the cities of Oak Ridge and Knoxville, Tennessee, for the years of 2013 (NOAA 2017-TN6071 and NOAA 2017-TN6070, respectively) (which the applicant referenced in its ESPA) and 2016 (NOAA 2017-TN6067 and NOAA 2017-TN6068, respectively) (the most recent year for which data were available to the staff at time of the review). The staff confirmed the applicant's climate description, including general temperature, precipitation, and severe weather trends for the region, and reviewed the topographic features of the area. Although not mentioned by the applicant in SSAR Section 2.3.1.1 (TVA 2019-TN5855), the staff notes that the State of Tennessee is divided into four climate divisions. The proposed CRN Site is located in Climate Division 1 (eastern Tennessee), which runs from Campbell County, along the northern border with Kentucky, continuing in a southwesterly direction to Hamilton County along the border with Georgia, and extends eastward over the remainder of the state to its borders with Virginia and North Carolina. The CRN Site is situated in Roane County whose western boundary abuts with Climate Division 2 (Cumberland Plateau). Based on its review of the information provided by the applicant, the staff finds the information to be an appropriate account of the general climate of the site region.

2.3.1.3.2 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 2.0-1 of the SSAR (TVA 2019-TN5855). These climate-related site characteristics are reviewed by the NRC staff in the following sections.

2.3.1.3.3 Severe Weather

2.3.1.3.3.1 *Thunderstorms, Hail, and Lightning*

SSAR Section 2.3.1.3.1, "Thunderstorms, Hail, and Lightning," provides a general understanding of these severe weather phenomena in the site region (TVA 2019-TN5855). However, the section does not result in the generation of site characteristics for use in design or operating bases.

According to the applicant, thunderstorms in the region occur on 42 to 55 days of the year, with the greatest incidence occurring during the months of May through August. Also, according to the applicant, severe hail events (featuring hail 0.75 in. in diameter or larger) have been reported 31 times during the period from 1950 to 2013 in Roane County, where the potential site is located. In the surrounding counties of Loudon and Knox, severe hail events were reported 43 and 81 times, respectively, since 1950, which is the beginning of the period of record (POR) for the NCEI Storm Events Database (NOAA 2017-TN6065). However, the NRC staff understands that the POR covered by the online Storm Events Database for hail events currently begins in 1955. The applicant also stated that the site area averages 13 cloud-to-ground lightning flashes per square mile (2.6 km^2) each year.

The staff reviewed the LCD annual summary publications from NCEI for the cities of Knoxville, Nashville, and Oak Ridge, Tennessee, and the tri-cities area (Bristol, Johnson City, and Kingsport, Tennessee) for the years of 2013 (NOAA 2017-TN6070, NOAA 2017-TN6072, NOAA 2017-TN6071, NOAA 2017-TN6074, respectively) and 2016 (NOAA 2017-TN6068, NOAA 2017-TN6073, NOAA 2017-TN6067, NOAA 2017-TN6075, respectively). The staff reviewed the 2013 LCDs referenced in the ESPA and the 2016 LCDs to confirm the data provided by the applicant. The staff also reviewed Vaisala's National Lightning Detection Network flash density (2005–2014) for the contiguous United States (Vaisala 2015-TN6130) and found that this portion of the SSAR (TVA 2019-TN5855) was acceptable for information purposes because information related to thunderstorms, hail, and lightning is not typically identified as site characteristics.

2.3.1.3.3.2 *Extreme Winds*

Estimating wind loading on plant structures involves identifying a site's "basic" (50-year recurrence interval) wind speed, which is defined by the American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) Standard 7-05, "Minimum Design Loads for Buildings and Other Structures" (ASCE/SEI 2005-TN6042), as the "3-second gust speed at 33 feet (ft) (10 meters (m)) above the ground in Exposure Category C." Exposure Category C relies on the surface roughness categories defined in Chapter 6, "Wind Loads." Exposure Category C is acceptable at the CRN Site because of scattered obstructions of various sizes in the immediate site area. Exposure Category B specifies that there must be "urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger" prevailing "in the upwind direction for a

distance of at least 2,600 ft (792 m) or 20 times the height of the building, whichever is greater." Exposure Category D specifies that there must be "flat, unobstructed areas and water surfaces" prevailing "in the upwind direction for a distance greater than 5,000 ft (1,525 m) or 20 times the building height, whichever is greater." Based on the site description in SSAR Section 2.3.3.2, "Primary Meteorological Facility," neither Exposure Category B nor Exposure Category D accurately describes the conditions at the CRN Site meteorological tower (TVA 2019-TN5855). ASCE/SEI 7-05 states that Exposure Category C shall apply for all cases for which neither Exposure Category B nor D applies (ASCE/SEI 2005-TN6042).

Using a plot of basic wind speeds presented in ASCE/SEI 7-05 (ASCE/SEI 2005-TN6042) for the portion of the United States that includes the proposed CRN Site, the applicant determined a 50-year return period 3-second gust wind speed of 90 mph. The applicant also included data from the 1974 Annual LCD for Knoxville, Tennessee (NOAA 2017-TN6069), which contained a maximum estimated fastest mile wind speed of 73 mph (which corresponds to a 3-second gust wind speed of 87 mph) recorded for the site region.

In addition, the applicant noted that, according to the reference "New Distributions of Extreme Winds in the United States," the 100-year return period fastest mile of wind near the CRN Site is approximately 90 mph (Thorn 1968-TN6062). The applicant also provided, for comparison purposes, hourly average wind speed measurements taken at the 33 ft (10 m) level from the CRN Site (2011–2013), TVA's Watts Bar Nuclear Plant (1973–2013), and TVA's Sequoyah Nuclear Plant (1971–2013). The maximum observed hourly values of 15.1 mph for the CRN Site, 30.0 mph for the Watts Bar site, and 40.0 mph for Sequoyah correspond to 3-second gust wind speeds of 23, 45, and 60 mph, respectively. The staff notes that the 2-year POR for the CRN Site wind data is not climatologically representative of extreme winds due to its short duration.

The staff confirmed the applicant's 3-second gust wind speed value of 90 mph based on ASCE/SEI 7-05 (ASCE/SEI 2005-TN6042). This value is associated with a mean recurrence interval of 50 years. Using the conversion factor of 1.07 listed in ASCE/SEI 7-05, Table C6-7, "Conversion Factors for Other Mean Recurrence Intervals" (ASCE/SEI 2005-TN6042), the applicant calculated a 100-year return period 3-second gust wind speed of 96.3 mph, as presented in SSAR Table 2.0-1 (TVA 2019-TN5855).

Because the applicant's determination of the basic wind speed site characteristic value is in accordance with the methods described in SRP Section 2.3.1 (NRC 2007/2018-TN5898), the staff finds this value reasonable and acceptable.

2.3.1.3.3.3 *Precipitation Extremes*

Based on the observations from four nearby first-order NWS monitoring stations and from TVA's Sequoyah and Watts Bar NPP sites, the applicant presented historical precipitation extremes for the region in SSAR Table 2.3.1-2, "Precipitation for Stations around Clinch River Nuclear Site" (reproduced as Table 2.3-1 in this report) (TVA 2019-TN5855). According to the applicant, the maximum estimated annual precipitation for the area ranges from 45 to 53 in., the maximum 24-hour rainfall is less than 10 in., and the maximum monthly rainfall measures less than 20 in. The probable maximum precipitation (PMP) values provided by the applicant are based on NOAA's HMR No. 52 (HMR-52), which determined the PMP values for a 1 mi^2 area to be 18.8 in./1 hr and 6 in./5 min. The applicant listed this PMP value as a "maximum rainfall rate" site characteristic in SSAR Table 2.0-1 (TVA 2019-TN5855). Section 2.4.3.3.2, "Probable Maximum Precipitation," of this FSER discusses the applicant's derivation of the 1 hr 1 mi^2 PMP value for the CRN Site.

Table 2.3-1 Precipitation for Stations around Clinch River Nuclear Site (reproduced from SSAR Table 2.3.1-2 [TVA 2019-TN5855])

Station	Normal Annual Rainfall (in.)	Max 24-hour Rainfall (in.)	Max Monthly Rainfall (in.)	Normal Annual Snowfall (in.)	Max 24-hour Snowfall (in.)	Max Monthly Snowfall (in.)
Oak Ridge NWS Station	50.91 30-year POR	7.48 66-year POR, Aug 1960	19.27 66-year POR, July 1967	11.1 30-year POR	12.0 52-year POR; March 1960	21.0 52-year POR; March 1960
Knoxville NWS Station	47.86 30-year POR	5.98 72-year POR; Sept 2011	12.67 72-year POR; Jan 2013	6.5 30-year POR	18.2 69-year POR; Nov 1952	23.3 69-year POR; Feb 1960
Chattanooga NWS Station	52.48 30-year POR	9.50 74-year POR; Sept 2011	16.32 74-year POR; March 1980	3.9 30-year POR	20.0 76-year POR; March 1993	20.0 76-year POR; March 1993
Nashville NWS Station	47.25 30-year POR	9.09 74-year POR; May 2010	16.43 74-year POR; May 2010	6.3 30-year POR	10.2 66-year POR; Dec 1963	18.9 66-year POR; Feb 1979
TVA Sequoyah	45.79 30-year POR	8.04 40-year POR; Sept 2004	13.34 40-year POR; March 1980	---	---	---
TVA Watts Bar	45.70 30-year POR	8.43 41-year POR; Sept 2011	12.33 41-year POR; March 1975	---	---	---

The staff reviewed the 2013 LCD publications for the first-order NWS stations at Chattanooga, Knoxville, Nashville, and Oak Ridge, Tennessee, and determined that the applicant's characterization of precipitation (rainfall) normals and extremes was reasonable. The staff also reviewed NOAA's HMR-52 (NOAA 1982-TN5943) to determine whether the applicant's PMP value listed as a site characteristic was appropriate for the CRN Site. The staff finds the PMP value acceptable because the applicant followed NRC guidance provided in SRP Section 2.4.3, "Probable Maximum Flood (PMF) on Streams and Rivers" (NRC 2007/2018-TN5898 The staff reviewed the NCDC TD-3200 daily data summaries for March 1993, which show that 18.5 in. was the daily snowfall total for March 13, and that 1.5 in. was recorded on the preceding day. Therefore, the staff concludes the maximum 24-hour snowfall total as listed in the referenced in SSAR (TVA 2019-TN5855) and FSER tables to be correct. See FSER Sections 2.3.1.3.3.6 and 2.3.1.3.3.6.2 for additional information.

2.3.1.3.3.4 *Tornadoes*

2.3.1.3.3.4.1 Tornado Strike Probability

The applicant stated that, according to the NCEI Storm Events Database (NOAA 2017-TN6065), five tornadoes were reported within 10 mi of the proposed site, and only one had greater than an EF-0 intensity (on the Enhanced Fujita Scale [EF]); these statistics are presented in SSAR Table 2.3.1-3, “Tornadoes Reported within 10 Miles of Clinch River Nuclear Site (1950-2013)” (TVA 2019-TN5855). The closest tornado reported near the CRN Site was rated an F3 (158–206 mph on the Fujita Tornado Intensity Scale [F]) at a distance of 4 mi. The staff independently confirmed this information by accessing the NCEI Storm Events Database (NOAA 2017-TN6065) for Roane, Morgan, Anderson, Knox, and Loudon Counties in Tennessee for the 64-year period of 1950 to 2013; each county has a part of its designated area located within 10 mi of the proposed site.

In addition, in SSAR Section 2.3.1.3.4 the applicant provided calculations of tornado strike probabilities that could potentially occur at the proposed site (TVA 2019-TN5855). The calculations are based on the tornado strike probability presented in Revision 2 of NUREG/CR-4461, “Tornado Climatology of the Contiguous United States” (Ramsdell and Rishel 2007-TN277), which uses the principle of geometric probability described by H.C.S. Thorn (1968-TN6062). According to H.C.S. Thorn, the probability of a tornado striking any point in a 1-degree latitude by 1-degree longitude square can be calculated as follows (Equation 2.3.1-1 from the SSAR [TVA 2019-TN5855]):

$$P = \frac{zt}{A}$$

where

P = mean probability of a tornado striking a point in any year within a 1-degree square
z = mean path area of a tornado (mi^2)
t = mean number of tornadoes per year
A = area (mi^2).

The applicant determined the mean probability of a tornado striking a point in any year in a 1-degree box to be 1.43 × 10^{-4} per year, which equals a recurrence interval of 6,993 years.

The applicant also provided additional information related to tornado strike probability that is included in NUREG/CR-4461 (Ramsdell and Rishel 2007-TN277). The SSAR mentions that the number of tornado events from 1950 to August 2003 within a 2-degree latitude/longitude box surrounding the CRN Site is 226 (TVA 2019-TN5855), which presents an annual average of four tornado events striking somewhere within the 2-degree box.

The staff independently reviewed the information referenced by the applicant and confirmed the applicant’s tornado strike probability calculations. The staff finds the applicant’s characterization of this material to be reasonable for informational purposes, because information in the section related to tornado strike probability does not result in the generation of site characteristics for use in design or operating bases.

2.3.1.3.3.4.2 Design Basis Tornado Parameters

In SSAR Section 2.3.1.3.4 (TVA 2019-TN5855), the applicant developed tornado site characteristics for the CRN Site based on parameters in RG 1.76 Revision 1 (NRC 2007-TN3294), which provides design basis tornado characteristics for three tornado-intensity regions throughout the contiguous United States, each with a 10^{-7} probability of occurrence. The proposed CRN Site is located within tornado-intensity Region I. The applicant proposed the following tornado site characteristics (US Customary Units), which are listed in SSAR Table 2.0-1 (TVA 2019-TN5855):

- maximum wind speed 103 m/s (230 mph)
- translational speed 21 m/s (46 mph)
- maximum rotational speed 82 m/s (184 mph)
- radius of maximum rotational speed 45.7 m (150 ft)
- pressure drop 83 millibars (mb) (1.2 psi)
- rate of pressure drop 37 mb/s (0.5 psi/sec).

Because the applicant's tornado site characteristics are based on parameters in Revision 1 of RG 1.76 (NRC 2007-TN3294) for the appropriate tornado-intensity region, the staff finds these characteristics to be acceptable.

2.3.1.3.3.5 *Hurricanes*

The applicant viewed the NCEI Storm Events Database (NOAA 2017-TN6065) and noted that one tropical storm, associated with Hurricane Ivan, on September 16, 2004, near Roane County caused minimal damage. From 1905 until the submittal of the SSAR in 2016, there have been 10 tropical storms within a 50 mi radius of the proposed site; however, some of these storms were initially classified as hurricanes before impacting the area. Potential impacts from these events included flood effects from heavy rains.

The applicant stated that they reviewed both RG 1.221 (NRC 2011-TN5931) and NUREG/CR-7005 (Vickery et al. 2011-TN5932) and came to the conclusion that because the site lies at an extended distance from the coast, hurricane winds will not present a safety concern for the proposed CRN Site; the 3-second gust wind speed contours provided in RG 1.221 (NRC 2011-TN5931) and NUREG/CR-7005 (Vickery et al. 2011-TN5932) (below) cease at 130 mph after certain distances inland from the U.S. coasts, as can be seen in Figure 2.3-1 of this FSER.

The staff reviewed the Storm Events Database (NOAA 2017-TN6065), provided through NCEI (formerly NCDC), and confirmed the applicant's information regarding one tropical storm that impacted the county on September 16, 2004. The applicant reviewed the NCEI Storm Events Database for tropical storms since 1950. However, the staff understands that the POR covered by the online Storm Events Database for tropical cyclone events (including, but not limited to, hurricanes and tropical storms) currently only begins in 1996. The staff also reviewed NOAA's Office for Coastal Management "Historical Hurricane Tracks" database (NOAA 2017-TN6066) by applying a 50-nautical mile search radius to the site location. This database contains comprehensive records that date back to the mid-1800s. The staff noted that no tropical cyclones with winds exceeding tropical storm strength have traversed the 50-nautical mile radius area around the proposed site.

The applicant provided a site characteristic hurricane wind speed of 130 mph (3-second wind gust speed) in SSAR Table 2.0-1. Based on Figure 2.3-1, which is reproduced from RG 1.221

(NRC 2011-TN5931) and confirms applicant's site hurricane wind speed, the staff agrees with the applicant's conclusion and finds this information acceptable.

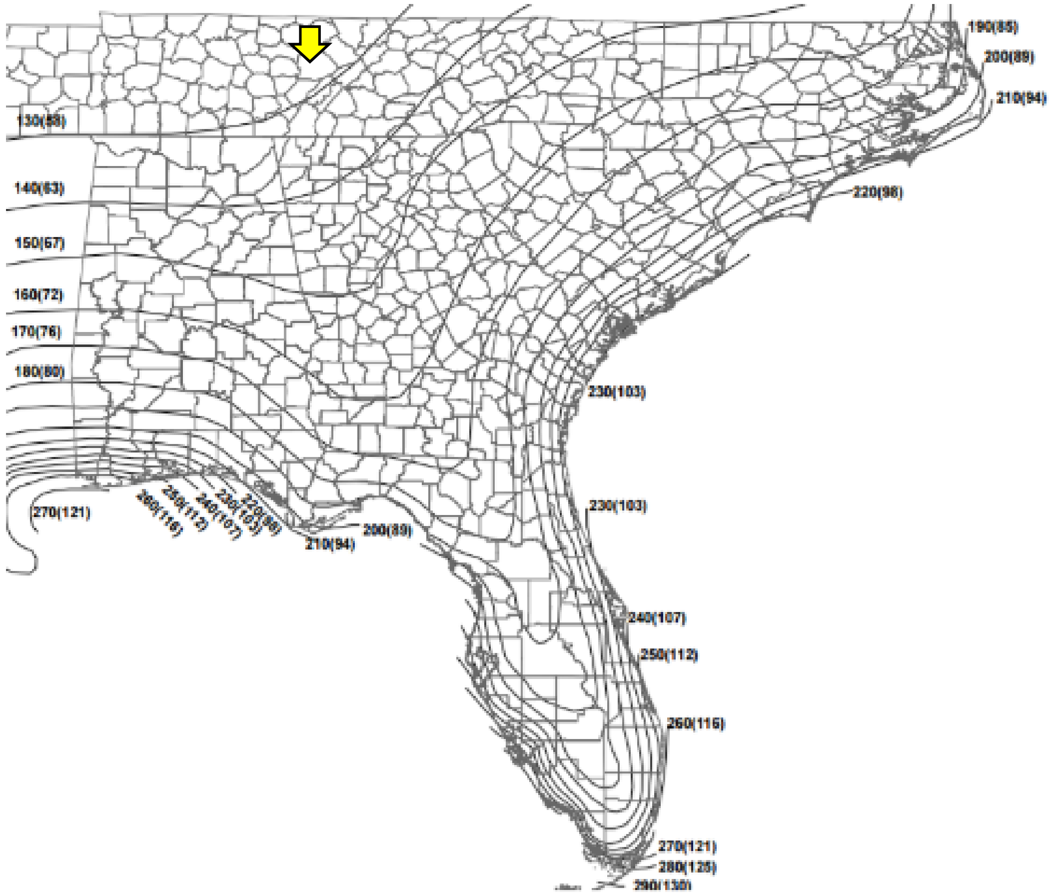

Figure 2.3-1 Design Basis Hurricane Wind Speeds for the Eastern Gulf of Mexico and Southeastern Atlantic U.S. Coastline Representing Exceedance Probabilities of 10^{-7} per Year (reproduced from RG 1.221 [NRC 2011-TN5931]). Values are nominal 3-second gust wind speeds in miles per hour (meters per second) at 33 ft (10 m) above ground over open terrain. The approximate location of the CRN Site is indicated by the yellow arrow.

2.3.1.3.3.6 *Winter Storm Events*

In SSAR Section 2.3.1.3.6, "Winter Storm Events" (TVA 2019-TN5855), the applicant identified a maximum reported snow depth at the Knoxville, Tennessee, first-order NWS station of 15 in. for February 1960 based on a 61-year POR. The applicant also identified a maximum 24-hour snowfall of 20.0 in. reported for March 1993 at Chattanooga, Tennessee.

See FSER Section 2.3.1.3.3.3 regarding the staff's evaluation of the maximum 24-hour snowfall total reported for the Chattanooga, Tennessee, NWS station. The staff confirmed the maximum reported snow depth for the Knoxville, Tennessee, NWS station but notes that this observation is not a controlling event directly used in estimating normal or extreme winter precipitation roof loads for the CRN Site, as discussed below in FSER Section 2.3.1.3.3.6.2.

2.3.1.3.3.6.1 Ice Storms

The applicant used the reference “Estimated Glaze Ice and Wind Loads at the Earth’s Surface for the Contiguous United States,” by Paul Tattleman and Irving I. Gringorton to characterize ice storms for the site area (Tattleman and Gringorton 1973-TN6078; NOAA 2017-TN6065). According to Tattleman and Gringorton, Region V (which includes Tennessee) experienced five ice storms involving more than or equal to 2.5 cm (1 in.) of ice accumulation and two ice storms involving more than or equal to 5 cm (2 in.) ice accumulation, both of which were determined for a period of 50 years. According to the same reference, ice thicknesses in Region V with wind gusts greater than or equal to 20 m/s (44.7 mph) are less than 1 in. for 25- and 50-year return periods and less than 1.4 in. for a 100-year return period (Tattleman and Gringorton 1973-TN6078).

The applicant also provided ice thickness data from Figure 10-2, “50-Year Mean Recurrence Interval Uniform Ice Thicknesses Due to Freezing Rain with Concurrent 3-Second Gust Speeds: Contiguous 48 States,” of the ASCE/SEI 7-05 standard (ASCE/SEI 2005-TN6042). The applicant stated that Roane County, which contains the proposed site, lies within the 0.75 in. ice thickness contour that has a concurrent 3-second wind gust of 30 mph.

In addition, the applicant discussed glaze ice point probabilities for ice thicknesses. For accumulations greater than or equal to 0.5 in., the probability equals 0.20, and for accumulations greater than or equal to 0.25 in., the probability equals 0.36. According to the applicant, these probabilities correspond to recurrence intervals of once in 5 years and once in 3 years, respectively. The applicant also mentioned that glaze ice results in little structural damage when the thicknesses are less than or equal to 0.5 in.; however, these lesser ice thicknesses present concerns for travel in affected areas and can damage above-ground utility wires, when combined with strong winds.

The staff reviewed the paper “A Review of the Effect of Ice Storms on the Power Industry,” by William B. Bendel and Dawna Paton (Bendel and Paton 1981-TN6077), which contains data based on Tattleman and Gringorten (1973-TN6078), as well as Figure 10-2 of the ASCE/SEI 7-05 standard (ASCE/SEI 2005-TN6042). Based on this review, the staff finds these references and the information provided by the applicant regarding ice storms to be reasonable for the proposed CRN Site region.

2.3.1.3.3.6.2 Normal and Extreme Winter Precipitation Events

In SSAR Section 2.3.1.3.6.2, “Normal and Extreme Winter Precipitation Events,” the applicant discussed the climatological data and the methods used to develop site characteristic values for the normal, extreme frozen, and extreme liquid winter precipitation events (TVA 2017-TN5387). In a letter dated April 9, 2018 (TVA 2018-TN5892), the applicant committed to updating SSAR Section 2.3.1.3.6.2 and SSAR Table 2.0-1 (TVA 2017-TN5387) with revised snowfall estimates consistent with the approach and terminology outlined in DC/COL-ISG-007 (NRC 2008-TN5930). The staff’s review of the proposed updates to SSAR Section 2.3.1.3.6.2 and SSAR Table 2.0-1 contained in the April 9, 2018 submittal confirmed that the applicant’s evaluations of these climate-related DBEs follow the guidance in DC/COL-ISG-007 (NRC 2008-TN5930), which clarifies the applicable acceptance criteria in SRP Section 2.3.1.

Based on this regulatory guidance, there are four components to be considered when estimating the ground snow load associated with the normal winter precipitation event (i.e., the 100-year return period snowpack [snow depth], the historical maximum snowpack [snow depth],

the 100-year return period 2-day snowfall event, and the historical maximum 2-day snowfall event in the site region). With respect to the 100-year return period snowpack (snow depth), the applicant identified a 50-year recurrence interval ground snow load for the Oak Ridge, Tennessee, area based on Figure 7-1 in ASCE/SEI Standard 7-05 (ASCE/SEI 2005-TN6042), and converted it appropriately to a 100-year recurrence interval value (i.e., 12.2 pounds per square foot [psf]) as discussed elsewhere in that standard.

Regarding the historical maximum snowpack (snow depth) component of the normal winter precipitation event, the applicant identified a ground snow load for the proposed site region of 15.3 psf based on a 19 in. snow depth recorded over a 77-year POR at the first-order NWS station located in Chattanooga, Tennessee. The applicant converted this measured snow depth to a ground snow load in accordance with DC/COL-ISG-007 (NRC 2008-TN5930). A designated ground snow load of 21.9 psf, said to represent the historical maximum 2-day snowfall event, was based on snowfall (precipitation) measured at the Westbourne, Tennessee, cooperative observing station (i.e., 28 in.), again using the calculation method in DC/COL-ISG-007 (NRC 2008-TN5930) and by conservatively assuming the upper limit of the range for snow densities in that guidance.

The applicant also estimated a ground snow load said to be associated with the 100-year return period 2-day snowfall event measured at the Knoxville, Tennessee, first-order NWS station. Based on the referenced guidance, this 21.1 in. snowfall event is equivalent to a ground-level weight of 16.5 psf.

Consistent with the guidance in DC/COL-ISG-007 (NRC 2008-TN5930), the applicant then designated the highest of these four component values (i.e., 21.9 psf, based on the historical maximum 2-day snowfall [precipitation] event) as representing the controlling normal winter precipitation event.

With respect to determining the extreme winter precipitation event, the applicant provided estimates for its two components (i.e., the extreme frozen and the extreme liquid winter precipitation events). Based on the guidance in DC/COL-ISG-007 (NRC 2008-TN5930), the extreme frozen winter precipitation event is considered to be the higher ground snow load associated with either the 100-year return period 2-day snowfall event or the historical maximum 2-day snowfall event, in this case designated by the applicant to be 21.9 psf.

The applicant developed the extreme liquid winter precipitation component, represented by the 48-hour PMWP, based on NOAA's HMR-53. The 48-hour PMWP value was estimated by logarithmic interpolation between the available 24- and 72-hour PMP plots for the combined months of January-February and for the month of March. The winter season was assumed to include March because historically higher snowpack (snow depths) have occurred in the site region during that month. This resulted in an estimate of 23.5 in. of rain for the 48-hour PMWP.

Finally, consistent with the guidance in DC/COL-ISG-007 (NRC 2008-TN5930), the staff notes that the extreme winter precipitation event live roof load is based on the sum of the roof loads associated with the controlling normal winter precipitation event plus the controlling extreme winter precipitation event and is evaluated in Chapter 3 of the COLA.

As indicated previously, in a letter dated April 9, 2018 (TVA 2018-TN5892), the applicant committed to updating SSAR Section 2.3.1.3.6.2 and SSAR Table 2.0-1 (TVA 2017-TN5387) with revised snowfall estimates consistent with the approach and terminology outlined in DC/COL-ISG-007 (NRC 2008-TN5930). This is Confirmatory Item 2.3-1.

In Revision 2 of the ESPA, TVA updated SSAR Section 2.3.1.3.6.2 to include the revised snowfall estimates (TVA 2019-TN5855). Hence, the staff determined that the applicant has used the data resources and analytical approaches established by the guidance in DC/COL-ISG-007 (NRC 2008-TN5930) and in SRP Section 2.3.1 in preparing SSAR Section 2.3.1.3.6.2. Therefore, Confirmatory Item 2.3-1 is closed. The staff has therefore concluded that the postulated site characteristics associated with normal, extreme frozen, and extreme liquid winter precipitation events are acceptable and reasonably representative of the proposed site region.

2.3.1.3.4 Design Basis Dry- and Wet-Bulb Temperatures

In SSAR Section 2.3.1.4, “Design Basis Dry- and Wet-Bulb Temperatures,” the applicant based its ambient (dry-bulb) air temperature and humidity site characteristics on an hourly data recorded at the first-order NWS station located at the Chattanooga Lovell Airport (TVA 2019-TN5855). The applicant presented the site characteristic temperature and humidity values in SSAR Table 2.0-1 and in SSAR Section 2.3.1.4 (TVA 2017-TN5387). In a letter dated April 9, 2018 (TVA 2018-TN5892), the applicant committed to updating SSAR Section 2.3.1.4 and in SSAR Table 2.0-1 to be more specific in its definition of the dry- and wet- bulb temperature site characteristic values.

The staff used the NCDC hourly data from Chattanooga Lovell Airport (1973–2016) and climate data from the American Society of Heating, Refrigerating and Air-Conditioning Engineers to verify that the applicant’s site-characteristic dry-bulb and wet-bulb temperatures presented in CRN Site SSAR Table 2.0-1 (TVA 2017-TN5387), as modified by the April 9, 2018 submittal (TVA 2018-TN5892), are appropriate.

By letter dated April 9, 2018 (TVA 2018-TN5892), the applicant provided markups to Revision 1 of SSAR Section 2.3.1.4 and SSAR Table 2.0-1 (TVA 2017-TN5387) for inclusion in the subsequent revision of the SSAR. The staff identified this as Confirmatory Item 2.3-2. The staff confirmed that Revision 2 of the SSAR (TVA 2019-TN5855) included the updated dry-bulb and wet-bulb site characteristics as provided in the April 9, 2018 letter. Therefore, Confirmatory Item 2.3-2 is closed.

During a public meeting on August 30, 2017, the staff requested that the applicant provide supplemental information regarding the methods used to calculate the 100-year return period coincident wet-bulb temperature for the CRN Site. In a letter dated September 7, 2017 (TVA 2017-TN5936), TVA submitted a CD-ROM with 100-year return period wet-bulb temperature input data and spreadsheet files. The staff reviewed the applicant’s submittal and the methods used to derive the site characteristic wet-bulb temperatures. Based on this review, the staff found the data and methods presented by the applicant in the aforementioned letter, as well as in SSAR Revision 2 (TVA 2019-TN5855), are conservative and consistent with the staff’s results, and are therefore acceptable.

2.3.1.3.5 Meteorological Data for Evaluating Ultimate Heat Sink

Revision 3 to RG 1.27 states that the UHS should be capable of providing sufficient cooling for at least 30 days (NRC 2015-TN5907). This means that a 30-day cooling-water supply should be available and that the design basis temperatures of safety-related equipment should not be exceeded. Therefore, the meteorological conditions resulting in the maximum evaporative and, if applicable, drift loss of water from the UHS, as well as the meteorological conditions resulting in minimum water cooling, should be considered to ensure that the UHS is available to perform its safety functions.

However, none of the designs in the CRN Site plant parameter envelope (PPE) being evaluated rely on external water sources as the UHS. Therefore, the criteria associated with a UHS water storage facility are not applicable.

2.3.1.3.6 Climate Changes

To be compliant with NRC regulations, NPPs must be built with consideration, in part, of the most severe natural 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. NPPs are designed with these stipulations on the environmental conditions that are considered at the site. Climate change is a concern because of the potential for unforeseen changes in extreme conditions in the local and regional environment. In SSAR Section 2.3.1.6, “Climate Changes,” the applicant provided a discussion of the climatology of the Clinch River region with regard to the trends in normal daily mean, maximum, and minimum temperatures and normal maximum precipitation (rainfall) (TVA 2017-TN5387).

In SSAR Section 2.3.1.6, the applicant analyzed trends in temperature and rainfall normals over a 90-year period for successive 30-year intervals by decade beginning in 1921 (e.g., 1921 through 1950, 1931 through 1960, etc.) for Knoxville and Oak Ridge, Tennessee (TVA 2017-TN5387). The applicant stated that the normal (i.e., 30-year average) temperature showed no significant variation in regional measurements over the 90-year period. The applicant also showed that there has been no significant change in local precipitation (rainfall) during the 90-year period.

SRP Section 2.3.1 (NRC 2007/2018-TN5898) states that historical data used to characterize a site should extend over a significant time interval to capture cyclical extremes. The staff obtained data sets considered to be of sufficient duration to determine the adequacy of the applicant’s proposed site characteristics. For example, snow load was evaluated using a 100-year return period and ambient design temperatures were based on a minimum of 30 years of hourly data and an estimated 100-year return period value. Tornado statistics were based on a 64-year POR and tornado wind speeds represented a 10^{-7} per year return interval as stated in Revision 1 to RG 1.76 (NRC 2007-TN3294). Extreme winds were based on a 100-year return period.

The U.S. Global Change Research Program (USGCRP) released a report to the President and Members of Congress in November 2018 titled, “Impacts, Risks, and Adaptation in the United States: Fourth Climate Assessment, Volume II (GCRP 2018-TN5847).” This report, produced by an advisory committee chartered under the Federal Advisory Committee Act (TN6079), summarizes the science of climate change and the potential impacts of climate change on the United States.

The USGCRP report found that the average annual temperature of the southeastern United States (which includes eastern Tennessee where the proposed CRN Site is located) did not change significantly over the past century as a whole, but the annual average temperature has risen approximately 1–2 °C (2-3 °F) since 1986 (GCRP 2018-TN5847). Climate models predict continued warming in all seasons across the Southeast and an increase in the rate of warming through the end of the 21st century. Average temperatures in the Southeast are projected to rise by 1 to 4°C (2 to 6.5°F) by the end of the century, depending on assumptions regarding global greenhouse-gas emissions.

The USGCRP report also states that there has been a 0 to 5 percent increase in observed annual average precipitation from 1986 to 2015 in the region where the proposed CRN Site is located (GCRP 2018-TN5847). Future changes in total precipitation are more difficult to project than changes in temperature. Model projections of future precipitation generally indicated that southern areas of the United States will have less precipitation in the summer months and conditions may remain the same the rest of the year. Except for indications that the amount of rainfall from individual hurricanes will increase, climatic models provide divergent results for future precipitation for most of the Southeast.

Although long-term tropical cyclone activity estimates are not addressed in SSAR Section 2.3.1.6 (TVA 2017-TN5387), the staff notes that in the USGCRP reports, due to the challenging nature of global tropical cyclone historical data, there is low to medium confidence in any reporting of long-term tropical cyclone activity estimates (GCRP 2018-TN5847). The USGCRP report states that

> …in a warmer world, there will be a greater potential for stronger tropical cyclones (also known as hurricanes and typhoons, depending on the region) in all ocean basins. Climate model simulations indicate an increase in global tropical cyclone intensity in a warmer world, as well as an increase in the number of very intense tropical cyclones, consistent with current scientific understanding of the physics of the climate system. In the future, the total number of tropical storms is generally projected to remain steady, or even decrease, but the most intense storms are generally projected to become more frequent, and the amount of rainfall associated with a given storm is also projected to increase.

The USGCRP report states that likely future changes for the United States and surrounding coastal waters include more intense hurricanes with related increases in wind and rain, but not necessarily an increase in the number of these storms that would make landfall and affect the CRN Site (GCRP 2018-TN5847).

The USGCRP further states that there is no clear trend in the frequency or strength of tornadoes since the 1950s for the United States as a whole (GCRP 2018-TN5847). Overall, the number of recorded tornado events has generally increased since detailed records have been routinely kept (beginning around 1950). However, much of this increase is attributable to a growing population, greater public awareness and interest, and technological advances in detection. The USGCRP states that a recent study (Kossin et al. 2017-TN6080) suggests a projected increase in the frequency of conditions favorable for severe thunderstorms that may include tornadoes (GCRP 2018-TN5847).

The USGCRP reports that the frequency of hail and severe thunderstorm wind events has changed little over the previous decades, and states that confidence in past trends for hail and severe thunderstorm winds is low (GCRP 2018-TN5847). Climate models project future increases in the frequency of environmental conditions favorable to severe thunderstorms. But the inability to adequately model the small-scale conditions involved in thunderstorm development remains a limiting factor in projecting the future character of severe thunderstorms and other small-scale weather phenomena.

The staff acknowledges that long-term climatic change resulting from human or natural causes may introduce changes in the most severe natural phenomena reported for the CRN Site. However, no conclusive evidence of or consensus of opinion is available about the rapidity or nature of such changes. There is a level of uncertainty in projecting future conditions because

the assumptions regarding the future level of emissions of heat-trapping gases depend on projections of population, economic activity, and choice of energy technologies.

If it becomes evident that long-term climatic change is influencing the most severe natural phenomena reported in the site region, the staff will follow the process described in SECY-16-0144, "Proposed Resolution of Remaining Tier 2 and 3 Recommendations Resulting from Fukushima Dai-Ichi Accident" (NRC 2016-TN5852), to address the effects that any changes in the climatological and meteorological environment may have on the design or operating basis for any future COL holders at the CRN Site, with the understanding that the evaluation will be focused on changes in extreme, not average, conditions. The framework outlined in SECY-16-0144 provides a graded approach that allows the staff to proactively, routinely, and systematically seek, evaluate, and respond to new information about natural hazards (NRC 2016-TN5852). Under this framework, the staff will collect, aggregate, review, and assess information related to natural hazards on an ongoing basis. The Commission approved the framework in Staff Requirements Memorandum SRM-SECY-16-0144 (NRC 2017-TN5851). The staff finds the applicant's characterization of climate change to be reasonable for informational purposes, because information provided in SSAR Section 2.3.1.6 (TVA 2017-TN5387) is not related to, or identified as, site characteristics.

2.3.1.3.7 Regional Air-Quality Conditions

The applicant's discussion of regional air-quality conditions in SSAR Section 2.3.1.7 (TVA 2017-TN5387) 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.

2.3.1.3.7.1 <u>Background Air Quality</u>

In SSAR Section 2.3.1.7.1, "Background Air Quality," the applicant provided a general discussion of background air-quality conditions in the CRN Site region (TVA 2017-TN5387). This included identifying the compliance status of criteria air pollutants for which the EPA has established National Ambient Air Quality Standards (NAAQSs) (i.e., carbon monoxide, nitrogen dioxide, ozone, particulate matter less than 10 microns and less than 2.5 microns in aerodynamic diameter [or PM_{10} and $PM_{2.5}$, respectively], sulfur dioxide, and lead). The applicant did not identify or discuss any differences or commonalities between the NAAQSs and AAQSs specific to the State of Tennessee.

The proposed CRN Site is located in Roane County, Tennessee. Although not so indicated in SSAR Section 2.3.1.7.1 (TVA 2017-TN5387), pursuant to 40 CFR 81.57 (under Subpart B of Part 81 [TN255]), the site is included in the Eastern Tennessee – Southwestern Virginia Interstate Air Quality Control Region (AQCR) (formerly the Bristol [Virginia] – Johnson City [Tennessee] Interstate AQCR).

Based on the information in 40 CFR 81.343 (under Subpart C of Part 81 [TN255]) and the EPA's "Green Book" (Nonattainment Areas for Criteria Pollutants) dated June 20, 2017 (EPA 2017-TN6131), the staff confirmed the NAAQS attainment status designations as in attainment (i.e., currently meets) or unclassifiable/in attainment (i.e., meeting the standard or expected to be meeting the standard despite a lack of monitoring data) for all criteria air pollutants. SSAR Table 2.3.1-5, "Ambient Air Quality Concentrations in the Vicinity of Clinch River Nuclear Site in 2013" (TVA 2017-TN5387), provides a limited illustration of the compliance status based on ambient monitoring results from Roane and adjacent counties for calendar year 2013 relative to

the NAAQSs. A small portion of Roane County (which is near, but does not include, the CRN Site) and several adjacent counties are currently designated as being in nonattainment for the annual and 24-hour $PM_{2.5}$ standards.

SSAR Section 2.3.1.7.1 (TVA 2017-TN5387) also provided a general discussion of two EPA programs designed to protect ambient air-quality levels and related characteristics (i.e., in Class 1 areas under the EPA's Prevention of Significant Deterioration of Air Quality program and the Regional Haze Rule). While not associated with any site characteristics listed in SSAR Table 2.0-1 (TVA 2017-TN5387), the applicant followed the NRC guidance provided in SRP 2.3.1; therefore, the staff finds the information provided in that discussion to be acceptable.

2.3.1.3.7.2 <u>Projected Air Quality</u>

SSAR Section 2.3.1.7.2, "Projected Air Quality," briefly indicates that the proposed facility is not expected to be a significant source of criteria air pollutants and air toxic emissions, nor would it significantly impact ambient air quality (TVA 2017-TN5387). If necessary, any applicable air-quality permits would be acquired in accordance with the regulations and guidance of the appropriate regulatory authorities. The staff finds the applicant's characterization of the projected air quality to be reasonable for informational purposes, because information provided in SSAR Section 2.3.1.7.2 (TVA 2017-TN5387) is not related to any site characteristics.

2.3.1.4 *Conclusion*

As discussed in the preceding sections, the applicant presented and substantiated information to establish the regional climatological characteristics applicable to the proposed CRN Site. The staff reviewed the information provided and, for the reasons given above, concludes that the applicant has provided appropriate information in its ESPA and has established site characteristics, where applicable, that are acceptable to meet the requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.20(c)(2) (TN282), and 10 CFR 100.21(d) (TN282).

The staff finds that the applicant has considered the most severe phenomena historically reported for the site and surrounding area in establishing the above site characteristics. The staff, following the guidance provided in SRP Section 2.3.1 (NRC 2007/2018-TN5898), and other applicable guidance listed in FSER Section 2.3.1.3, has accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics. Accordingly, the staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the staff finds acceptable the site characteristics previously identified by the applicant and reviewed by the staff for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL or construction permit (CP) application.

Therefore, the staff concludes that the identification and consideration of the climate-related site characteristics discussed above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.20(c)(2) (TN282), and 10 CFR 100.21(d) (TN282).

In view of the above, the staff finds the applicant's climate-related site characteristics for the proposed CRN Site to be acceptable.

2.3.2 Local Meteorology

In SSAR Section 2.3.2, "Local Meteorology" (TVA 2017-TN5387), the applicant presented (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.

2.3.2.1 *Summary of Application*

In SSAR Section 2.3.2 (TVA 2017-TN5387), 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 NPP and associated facilities that are planned to be built on the proposed site would influence the local meteorology, including the effects of plant structures, terrain modification, and heat and moisture sources resulting from plant operation; and
- a topographical description of the site and its environs.

In Section 2.3.2 of this report, the 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 Basis*

The acceptance criteria, as identified in SRP Section 2.3.2, "Local Meteorology" (NRC 2007/2018-TN5898), for identifying local meteorological parameters are based on meeting the relevant requirements of 10 CFR 52.17 (TN251) and 10 CFR Part 100 (TN282). The staff considered the following regulatory requirements in reviewing the applicant's identification of local meteorological and topographic conditions:

- 10 CFR 52.17(a)(1)(ix) (TN251), as it relates to the requirement that an applicant perform an evaluation and analysis of a postulated fission product release, together with applicable site characteristics, including site meteorology, to evaluate the offsite radiological consequences;
- 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) (TN282), as it relates to the requirement that site atmospheric dispersion characteristics be evaluated and dispersion parameters established such 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; and
  - radiological dose consequences of postulated accidents meet the criteria set forth in 10 CFR 50.34(a)(1) (TN249) for the type of facility proposed to be located at the site;

- 10 CFR 100.21(d) (TN282), as it relates to the requirement that the physical characteristics of the site, including meteorology, be evaluated and site characteristics be established to ensure that the potential threats from such physical characteristics would pose no undue risk to the type of facility proposed to be located at the site.

To the extent applicable to the above-outlined acceptance criteria included in SRP Section 2.3.2 (NRC 2007/2018-TN5898), the applicant applied the following NRC-endorsed meteorological monitoring methodologies and techniques:

- RG 1.23, Revision 1, “Meteorological Monitoring Programs for Nuclear Power Plants” (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.

When independently assessing the information presented by the applicant in SSAR Section 2.3.2 (TVA 2017-TN5387), the staff applied the same above-cited methodologies and techniques.

2.3.2.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.3.2 (TVA 2017-TN5387) to ensure that the ESPA represents the complete scope of information related to this review topic. The staff’s review confirmed that the applicant addressed the required information related to local meteorology.

2.3.2.3.1 Local Meteorology

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 eastern Tennessee) to provide additional data to establish the representativeness of the 2-year onsite monitoring data summaries and potential site conditions.

In addition, the applicant described the topography around the site as a primary influence on local climate. Based on discussions of the local topography in SSAR Section 2.3.2 (TVA 2017-TN5387) and site visits by the staff, the information regarding local climate and the topography are acceptable to the staff.

2.3.2.3.1.1 <u>Normal and Extreme Values of Meteorological Parameters</u>

The applicant examined long-term temperature and precipitation records to determine if data collected at the CRN Site are consistent with regional conditions, both spatially and temporally.

The applicant compared common measurements from different data periods to determine whether site meteorological conditions are changing significantly over time. The comparisons are shown in SSAR Table 2.3.2-2, “Comparisons of Meteorological Tower Measurements,” Section a, “Historical Primary Tower Measurements” (TVA 2017-TN5387). The applicant stated that most of the common variables (such as wind speed, temperature, and dew point) can be compared directly, but wind direction is too dependent on topography for direct comparison, particularly with offsite data. The applicant stated that the data in SSAR Table 2.3.2-2, Section a, show that there is generally good agreement between the different data periods and

that the differences fall within the normally expected variations (TVA 2017-TN5387). The applicant concluded that the meteorological characteristics of these variables at the CRN Site have not changed significantly over time.

Comparing meteorological data from nearby offsite locations (Oak Ridge NWS station and the Watts Bar nuclear station) helps determine whether the CRN Site conditions are consistent with regional conditions. Wind speed, temperature, and dew point data were provided by the applicant for the period of April 21, 2011 to June 30, 2012 and are shown in SSAR Table 2.3.2-2, Section b, “Comparison of CRN Site with Offsite Locations” (TVA 2017-TN5387). The applicant stated that there is good agreement between the data for the CRN Site and those for the offsite locations, especially between the average values.

The applicant stated that these comparisons indicate that, for these variables, conditions at the CRN Site are consistent with overall meteorological conditions in the vicinity. The applicant asserted that this is characteristic of the similarity in controlling synoptic influences throughout the region and that other meteorological parameters are subject to the same synoptic controls.

The staff reviewed data representing meteorological parameters for the CRN Site and surrounding area (data from Chattanooga and Knoxville, Tennessee), and finds the applicant’s data and discussion to be acceptable.

2.3.2.3.1.1.1 Winds

In SSAR Section 2.3.2.1.1, “Winds,” the applicant stated that 10 m (33 ft) wind data were collected by the meteorological tower at the CRN Site during 2011–2013, and that the meteorological facility generally met the criteria for obtaining data representative of the atmospheric conditions (TVA 2017-TN5387). However, due to concerns regarding nearby obstructions that exceeded the 1-to-10 height-to-distance criterion specified in RG 1.23 Revision 1 (NRC 2007-TN278), the applicant stated that an evaluation of these obstructions was performed and the applicant determined they would have minimal impact on wind measurements at the CRN Site. The staff review of this evaluation is discussed in FSER Section 2.3.3.3.1.2, “Primary Meteorological Facility.”

The applicant stated that the average wind direction and wind speed conditions at the CRN Site are summarized in joint frequency distributions (JFDs) of 10 m (33 ft) wind direction and wind speed and atmospheric stability class (determined as a function of temperature change with height) from instruments at the site and are presented in SSAR Section 2.3.4, “Short-Term (Accident) Diffusion Estimates” (TVA 2017-TN5387). The site data are presented as wind roses in SSAR Figures 2.3.2-3 through 2.3.2-28. Wind roses for the Chattanooga NWS station, based on 10 years of data (2000–2009), are presented in SSAR Figures 2.3.2-29 through 2.3.2-41. Wind roses for the Oak Ridge NWS station, based on 10 years of data (2000–2009), are presented in SSAR Figures 2.3.2-42 through 2.3.2-54 (TVA 2017-TN5387).

The applicant described the wind speeds at the CRN Site during 2011–2013 (shown in SSAR Table 2.3.2-3, “Average (Scalar) Wind Speed for Clinch River Nuclear Site (2011-2013)”) as generally light with an average 10 m (33 ft) speed of 1.22 m/s (2.74 mph) (TVA 2017-TN5387). The highest 10 m (33 ft) hourly average observed speed was 6.75 m/s (15.1 mph). The applicant stated that the geographic orientation of the ridges and valleys generally aligns with the prevailing regional winds from the southwest, but the gaps in the ridges permit wind flow from other directions as well. The SSAR states that the combination of high pressure associated with the Azores-Bermuda anticyclonic circulation and the nearby ridges result in

generally light wind speeds and average surface wind speeds for the site of less than 1.8 m/s (4 mph) (TVA 2017-TN5387). As stated by the applicant in SSAR Section 2.3.2.1.1, “The CRN Site is surrounded by complex terrain, with alternating ridges and valleys oriented along a southwest (SW) to northeast (NE) axis. The local wind patterns are influenced by the complex terrain, with up-valley (SW-WSW)/down-valley (NE-ENE) flow patterns common and stable conditions with light winds frequently observed, especially during the summer and fall seasons. These nonlinear flow patterns influence the dispersion around the CRN Site” (TVA 2017-TN5387).

Using hourly data from the onsite meteorological measurements program and spreadsheets, the staff was able to recreate the wind roses and JFDs provided by the applicant. Given the description in SSAR Section 2.3.3.2.4, “Data Recording and Display” (TVA 2017-TN5387), and the staff’s evaluation in FSER Section 2.3.3.3.1.2.2, wind roses and other wind-related data summaries appear to be based on vector-averaged wind directions and scalar-averaged wind speeds. However, the SSAR does not include details about whether the earlier onsite wind data summaries (SSAR Figure 2.3.2-2, “Effects of Topography on Wind Flow in the Clinch River Nuclear Site Vicinity [TVA 2017-TN5387]) are based on either scalar- and/or vector-averaged wind direction and wind speed averages as discussed in a letter dated April 9, 2018 (TVA 2018-TN5892). Similarly, the applicant’s comparison of onsite to offsite NWS wind roses for Chattanooga (SSAR Figures 2.3.2-29 through 2.3.2-41 [TVA 2017-TN5387]) and Oak Ridge, Tennessee (SSAR Figures 2.3.2-42 through 2.3.2-54 [TVA 2017-TN5387]), which may be a composite of both scalar- and vector-averaged wind direction and/or wind speed values, make it difficult to support a determination that the onsite wind direction data are representative of long-term conditions at the site. Due to the complex nature of the terrain surrounding the CRN Site, it is unknown how much of the difference between the onsite and offsite wind roses is due to the relative location of the stations, or the data collection and processing methods, or both. However, these differences do not exclude the onsite meteorological data from being used in the atmospheric dispersion models because the collection of meteorological data at the site is still the most accurate way to capture the conditions directly influencing accident and routine airborne releases at the site. The Audit Report (NRC 2018-TN6152) further discusses the staff’s review of the potential implications of the applicant’s use of vector-averaged wind directions and scalar-averaged wind speeds as input to wind-related data summaries and as input to dispersion modeling analyses.

In describing the wind direction persistence, the applicant stated that generally, the longer the winds blow in the same direction, the lower the dilution potential will be because effluent is not dispersing significantly to other downwind sectors. Wind direction persistence is an indicator of the duration of atmospheric transport, as summarized by the applicant, from a single 22.5-degree sector, from three adjoining sectors (67.5 degrees in total), and five adjoining sectors (112.5 degrees in total). For the CRN Site, SSAR Table 2.3.2-4, “Wind Direction Persistence for Clinch River Nuclear Site (2011-2013),” shows that the maximum persistence at 10 m (33 ft) is 19 hours from the W sector, 46 hours from the WNW clockwise through the NNW sectors (i.e., ± 1 sector centered on the NW sector), and 106 hours from the SW clockwise through the NW sectors (i.e., ±2 sectors centered on the W sector) (TVA 2017-TN5387).
The applicant stated that the wind data show a consistent pattern of wind directions with predominant winds from the WSW-NW, and with little seasonal variation (SSAR Figure 2.3.2-55 [TVA 2017-TN5387]). The applicant concluded that due to the combination of uniformly light wind speeds and surrounding terrain, there will often be little transport away from the site.

Through analysis of data from the onsite meteorological measurements program, the staff independently confirmed the wind direction persistence measurements at the CRN Site, noting, as for the wind rose summaries, that wind direction data represent vector averages.

2.3.2.3.1.1.2 Air Temperature

In SSAR Section 2.3.2.1.2, "Air Temperature," the applicant characterized normal and extreme temperatures for the CRN Site based on temperature data for Knoxville and Oak Ridge, Tennessee (TVA 2017-TN5387). These data are presented in SSAR Tables 2.3.2-5, "Air Temperatures for Knoxville, Tennessee," and 2.3.2-6, "Air Temperatures for Oak Ridge, Tennessee," respectively (TVA 2017-TN5387). The normal temperatures ranged from the upper 30s°F in the winter to the upper 70s°F in the summer at both locations. Normal daily maximum temperatures ranged from about 47°F in mid-winter to about 88°F in mid-summer. The normal daily minimum temperatures ranged from about 29°F in mid-winter to about 69°F in mid-summer. The extreme daily maxima recorded were 105°F (June and July 2012) at the Knoxville NWS station and 105°F (July 1952 and June 2012) at the Oak Ridge NWS station, while the extreme daily minima (during January 1985) were -24°F and -17°F, respectively. Through independent review of data from these NWS stations (NOAA 2017-TN6064), the staff confirmed the temperature discussion provided by the applicant.

2.3.2.3.1.1.3 Atmospheric Moisture

In SSAR Section 2.3.2.1.3, "Atmospheric Moisture," the applicant provided long-term relative humidity and absolute humidity data for Knoxville and Oak Ridge (TVA 2017-TN5387). The data are presented in Table 2.3.2-7, "Humidity Values for Knoxville and Oak Ridge, Tennessee," which also lists the mean dry-bulb temperature and mean dew point temperature. Short-term humidity data based on measurements at the onsite meteorological facility are summarized in SSAR Table 2.3.2-8, "Humidity Values for Clinch River Nuclear Site" (TVA 2017-TN5387). The table also lists the mean dry-bulb temperature and uses Tables 2.3.2-7 and 2.3.2-8 to compare the humidity data among the three sites (Knoxville, Oak Ridge, and CRN Site). The applicant stated that the CRN Site data match well with the long-term data from Knoxville and Oak Ridge.

The staff independently reviewed temperatures and dew points from the 2013 Annual Knoxville and Oak Ridge, Tennessee LCD. The staff was able to confirm the data provided by the applicant and therefore finds the temperature and relative humidity data presented by the applicant acceptable.

2.3.2.3.1.1.4 Precipitation

The applicant stated that valid reliable onsite precipitation observations were not available from the CRN Site. Therefore, hourly data collected at the Oak Ridge NWS station (approximately 19.3 km [12 mi] northeast of the CRN Site) are being used as an alternative because it is the nearest data source to the site.

The precipitation data from Oak Ridge are presented in SSAR Table 2.3.2-9, "Historical Precipitation Data for Oak Ridge, Tennessee" (TVA 2017-TN5387). The applicant stated that based on the data, precipitation occurs an average of about 125 days per year, and the normal annual precipitation is nearly 130 cm (51 in.). The maximum monthly rainfall has ranged from about 17.8 cm (7 in.) to just over 48.2 cm (19 in.). The minimum monthly amount was a trace in 1963. The maximum in 24 hours was 19.0 cm (7.48 in.) in August 1960. The SSAR states that, with the exception of the drier period during late-summer/early-autumn, precipitation is fairly

uniformly distributed throughout the year (TVA 2017-TN5387). July and March are normally the wettest months of the year.

The Oak Ridge precipitation data for the 2011–2013 CRN Site sampling period are presented in SSAR Table 2.3.2-10, “Precipitation (Inches) for Oak Ridge During 2011–2013 from Oak Ridge Monthly Local Climatological Data” (TVA 2017-TN5387). The applicant stated that the data indicate wetter than normal precipitation during 2011 and 2013, and drier than normal precipitation during 2012. Overall, precipitation was slightly above normal. Maximum rainfall, estimated by statistical analysis of regional precipitation data, is presented in SSAR Table 2.3.2-16, “Point Precipitation (Inches) by Recurrence Interval for Region,” for return periods of 1 to 100 years and for rainfall durations from 5 minutes to 10 days (TVA 2017-TN5387).

The applicant states that for a 100-year return period the point precipitation values for the CRN Site area for 6, 12, 24, and 48 hours are 5.0, 6.0, 6.8, and 8.0 in., respectively. SSAR Section 2.3.2.1.4 describes this information as the PMP for the site (TVA 2017-TN5387). The staff does not agree that these values represent the PMP, which is commonly defined as the greatest depth of precipitation meteorologically possible and generally has a recurrence interval much less frequent than 100 years. The PMP values for Maximum Rainfall Rates (as provided in SSAR Table 2.0-1) for the CRN Site are discussed in more detail in FSER Sections 2.4.2, “Floods,” and 2.4.3, “Probable Maximum Flood (PMF) on Streams and Rivers” (TVA 2017-TN5387).

The applicant stated that approximately 49 thunderstorms occur in a typical year. SSAR Table 2.3.2-9 shows that thunderstorm activity is most predominant in the spring and summer seasons, and the maximum frequency of thunderstorm days normally occurs in July (TVA 2017-TN5387).

The applicant stated that appreciable snowfall is relatively infrequent in the area of the CRN Site. The snowfall data are summarized in SSAR Table 2.3.2-11, “Historical Snowfall for Knoxville and Oak Ridge, Tennessee” (TVA 2017-TN5387). Normal annual snowfall has ranged from about 6.5 in. in Knoxville to about 11 in. in Oak Ridge, Tennessee. The applicant noted that generally, significant snowfalls are limited to December through March. Respective 24-hour maximum snowfalls have been 18 in. and 12 in. in Knoxville and Oak Ridge.

SSAR Table 2.3.2-12, “Oak Ridge Precipitation by Clinch River Nuclear Site Wind Direction,” shows composite 2011–2013 precipitation data based on Oak Ridge hourly precipitation and CRN Site wind directions (TVA 2017-TN5387). Precipitation is mostly associated with wind directions from SW clockwise through the NW sectors. There is a secondary maximum with wind directions from NE and ENE sectors. As mentioned for other wind-related data summaries, wind directions appear to be based on vector-averaged data.

Using snowfall and rainfall data from the Knoxville (NOAA 2017-TN6068) and Oak Ridge (NOAA 2017-TN6067) NWS stations, the NRC staff verified the precipitation statistics presented in SSAR Section 2.3.2 (TVA 2017-TN5387) and finds them acceptable.

2.3.2.3.1.1.5 Fog

Fog data for Knoxville and Oak Ridge, Tennessee, are presented in SSAR Table 2.3.2-13, “Fog Occurrence for Knoxville and Oak Ridge, Tennessee” (TVA 2017-TN5387). In SSAR Section 2.3.2.1.5, “Fog,” the applicant stated that these data indicate that heavy fog (visibility ≤1/4 mi) occurs about 30 days per year at Knoxville and 52 days per year at Oak Ridge, with

autumn normally being the foggiest season (TVA 2017-TN5387). The applicant stated that the CRN Site has conditions more similar to those at Oak Ridge.

Using the 2013 LCDs for Knoxville (NOAA 2017-TN6068) and Oak Ridge (NOAA 2017-TN6067), the staff confirmed the applicant's assertion that the Oak Ridge station reports approximately 52 days per year with heavy fog observations. The staff agrees that the frequency of fog conditions at Oak Ridge is expected to be similar to that at the proposed CRN Site because of the similarity of topographic features at both locations.

2.3.2.3.1.1.6 Atmospheric Stability

The applicant classified atmospheric stability in accordance with the guidance provided in RG 1.23 Revision 1 (NRC 2007-TN278). Atmospheric stability is a critical parameter for estimating dispersion characteristics as applicable for SSAR Sections 2.3.4 and 2.3.5, "Long-Term (Routine) Diffusion Estimates" (TVA 2017-TN5387). Dispersion of effluents is greatest for extremely unstable conditions (i.e., Pasquill stability Class A) and decreases progressively through extremely stable conditions (i.e., Pasquill stability Class G) as discussed in RG 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants" (NRC 1983-TN279).

The applicant based its stability classification on temperature change with height (i.e., delta-temperature or $\Delta T/\Delta Z$) between the 60 m (197 ft) and 10 m (33 ft) heights, as measured by the CRN Site onsite meteorological monitoring program between June 1, 2011 and May 31, 2013. In SSAR Table 2.3.2-14, "Pasquill Atmospheric Stabilities for the Clinch River Nuclear Site," the applicant provided the percent occurrence of Pasquill atmospheric stability classes (by quarter) for the 2-year period (TVA 2017-TN5387). The table shows that there is a predominance of neutral (Pasquill stability Class D) and slightly stable (Pasquill stability Class E) conditions at the proposed CRN Site. Extremely unstable conditions (Pasquill stability Class A) occur about 3 percent of the time. Extremely stable conditions (Pasquill stability Class G) occur about 17 percent of the time. Based on the staff's past experience with stability data at various sites, a predominance of neutral (Pasquill stability Class D) and slightly stable (Pasquill stability Class E) conditions at the proposed CRN Site is generally consistent with expected meteorological conditions (TVA 2017-TN5387).

Through analysis of the hourly data from the onsite meteorological measurements program, collected from June 1, 2011 through May 31, 2013, the staff independently confirmed the atmospheric stability measurements at the proposed CRN Site, and thus finds the applicant's data and discussion acceptable.

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

The staff has found through previous COL and ESP reviews that the associated paved, concrete, or other improved surfaces resulting from the construction of the proposed nuclear facility would be insufficient to generate discernible long-term effects on local-scale meteorological conditions. Wind flow may be altered immediately adjacent to and downwind of larger site structures, but these effects would likely dissipate within 10 structure heights downwind. Although temperature may increase above altered surfaces at the proposed CRN Site, the effects would be too limited in their vertical profile and horizontal extent to alter local- or regional-scale ambient temperature changes. Due to the limited and localized nature of the expected modifications associated with the proposed plant structures and the associated

improved surfaces, the staff concludes that the proposed facility would not have significant impacts on local meteorological conditions.

The SSAR stated that the cooling-tower evaluation for the CRN Site assumes that the site would include linear mechanical draft cooling towers (TVA 2017-TN5387). The plume from these towers was evaluated by the applicant using the Electric Power Research Institute-sponsored Seasonal/Annual Cooling Tower Impact (SACTI) computer model. The SSAR also stated that in addition to the plume, small water droplets associated with the circulating water and containing dissolved solids, known as drift, could be emitted from the cooling towers (TVA 2017-TN5387). These could eventually deposit on the local surroundings including land surfaces, buildings, and vegetation.

The 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. The staff found that there would be a minimal threat of fogging and icing in the vicinity immediately surrounding the cooling towers. The applicant also stated that a small amount of dissolved and suspended solids could result in solid particle deposition on the surface, primarily in close proximity to the plant. The staff has confirmed that 2 months of salt accumulation would result in 0.0422 mg/cm^2 on the switchyard, which is near the lower end of the "Light Contamination Level" range defined by the Institute of Electrical and Electronic Engineers standard (IEEE 1995-TN6191). The staff concludes that total accumulation reaching amounts that require mitigation is highly unlikely because local precipitation removes any salt deposits before it reaches a level of concern. The highest salt deposition amounts at 300 m from the cooling towers occurred to the west and had a total salt deposition of 0.0605 mg/cm^2/2 mo. The staff confirmed the information presented in this SSAR section (TVA 2017-TN5387). The staff finds the applicant's conclusion acceptable.

At the COL or CP stage, if the applicant chooses a plant design that requires the use of an UHS cooling tower, the applicant would need to verify the appropriate meteorological characteristics (i.e., maximum evaporation and drift loss and minimum water cooling conditions) used to evaluate the design of the chosen UHS cooling tower. In accordance with 10 CFR 52.17(a)(1)(iii), "Contents of applications; general information" (TN251), at the time of the COL or CP application, the applicant would provide information about the type of cooling system that may be associated with each facility; if the plant design uses an UHS, the characteristics of the UHS would be provided. Therefore, the staff identified the following COL Action Item:

- <u>COL Action Item 2.3-1</u>: 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 SSAR Section 2.3.1 (TVA 2017-TN5387) and are reviewed by the staff in FSER Section 2.3.1.

2.3.2.4 *Conclusion*

As discussed above, the applicant presented and substantiated information about local meteorological, air-quality, and topographic characteristics of importance to the safe design and

operation of a NPP or NPPs, falling within the applicant's PPE, that might be constructed on the proposed CRN Site. The staff reviewed the information provided and, for the reasons given, concludes that the applicant's identification and consideration of the meteorological, air-quality, and topographical characteristics of the site and the surrounding area meet the requirements of 10 CFR 52.17(a)(1)(ix) (TN251), 10 CFR 100.20(c)(2) (TN282), 10 CFR 100.21(c) (TN282), and 10 CFR 100.21(d) (TN282), and are sufficient to determine the acceptability of the site.

2.3.3 Onsite Meteorological Measurements Program

In SSAR Section 2.3.3, "Onsite Meteorological Measurements Program" (TVA 2017-TN5387), the applicant presented information concerning the onsite meteorological measurements program in support of its ESPA.

2.3.3.1 *Summary of Application*

In SSAR Section 2.3.3 (TVA 2017-TN5387), the applicant provided the following information:

- a description of meteorological instrumentation, including the 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; and
- hourly meteorological data, including consideration of the POR and amenability of the data for use in characterizing atmospheric dispersion conditions.

2.3.3.2 *Regulatory Basis*

The acceptance criteria for the development and implementation of an onsite meteorological program are based on meeting the relevant requirements of 10 CFR 52.17 (TN251) and 10 CFR Part 100 (TN282). The staff considered the following regulatory requirements in reviewing the applicant's development and implementation of an onsite meteorological program:

- 10 CFR 52.17(a)(1)(ix) (TN251), as it relates to the requirement that an applicant perform an evaluation and analysis of the postulated fission product release, together with applicable site characteristics, including site meteorology, to evaluate the offsite radiological consequences;
- 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) (TN282), as it relates to the requirement that site atmospheric dispersion characteristics be evaluated and dispersion parameters be established such 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, and
  - radiological dose consequences of postulated accidents meet the criteria set forth in 10 CFR 50.34(a)(1) (TN249) for the type of facility proposed to be located at the site.

The assessment and conclusions made in this section regarding the adequacy of onsite meteorological instrumentation (including the siting of sensors, sensor performance specifications, methods and equipment for recording sensor output, the QA program for sensors

and recorders, and data acquisition and reduction procedures) are pertinent to the staff's evaluation in FSER Chapter 13 of the applicant's proposed emergency plan, in accordance with the requirements of 10 CFR 50.47, "Emergency Plans" (TN249), and 10 CFR Part 50, Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities" (TN249).

The development and implementation of an onsite meteorological program is necessary for the collection of onsite meteorological information. This information is necessary for the applicant to demonstrate compliance with the numerical guides for doses contained in 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents" (TN249).

The following RG is applicable 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.

The related acceptance criteria from SRP Section 2.3.3, "Onsite Meteorological Measurements Program" (NRC 2007/2018-TN5898), are as follows:

- The preoperational and operational monitoring programs should be described, including (1) a site map (drawn to scale) that shows tower location and true north with respect to manmade structures, topographic features, and other features that may influence site meteorological measurements; (2) distances to nearby obstructions of airflow in each downwind sector; (3) measurements made; (4) elevations of measurements; (5) exposure of instruments; (6) instrument descriptions; (7) instrument performance specifications; (8) calibration and maintenance procedures and frequencies; (9) data output and recording systems; and (10) data processing, archiving, and analysis procedures.
- Meteorological data should be presented in the form of JFDs of wind speed and wind direction by atmospheric stability class in the format described in RG 1.23 Revision 1 (NRC 2007-TN278). An hour-by-hour listing of the hourly averaged parameters should be provided in the format described in RG 1.23 Revision 1 (NRC 2007-TN278). If possible, evidence of how well these data represent long-term conditions at the site should also be presented, possibly through comparison with offsite data.
- At least two consecutive annual cycles (and preferably three or more whole years), including the most recent 1-year period, should be provided with the ESPA. These data should be used by the applicant to calculate (1) the short-term atmospheric dispersion estimates for accident releases discussed in FSER Section 2.3.4, and (2) the long-term atmospheric dispersion estimates for routine releases discussed in FSER Section 2.3.5.

The applicant should identify and justify any deviations from the guidance provided in RG 1.23 Revision 1 (NRC 2007-TN278).

2.3.3.3 *Technical Evaluation*

Using the approaches and methodologies described in SRP Section 2.3.3 (NRC 2007/2018-TN5898), the staff reviewed the ESPA. The applicant used the pre-application onsite meteorological measurements program at the CRN Site to collect data, which the staff determined to be adequate for evaluating the suitability of the site. The COL applicant,

however, may need to update the description of the proposed operational onsite meteorological measurements program, as appropriate, at the time of the COLA.

2.3.3.3.1 Onsite Meteorological Measurements Program

2.3.3.3.1.1 *Meteorological Measurements History*

To support the CRN Site ESPA, 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 CRBRP. The 110 m primary tower used to collect these data was physically removed at the end of the observation period. A new tower would be installed to collect data during the CRN Site operational phase as stated in SSAR Section 2.3.3.1, "Meteorological Measurements History" (TVA 2017-TN5387).

2.3.3.3.1.2 *Primary Meteorological Facility*

In RAI Letter No. 9 (eRAI-8972, Question 30256 [NRC 2017-TN5933]), the staff requested that the applicant provide a description of the type of meteorological tower used to collect data and the location of the wind and temperature sensors on the tower. The applicant provided a response to the RAI on September 25, 2017 (TVA 2017-TN5891), which contained the requested information, and the applicant subsequently updated the SSAR with this information. The staff confirmed that the applicable information provided in applicant's letter dated September 25, 2017, was included in the SSAR (TVA 2019-TN5855), and therefore, this RAI is closed.

According to the applicant, the primary meteorological tower is an open-lattice tower with observation equipment mounted at heights of 10 and 60 m above ground level (TVA 2017-TN5387). Measured data include wind speed and direction at 10 and 60 m, temperature at 10 and 60 m, differential temperature between 60 and 10 m, dew point temperature (calculated based on coincident ambient temperature and relative humidity measurements) at 10 and 60 m, and precipitation and solar radiation near the tower base (ground level). The wind sensors were mounted on booms extending more than 2 tower widths from the tower and the temperature and dew point sensors were mounted in downward-pointed radiation shields 1.5 tower widths from the tower. After reviewing the information provided by the applicant, the staff finds that these sensor mounts met the criteria in RG 1.23 Revision 1 (NRC 2007-TN278) and should preclude the tower from affecting the wind and temperature measurements.

The applicant also explained that the base of the meteorological tower is at an elevation 7 m below plant grade and is located approximately 830 m south-southeast of the expected plant site (TVA 2017-TN5387). The applicant stated that an environmental data station, located near the meteorological tower, housed the data processing and recording instrumentation, as well as a system of lightning and surge protection circuitry and proper grounding.

RG 1.23 Revision 1 (NRC 2007-TN278) indicates that obstructions to airflow (such as buildings) should be located at least 10 obstruction heights from the meteorological tower to prevent adverse building wake effects. As described in SSAR Section 2.3.3.2, two obstructions to wind flow near the onsite meteorological tower have been evaluated by the applicant and were determined to have a minimal impact on the wind measurements (TVA 2017-TN5387). The applicant describes these obstructions as a lattice structure transmission tower approximately 120 m northeast of the primary tower and a row of trees approximately 70 m southeast of the tower. Images of these obstructions are provided in SSAR Figure 2.3.3-2, "Primary Met Tower

Wind Obstructions." The locations of the obstructions with respect to the tower are shown in SSAR Figure 2.3.3-1, "Map of Obstructions Related to Primary Met Tower." The staff reviewed the figures provided by the applicant and viewed the tower location during a site audit (NRC 2017-TN5934). Because of the distance from the meteorological tower, and the relatively small cross sections of the obstructions, the staff finds it reasonable to conclude that the obstructions had little to no impact on the meteorological observations.

2.3.3.3.1.2.1 Instrument Maintenance

In SSAR Section 2.3.3.2.5, "Equipment Servicing, Maintenance, and Calibration," the applicant described how often the meteorological equipment is inspected and serviced (TVA 2017-TN5387). The applicant stated that most equipment is calibrated or replaced at least every 6 months. The staff reviewed this information and concludes that the instrument maintenance practices, as described in SSAR Section 2.3.3.2.5 (TVA 2017-TN5387), conform to the guidance provided in RG 1.23 Revision 1 (NRC 2007-TN278). Accordingly, the staff finds these descriptions acceptable.

2.3.3.3.1.2.2 Data Collection and Analysis

In SSAR Section 2.3.4.2, "Calculation Methodology and Assumptions," the applicant discussed the meteorological data and its acceptable use for atmospheric dispersion analysis (TVA 2017-TN5387). For the 2011–2013 data set, the average data recovery rates were stated to be above the 90 percent criterion established in RG 1.23 Revision 1 (NRC 2007-TN278) for all variables. The SSAR stated that the operational meteorological program would be consistent with the guidance in RG 1.23 (NRC 2007-TN278) to maintain 90 percent recoverability for all data collected (TVA 2017-TN5387). The staff reviewed the applicant's meteorological data set and confirms that each measured parameter exceeded the 90 percent recovery criterion. The meteorological data are scanned periodically by the applicant and the data values are stored as stated in SSAR Section 2.3.3.2.4, "Data Recording and Display" (TVA 2017-TN5387).

The staff performed a quality review of the 2011–2013 hourly meteorological database using the methodology described in NUREG-0917, "Nuclear Regulatory Commission Staff Computer Programs for Use with Meteorological Data," issued in July 1982 (NRC 1982-TN5935). The staff's examination of the data revealed generally stable and neutral atmospheric conditions at night and unstable conditions during the day. Wind speed, wind direction, and stability class frequency distributions for each measurement channel were reasonable. As discussed in FSER Section 2.3.2, the staff verified and was able to reproduce the lower- and upper-level JFDs and wind roses provided by the applicant.

Revision 1 to RG 1.23(NRC 2007-TN278) specifically references American National Standards Institute/American Nuclear Society (ANSI/ANS) Standard 3.11-2005, "Determining Meteorological Information at Nuclear Facilities" (ANSI 2005-TN6081), with respect to best practices for onsite meteorological measurements programs at commercial NPPs. Section 5.3.1 of ANSI/ANS-3.11-2005 states that the transport wind direction for straight-line Gaussian models should be based on the scalar mean (or unit vector) wind direction. The PAVAN and XOQDOQ atmospheric dispersion models used in SSAR Sections 2.3.4 and 2.3.5 (TVA 2017-TN5387) are straight-line Gaussian models.

In RAI Letter No. 9 (eRAI-8972, Question 30595 [NRC 2017-TN5933]), the staff requested that the applicant clarify the collection and use of scalar- versus vector-averaged wind speed and wind direction values. The applicant provided a response to the RAI on September 25, 2017

(TVA 2017-TN5891), which stated that scalar meteorological data were used to develop the wind roses in SSAR Section 2.3.2 (TVA 2017-TN5387) and to prepare the JFDs used as input to the straight-line Gaussian dispersion models discussed in FSER Sections 2.3.4 and 2.3.5. However, in its response, the applicant did not provide the requested justification regarding why the chosen type of wind direction and/or wind speed data (i.e., scalar and/or vector average) were used to generate wind-related data summaries and model input data.

It was eventually determined that the applicant, in fact, had used vector-averaged wind direction data as input to these straight-line Gaussian dispersion models, so the staff contends that the applicant did not follow the best practice guidance described in RG 1.23 (NRC 2007-TN278) (and by extension ANSI/ANS 3.11-2005 ANSI 2005-TN6081]) and the SRP. The applicant voluntarily provided a submittal on April 9, 2018 (TVA 2018-TN5892), which evaluated the effects of having used vector-averaged wind directions in lieu of scalar-averaged wind directions on the results of the accident and routine-release atmospheric dispersion estimates presented in SSAR Sections 2.3.4 and 2.3.5 (TVA 2017-TN5387).

With respect to the accident-related dispersion estimates, the applicant's analysis showed that the PAVAN modeling results were conservatively higher based on the use of vector-averaged wind directions. However, regarding the XOQDOQ modeling of airborne routine radiological releases, the applicant acknowledged that atmospheric dispersion and deposition factors were higher in some directions and lower in others using scalar-averaged wind directions. Consequently, the applicant evaluated the associated normal radiological doses. The applicant concluded that for normal (as well as accident-related) gaseous release dose assessments, the existing analyses included in the ESPA, which are based on vector-averaged wind directions, are conservative and remain the basis of the CRN Site ESPA.

The staff conducted an audit (NRC 2018-TN5893) of the calculation packages that supported the applicant's April 9, 2018, voluntary submittal related to comparing the results of the offsite accident and routine-release dispersion modeling analyses and the resulting radiological doses using vector- versus scalar-averaged wind directions and scalar-averaged wind speeds as meteorological input. The Audit Report (NRC 2018-TN6152) documents the staff's review and conclusion that the applicant's calculations supported its April 9, 2018 submittal and the applicant's position that the doses from airborne accident and normal releases presented in the SSAR (TVA 2017-TN5387), calculated using vector-averaged wind direction data, are bounding.

Because the applicant provided adequate justification for using vector-averaged wind direction data along with scalar-averaged wind speed data for determining the accident and routine-release atmospheric dispersion and deposition factors (i.e., the resulting doses as presented in the SSAR are bounding), the staff concludes that eRAI-8972, Question 30595 (NRC 2017-TN5933), is closed. However, Section 2.3.3.4 further discusses the limitation of this conclusion to the CRN Site and to the 2-year POR of onsite meteorological data referenced in the SSAR (TVA 2017-TN5387).

2.3.3.3.1.3 *Operational Meteorological Program*

In SSAR Section 2.3.3.3, "Operational Meteorological Program" (TVA 2017-TN5387), the applicant stated that a new tower would be installed to collect data during the CRN Site operational phase and the resulting meteorological program would be consistent with the guidance given in RG 1.23 (NRC 2007-TN278). The meteorological monitoring system used to collect onsite measurements for the ESPA was dismantled and removed after collecting the necessary data. To ensure that any future onsite meteorological measurement system used for

a COL or a CP application is consistent with the system described in the ESP, the staff identified the following COL Action Items:

- COL Action Item 2.3-2: An applicant for a COL or a CP referencing this ESP should verify that the onsite meteorological measurement system, including the instrument tower, expected at the site prior to operation, is as described in site safety analysis report (SSAR) Section 2.3.3. Any differences in instrumentation, exposure, or siting should be identified and discussed to demonstrate that the meteorological measurements program continues to meet the guidance provided in Regulatory Guide (RG) 1.23.
- COL Action Item 2.3-3: An applicant for a COL or a CP referencing this ESP should clarify whether the operational phase of the onsite meteorological measurements program will include wind data averaging on the basis of scalar or vector averages.
- COL Action Item 2.3-4: An applicant for a COL or a CP referencing this ESP should identify and justify the wind speed and direction averaging approach(es) (either vector or scalar) used in the COL or CP application:
  - for modeling accident-related Control Room and Technical Support Center (TSC) atmospheric dispersion; and
  - for use during the operational phase to support emergency planning.

2.3.3.3.2 COL Action Items Related to the Onsite Meteorological Measurements Program

The CRN Site ESPA, Part 5A, "Emergency Plan (Site Boundary EPZ)" (TVA 2017-TN5443), describes the information "to ensure compatibility of the proposed emergency plans (for onsite areas) with facility design features, site layout, and site location." Part 5A is based on TVA's "Nuclear Power Radiological Emergency Plan (NP-REP)," which the NRC has approved for use at all TVA operating nuclear facilities. In accordance with 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants" (TN251), Part 5A (TVA 2017-TN5443) addresses the emergency planning requirements of Appendix E to 10 CFR Part 50, Section III, the "Final Safety Analysis Report; Site Safety Analysis Report" (TN249). 10 CFR Part 50, Appendix E (III) (TN249) states, "[t]he final safety analysis report or the SSAR for an early site permit that includes major features of emergency plans under 10 CFR 52.17(b)(2)(i) (TN251) of this chapter shall contain the plans for coping with emergencies."

The CRN Site Emergency Management Organization is divided into two categories: the Onsite Organization and the Offsite Emergency Organization, which are designated the Central Emergency Control Center (CECC) staff. The CECC staff is responsible for directing and coordinating the overall TVA response to an emergency condition. The following positions within the CECC are responsible for meteorological data and analysis:

- Radiological Assessment Coordinator (ESP Part 5A, Section 3.3.17 [TVA 2017-TN5443]): Coordinates dose assessment, environs, and meteorological assessment activities in the Radiological Assessment Area located in the CECC; ensures that information about dose projections, environs measurements, and meteorological conditions is provided to the TSC.
- Meteorologist (ESP Part 5A, Section 3.3.20 [TVA 2017-TN5443]): Coordinates the analysis of environs samples with the Western Area Radiological Laboratory; evaluates meteorological data and develops forecasts that may be used for dose assessment and other emergency preparedness activities; reviews the adequacy of observed data and replaces missing or invalid observations; forecasts dispersion conditions that affect

radiological effluents; provides dispersion knowledge to dose assessment staff; prepares other meteorological forecasts needed for emergency preparedness activities.

These COL Action Items would be addressed by the COL applicant as part of developing the COLA, and the requirements would be met by way of fulfilling COL Action Item 13.3-1. This COL Action Item is addressed in Section 13.3, “Emergency Planning,” of this report.

2.3.3.4 *Conclusion*

As discussed above, the applicant presented and substantiated information to establish the onsite meteorological monitoring program and the resulting database in support of the CRN Site ESPA. The staff reviewed the information provided and, for the reasons given above, concludes that the onsite meteorological monitoring system provided adequate data to represent onsite meteorological conditions as required by 10 CFR 100.20 (TN282) and 10 CFR 100.21 (TN282). The onsite data also provide an acceptable basis for (1) making estimates of atmospheric dispersion for DBA releases and routine releases from a NPP or NPPs that might be constructed on the proposed site, and (2) meeting the requirements of 10 CFR Part 20 (TN283), 10 CFR Part 50, Appendix I (TN249), and 10 CFR Part 100 (TN282).

However, the applicant’s use of vector-averaged wind directions and scalar-averaged wind speeds as input to the accident and routine-release dispersion modeling analyses in SSAR Sections 2.3.4 and 2.3.5, respectively, and for developing wind-related data summaries in SSAR Section 2.3.2 (TVA 2017-TN5387), introduced uncertainties as discussed in the staff’s Audit Report evaluating its potential implications (NRC 2018-TN6152). Because the staff maintains that this approach is a departure from the guidance in RG 1.23 (NRC 2007-TN278),the staff’s acceptance of the offsite accident and routine-release dispersion modeling analyses, the corresponding downstream dose estimates, and wind-related data summaries presented in the SSAR for the CRN Site (TVA 2017-TN5387) is limited to this site only and to the 2-year POR of onsite meteorological data referenced in the SSAR.

2.3.4 Short-Term Atmospheric Dispersion Estimates for Accident Releases

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.

2.3.4.1 *Summary of Application*

In SSAR Section 2.3.4 (TVA 2017-TN5387), the applicant presented specific information about 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 the χ/Q values used for assessment of consequences of postulated radioactive atmospheric releases from DBAs.

2.3.4.2 *Regulatory Basis*

The acceptance criteria identified in SRP Section 2.3.4 (NRC 2007/2018-TN5898), for calculating atmospheric dispersion estimates for postulated accidental airborne releases of radioactive effluents are based on meeting the relevant requirements of 10 CFR 52.17 (TN251) and 10 CFR Part 100 (TN282). The staff considered the following regulatory requirements when reviewing the applicant's calculations:

- 10 CFR 52.17(a)(1)(ix) (TN251), as it relates to the requirement that an applicant perform an evaluation and analysis of the postulated fission product release, together with applicable site characteristics, including site meteorology, to evaluate the offsite radiological consequences;
- 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; and
- 10 CFR 100.21(c)(2) (TN282), as it relates to the requirement that site atmospheric dispersion characteristics be evaluated and dispersion parameters established such that radiological dose consequences of postulated accidents meet the criteria set forth in 10 CFR 50.34(a)(1) (TN249) for the type of facility proposed to be located at the site.

The related acceptance criteria from SRP Section 2.3.4 (NRC 2007/2018-TN5898) are as follows:

- a description of the atmospheric dispersion models used to calculate χ/Q values for accidental releases of radioactive and hazardous materials to the atmosphere;
- meteorological data used for the evaluation (as input to the dispersion models), which represent annual cycles of hourly values of wind direction, wind speed, and atmospheric stability for each mode of accidental release;
- a discussion of atmospheric diffusion parameters, such as lateral and vertical plume spread (i.e., σ_y and σ_z, respectively) as a function of distance, topography, and atmospheric conditions, related to measured meteorological data; and
- hourly cumulative frequency distributions of χ/Q values from the effluent release point(s) to the EAB and LPZ constructed to describe the probabilities of these χ/Q values being exceeded.

The following 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 1.145, Revision 1 (NRC 1983-TN279), as it relates to the use of dispersion models.

2.3.4.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.3.4 (TVA 2017-TN5387) to ensure that the CRN Site ESPA includes the complete scope of information related to this review topic. The staff's review confirmed that the ESPA addresses the required information related to the short-term dispersion estimates.

To evaluate atmospheric dispersion characteristics with respect to airborne radiological releases, detailed design information (e.g., vent heights, intake heights, and distance and direction from release vents to the control room and TSC) is necessary. Because the ESPA uses a PPE, and therefore little detailed and specific design information is available at this stage about the NPP or NPPs that might be constructed on the proposed site, a COL or CP applicant citing an ESP for the CRN Site, if granted will need to assess the dispersion of airborne radioactive materials to the control room and TSC in any future COL or CP application.

2.3.4.3.1 Atmospheric Dispersion Model

In its ESPA, the applicant used the computer code PAVAN (NUREG/CR-2858, "PAVAN: An Atmospheric Dispersion Program for Evaluating Design-Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations" [Bander 1982-TN538]) to estimate χ/Q values at the EAB and at the outer boundary of the LPZ for potential accidental releases of radioactive material. The PAVAN model implements the methodology outlined in RG 1.145, Revision 1 (NRC 1983-TN279), as described in SSAR Section 2.3.4.2 (TVA 2017-TN5387).

The PAVAN code estimates χ/Q values for various time-average periods ranging from 2 hours to 30 days (Bander 1982-TN538). The meteorological input to PAVAN consists of a JFD of hourly values of wind speed and wind direction by atmospheric stability class. The χ/Q values calculated by using PAVAN are based on the theoretical assumption that material released to the atmosphere would be normally distributed (Gaussian) about the plume centerline. A straight-line trajectory is assumed between the point of release and all distances for which χ/Q values are calculated.

For each of the 16 downwind direction sectors (e.g., N, NNE, NE, ENE), PAVAN (Bander 1982-TN538) calculates χ/Q values for each combination of wind speed and atmospheric stability at the appropriate downwind distance (e.g., the EAB and the outer boundary of the LPZ). The χ/Q values calculated for each sector are then ordered from greatest to smallest and an associated cumulative frequency distribution is derived based on the frequency distribution of wind speed and stabilities for each sector. The smallest χ/Q value in a distribution would have a corresponding cumulative frequency equal to the wind direction frequency for that particular sector. For each sector, PAVAN determines an upper envelope curve based on the derived data (plotted as χ/Q versus the probability of being exceeded) such that no plotted point is above the curve (Bander 1982-TN538). From this upper envelope, the χ/Q value, which is equaled or exceeded 0.5 percent of the total time, is obtained. The maximum 0.5 percent χ/Q value from the 16 sectors becomes the 0-to-2-hour "maximum sector χ/Q value".

Using the same approach, PAVAN (Bander 1982-TN538) also combines all χ/Q values independent of wind direction into a cumulative frequency distribution for the entire site. An upper envelope curve is determined, and the program selects the χ/Q value, which is equaled or exceeded 5.0 percent of the total time. This is known as the 0-to-2-hour "5 percent overall site χ/Q value."

The larger of the two χ/Q values, either the 0.5 percent maximum sector-dependent value or the 5 percent overall site value, is selected to represent the χ/Q value for the 0-to-2-hour time interval (note that this resulting χ/Q value is based on 1-hour averaged data but is conservatively assumed to apply for 2 hours).

To determine χ/Q values for longer time periods during an accident scenario (i.e., 0 to 8 hours, 8 to 24 hours, 1 to 4 days, and 4 to 30 days), PAVAN (Bander 1982-TN538) performs a logarithmic interpolation between the 0-to-2-hour χ/Q values and the annual average χ/Q values for each of the 16 sectors and the overall site. For each time period, the highest χ/Q value from among the 16 sectors and the overall site is identified and becomes the short-term site characteristic χ/Q value for that time period.

2.3.4.3.2 M*eteorological Data Input*

The meteorological input to PAVAN used by the applicant consisted of a JFD of wind speed, wind direction, and atmospheric stability based on hourly onsite data from June 1, 2011, through May 31, 2013, as described in SSAR Section 2.3.4.4.1 (TVA 2017-TN5387). The wind data were obtained from the 9.78 m (32.1 ft) (nominal 10 m) level of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken at the 59.22 m (194.3 ft) (nominal 60 m) and 9.78 m (32.1 ft) levels of the onsite meteorological tower.

The staff independently developed an annual wind rose for each level of the meteorological tower from the hourly meteorological database provided by the applicant. The onsite wind roses developed by the staff and the onsite and offsite wind roses provided by the applicant in SSAR Figures 2.3.2-3 through 2.3.2-54 show high frequencies of winds from the west-southwest through the northwest (clockwise) (TVA 2017-TN5387). As stated in Section 2.3.2 of this report, this is generally consistent with the wind patterns recorded in the site region.

The wind rose presented in SSAR Figure 2.3.2-3, “Wind Rose Clinch River Nuclear Site 10 m All Data” (TVA 2017-TN5387), depicts the wind patterns and wind speeds for all 16 wind direction sectors. The figure also states that the wind was calm during 24.85 percent of all hours recorded. The staff compared the number of calms in the wind rose to the JFDs included in SSAR Tables 2.3.4-2 through 2.3.4-8 (TVA 2017-TN5387). The staff determined that the wind rose in the SSAR followed the guidance provided in Table 3 of Revision 1 to RG 1.23 (NRC 2007-TN278), and defined any wind speed below the 0.5 m/s (1.1 mph) threshold as “calm.” The JFD tables in SSAR Section 2.3.4 provide a summary of the wind speed distribution by stability class. The wind speeds rendered as “CALM” in SSAR Figure 2.3.2-3 (TVA 2017-TN5387) are accounted for by the first three winds speed classes in the referenced JFD tables (i.e., CALM [0.0 mph], greater than 0.0 mph and less than or equal to 0.50 mph, and greater than 0.50 mph to less than or equal to 1.10 mph). The staff noted and accounted for the different units of measure between the wind roses and the JFD tables in the SSAR (TVA 2017-TN5387).

As discussed in Sections 2.3.2 and 2.3.3 of this report, the staff considers the 2011–2013 onsite meteorological database suitable for input to the PAVAN model (Bander 1982-TN538). During an audit of documents added to the CRN Site electronic reading room (ERR) conducted during May 2018 (NRC 2018-TN6152), the staff reviewed JFDs derived using scalar-averaged wind speed and direction. The staff determined that the scalar-averaged wind speed and wind direction frequencies used in the PAVAN dispersion model (Bander 1982-TN538) as provided in the ERR show some differences when compared against the scalar-averaged wind speed and vector-averaged wind direction data provided in the CRN Site ESP SSAR (TVA 2017-TN5387).

However, because the controlling accident-related χ/Q value and the resulting dose calculations based on vector-averaged wind directions remain the bounding value, the staff finds the meteorological data provided in the SSAR (TVA 2017-TN5387), confirmed during the audit, and as documented in the Audit Report, to be acceptable. Further details are discussed in FSER Sections 2.3.3.3.1.2.2, Data Collection and Analysis, and 2.3.4.3.4, Conservative Short-Term Atmospheric Dispersion Estimates for the EAB and LPZ.

2.3.4.3.3 Diffusion Parameters

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.145 (NRC 1983-TN279) as a function of atmospheric stability for its PAVAN model runs, as described in SSAR Section 2.3.4.2 (TVA 2017-TN5387). The staff evaluated the applicability of the PAVAN diffusion parameters and concluded that no unique topographic features (such as rough terrain, restricted flow conditions, or coastal or desert areas) preclude the use of the PAVAN model (Bander 1982-TN538) for the CRN Site at the EAB and outer boundary of the LPZ. Therefore, the staff finds the applicant's use of diffusion parameter assumptions, as outlined in RG 1.145 (NRC 1983-TN279), acceptable.

2.3.4.3.4 Conservative Short-Term Atmospheric Dispersion Estimates for the EAB and LPZ

The applicant modeled one ground-level release point and did not take credit for building wake effects, as described in SSAR Section 2.3.4.2 (TVA 2017-TN5387). SSAR Table 2.0-2 lists the ground-level release point elevation as a design parameter for any future uses of an ESP for the CRN Site, if granted (TVA 2017-TN5387). Not accounting for building wake effects for a ground-level release decreases the amount of atmospheric turbulence assumed to be in the vicinity of the release point, resulting in higher (more conservative) χ/Q values. A ground-level release assumption is, therefore, acceptable to the staff.

The applicant described the EAB to be the CRN Site property boundary that encompasses the nuclear island and the analytical EABs, as described in SSAR Section 2.3.4.2 (TVA 2017-TN5387). The CRN Site SSAR describes the EAB as follows:

> RG 1.145 requires that, for each of the 16 compass sectors, the distance to the EAB should be the minimum distance between the release point and the EAB within a 45-degree sector centered on the compass direction of interest. For conservatism and simplicity, the effluent release point is evaluated as a circular effluent release boundary (ERB) that encloses potential release points from the nuclear island as shown in Figure 2.3.4-1 [reproduced below as Figure 2.3-2]. A circular analytical EAB is established 1100 ft (335 m) from the ERB. For χ/Q modelling (SSAR Table 2.3.4-11), the analytical EAB is used as a bounding representative distance to the EAB. To account for multiple units on site, nuclear islands are positioned at multiple locations within the power block area with associated ERBs and EABs as shown in SSAR Figure 2.3.4-1. The analytical EABs can be encompassed by an ellipse fixed completely within the CRN property boundary, i.e. the actual EAB (SSAR Figure 2.3.4-1), which demonstrates that dispersion factor computations are conservative.

As described in SSAR Section 2.3.4.2, "Calculation Methodology and Assumptions" (TVA 2017-TN5387), the nuclear island ERB is used to conservatively enclose all possible release points for the selected reactor technologies. The distance from the outer edge of the power block area to the EAB is 335 m (1,100 ft), as shown in SSAR Table 2.3.4-11, "Distances and Elevations for

the EAB and LPZ in the 16 Wind Direction Sectors," and SSAR Figure 2.3.4-1 (reproduced below as Figure 2.3-2) (TVA 2017-TN5387). To account for the potential for multiple units on the site, nuclear islands are positioned at multiple locations within the power block area with associated ERBs and EABs, as shown in Figure 2.3-2 below. A circular analytical EAB is established 335 m (1,100 ft) from the ERB. All of the potential nuclear island sites are bounded by the ellipse shown below that encompasses all of the analytical EAB and is completely contained within the CRN Site. Because the distance from the outer edge of the power block to the EAB is less than the actual distance from the nuclear island to the EAB, and would result in higher (more conservative) χ/Q values, the staff considers the assumptions in the dispersion analysis to be reasonable.

The outer boundary of the LPZ for the CRN Site is a circle surrounding the power block area that has a radius of 1,609 m (1 mi). The distance from the center point of the site to the LPZ is shown in SSAR Table 2.3.4-11 and SSAR Figure 2.3.4-2, "Site Center Point and Distance to the LPZ" (TVA 2017-TN5387).

SSAR Tables 2.3.4-12, 2.3.4-13, and 2.3.4-14 (TVA 2017-TN5387) list the short-term atmospheric dispersion estimates for the EAB and the outer boundary of the LPZ that the applicant derived from its PAVAN (Bander 1982-TN538) modeling run results. The applicant identified these χ/Q values as site characteristics in SSAR Table 2.0-1 (TVA 2017-TN5387). The staff finds these χ/Q values acceptable for use as site characteristics because the applicant followed an acceptable method provided by RG 1.145 (NRC 1983-TN279) to determine the atmospheric dispersion factors at the proposed CRN Site. The applicant uses these atmospheric dispersion site characteristics to demonstrate compliance with the requirements of 10 CFR 100.21(c)(2) (TN282) for the radiological dose consequences of postulated accidents.

The Audit Report (NRC 2018-TN6152) describes, among other things, the staff's review of the applicant's comparison of accident-related atmospheric dispersion results using vector-averaged versus scalar-averaged wind directions and scalar-averaged wind speeds as input to the PAVAN model (Bander 1982-TN538). The controlling accident χ/Q value (i.e., in this case, the highest 0.5 percent, sector-dependent χ/Q for the 0- to 2-hour period at the analytical EAB distance of 335 m downwind) based on vector-averaged wind directions remains the bounding value relative to the corresponding accident-related χ/Q values based on scalar-averaged wind directions. As stated in the Audit Report, the dominant sector (i.e., WNW) was unchanged using either wind direction data-averaging approach (NRC 2018-TN6152).

The applicant provided tabular summaries of JFDs of wind speed and wind direction by atmospheric stability class used as meteorological input to the PAVAN dispersion model (Bander 1982-TN538) in SSAR Tables 2.3.4-2 through 2.3.4-8 (TVA 2017-TN5387). The staff notes that in letter CNL-18-045, dated April 9, 2018 (TVA 2018-TN5892), the applicant proposed to correct the column labels in these tables to represent the actual ranges of the wind speed classes rather than the current labels in the SSAR (TVA 2017-TN5387), which imply that the JFDs represent cumulative frequency distributions. These proposed changes were tracked as Confirmatory Item 2.3-3. Revision 2 of the ESPA included the aforementioned changes to SSAR Tables 2.3.4-2 through 2.3.4-8 (TVA 2019-TN5855). Therefore, Confirmatory Item 2.3-3 is closed.

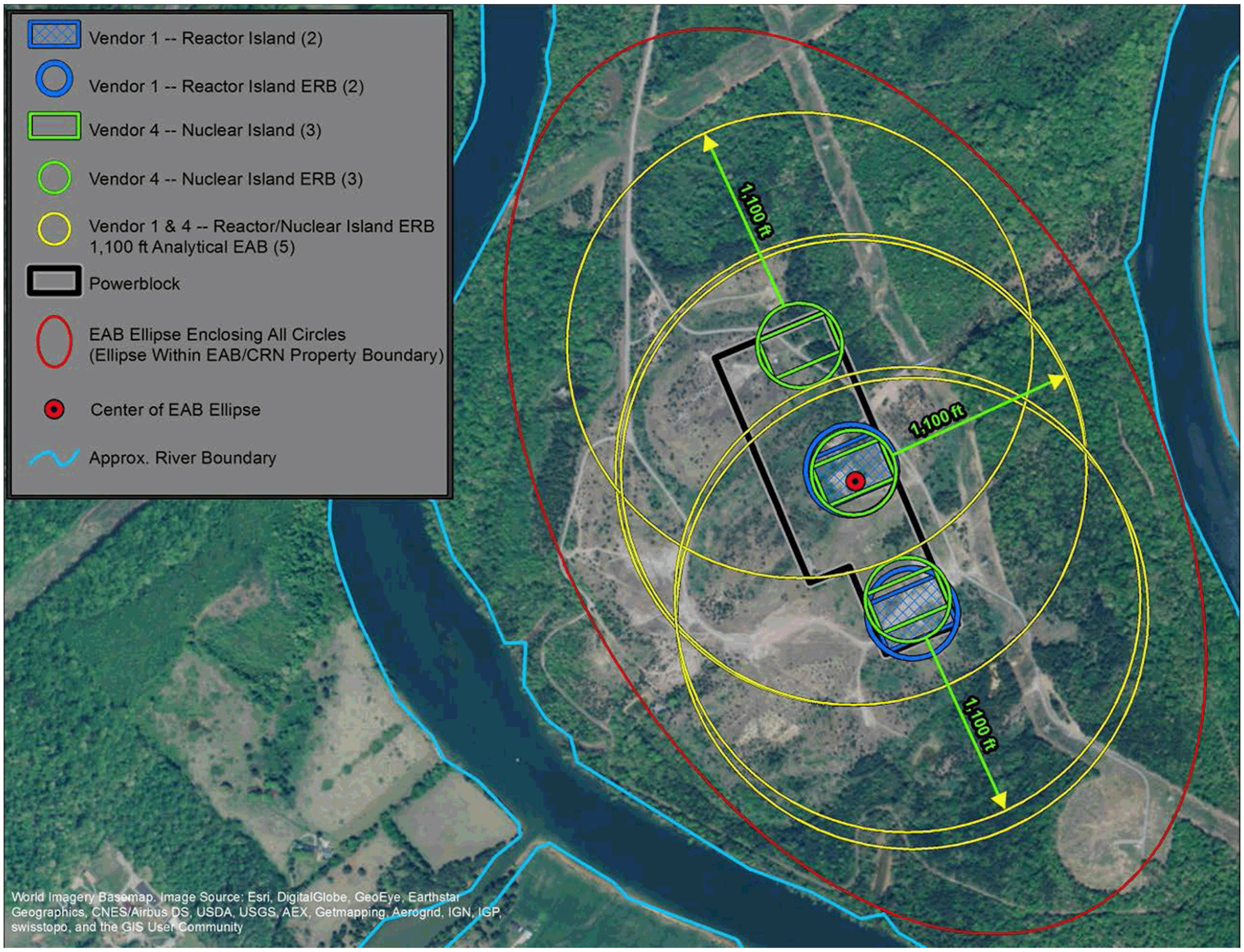

Figure 2.3-2 Effluent Release Zones with Analytical EABs

Using the information presented by the applicant in SSAR Table 2.3-10, "List of Inputs Used in the PAVAN Modeling," including the JFDs of wind speed and wind direction measured at the 10 m (33 ft) level, and atmospheric stability, the staff confirmed the applicant's χ/Q values by creating an independent JFD from the applicant's onsite hourly meteorological database, running the PAVAN computer code (Bander 1982-TN538), and obtaining consistent results (within about 1 percent). The staff accepts the short-term accident χ/Q values presented by the applicant.

2.3.4.4 *Conclusion*

As discussed above, the applicant presented and substantiated information to establish short-term (post-accident) atmospheric dispersion site characteristics. The staff reviewed the information provided and, for the reasons given above, concludes that the applicant has established site characteristics and design parameters that are acceptable to meet the requirements of 10 CFR 52.17(a)(1)(ix) (TN251), 10 CFR 100.20(c)(2) (TN282), and 10 CFR 100.21(c)(2) (TN282). Section 2.3.3.4 of this report further discusses the limitation of this conclusion to the CRN Site and to the staff's acceptance of these accident χ/Q values.

2.3.5 Long-Term Atmospheric Dispersion Estimates for Routine Releases

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.

2.3.5.1 *Summary of Application*

In SSAR Section 2.3.5 (TVA 2017-TN5387), the applicant provided details about the following specific areas:

- atmospheric dispersion and deposition models used to calculate concentrations in air and the amount of material deposited as a result of routine releases of radioactive material to the atmosphere;
- meteorological data and other assumptions used as input to the atmospheric dispersion models;
- derivation of diffusion parameters (e.g., σ_z);
- atmospheric dispersion (relative concentration) factors (χ/Q values) and deposition factors (D/Q values) used for assessment of consequences of routine airborne radioactive releases;
- the characteristics of each release mode;
- the location of potential receptors for offsite dose computations; and
- any additional information requirements prescribed in the “Contents of Application” section of 10 CFR Part 52, Subpart A, “Early Site Permits” (TN251).

2.3.5.2 *Regulatory Basis*

The acceptance criteria identified in SRP Section 2.3.5 (NRC 2007/2018-TN5898), for calculating atmospheric dispersion estimates for routine releases of radiological effluents are based on meeting the relevant requirements of 10 CFR Part 50 (TN249) and 10 CFR Part 100 (TN282). The staff considered the following regulatory requirements in reviewing the applicant’s calculation of atmospheric dispersion estimates for routine releases of radiological effluents:

- 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; and
- 10 CFR 100.21(c)(1) (TN282), 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 of 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 (TN249).

The following 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 (NRC 1977-TN90), as it relates to calculating offsite doses; and
- RG 1.111, “Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors,” Revision 1 (NRC 1977-TN5887), as it relates to calculating offsite doses.

The related acceptance criteria from SRP Section 2.3.5 (NRC 2007/2018-TN5898) 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 (σ_z) 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 (8 km) radius of the site); and
- 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 (NRC 2007-TN3035): (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*

The staff reviewed SSAR Section 2.3.5 (TVA 2017-TN5387) to ensure that the ESPA includes the complete scope of information related to this review topic. The staff’s review confirmed that the ESPA addresses the required information related to long-term atmospheric dispersion estimates.

2.3.5.3.1 Atmospheric Dispersion Model

The applicant used the NRC-sponsored computer code XOQDOQ (described in NUREG/CR-2919, “XOQDOQ Computer Program for the Meteorological Evaluation of Routine Releases at Nuclear Power Stations”) (Sagendorf et al. 1982-TN280), to estimate χ/Q and D/Q values resulting from routine releases, as described in SSAR Section 2.3.5.2, “Calculation

Methodology and Assumptions" (TVA 2017-TN5387). The XOQDOQ model implements the constant mean wind direction methodology outlined in RG 1.111 Revision 1 (NRC 1977-TN5887).

The XOQDOQ model is a straight-line Gaussian plume model based on the theoretical assumption that material released to the atmosphere would be normally distributed (Gaussian) around the plume centerline (Sagendorf et al. 1982-TN280). In predictions of χ/Q and D/Q values for long time periods (e.g., annual averages), the plume's horizontal distribution is assumed to be evenly distributed within the downwind direction sector (i.e., "sector averaging"). A straight-line trajectory is assumed between the release point and all receptors.

To account for the complex terrain surrounding the CRN Site, the applicant compared the NRC-endorsed XOQDOQ model (Sagendorf et al. 1982-TN280) and the CALPUFF modeling system developed by the EPA (2018-TN6082). The EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) web site (EPA 2018-TN6132) describes CALPUFF as "a non-steady-state puff dispersion model that simulates the effects of time- and space-varying meteorological conditions on pollution transport, transformation, and removal. CALPUFF can be applied for long-range transport and for complex terrain."

2.3.5.3.2 Release Characteristics and Receptors

As described in the SSAR, the applicant modeled one ground-level release point, setting the minimum building cross-sectional area and building height to zero (TVA 2017-TN5387). SSAR Table 2.0-2 lists the ground-level release point elevation as a design parameter for any future uses of an ESP for the CRN Site, if granted (TVA 2017-TN5387). A ground-level release is a conservative assumption because it results in higher χ/Q and D/Q values compared to a mixed-mode (e.g., part-time ground, part-time elevated) release or a 100 percent elevated release, as discussed in RG 1.111 Revision 1 (NRC 1977-TN5887). A ground-level release assumption is, therefore, acceptable to the staff.

The distance to the receptors of interest (i.e., the nearest meat animal [cow], residence, and vegetable garden) were presented in CRN ESP SSAR Table 2.3.5-5, "CRN Site Offsite Receptor Locations" (TVA 2017-TN5387). Directional sectors without a receptor within 8 km (5 mi) were not modeled. The applicant calculated the distances to each of the receptors from a location defined as the center point of the site.

The CALPUFF model also used a single ground-level source located at the center point of the site with no building wake credit given (EPA 2018-TN6082). The applicant provided a summary of the CALPUFF input assumptions in SSAR Section 2.3.5.3, "Complex Terrain Modeling Analysis," and in SSAR Table 2.3.5-2, "CALPUFF Model Input Configuration for Complex Terrain Analysis" (TVA 2017-TN5387). The staff reviewed the CALPUFF input and determined that the inputs accurately reflected the conditions and topography near the CRN Site and are therefore acceptable.

2.3.5.3.3 Meteorological Data Input

As discussed in SSAR Section 2.3.5.3 (TVA 2017-TN5387), the meteorological data used to create the JFD input to XOQDOQ (Sagendorf et al. 1982-TN280) included wind speed, wind direction, and atmospheric stability based on hourly onsite data from a 2-year period from June 1, 2011 through May 31, 2013. The applicant used this same hourly onsite data as input to CALPUFF (EPA 2018-TN6082). The wind data were obtained from the 10 m (33 ft) level of

the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 59.2 m (194.3 ft) and 8.44 m (27.7 ft) levels on the onsite meteorological tower. For conservatism in comparing airborne concentrations between the XOQDOQ (Sagendorf et al. 1982-TN280) and CALPUFF (EPA 2018-TN6082) models, SSAR Section 2.3.5.3 states that CALPUFF options for wet and dry deposition of iodine-131 were not considered during the analysis (TVA 2017-TN5387). The staff confirmed that the CALPUFF modeling did not include any plume washout and that deposition and depletion were ignored for this comparison.

The wind rose presented in SSAR Figure 2.3.2-3 depicts the wind patterns and wind speeds for all 16 directions (TVA 2017-TN5387). The figure also states that the wind was calm during 24.85 percent of all hours recorded. The staff compared the number of calms in the wind rose to the JFDs included in SSAR Tables 2.3.4-2 through 2.3.4-8 (TVA 2017-TN5387). The staff determined that the applicant followed the guidance provided in Table 3 of Revision 1 of RG 1.23 (NRC 2007-TN278), and defined any wind speed below the 0.5 m/s (1.1 mph) threshold as "calm." The JFD tables in SSAR Section 2.3.4 provide a summary of the wind speed distribution by stability class (TVA 2017-TN5387). The wind speeds rendered as "CALM" in SSAR Figure 2.3.2-3 (TVA 2017-TN5387) are accounted for by the first three wind speed classes in the referenced JFD tables (i.e., CALM [0.0 mph], greater than 0.0 mph and less than or equal to 0.50 mph, and greater than 0.50 mph to less than or equal to 1.10 mph). The staff noted and accounted for the different units of measure between the wind roses and the JFD tables in the SSAR (TVA 2017-TN5387).

Based on the discussions provided in FSER Sections 2.3.2, 2.3.3.3.1.2.2, and 2.3.4, the staff considers the 2011–2013 onsite meteorological database suitable for input to the XOQDOQ model (Sagendorf et al. 1982-TN280). However, the staff notes that SSAR Section 2.3.5.4 (TVA 2017-TN5387) asserts that the "representativeness of observed meteorology at the site was assessed, and no long-term trends were observed which would bias the χ/Q and D/Q estimates. Therefore, the long-term, routine-release χ/Q and D/Q values correspond to conditions that would be estimated using climatological (30-year) data." Due to the complex nature of the terrain surrounding the CRN Site, it is unknown how much of the difference between the onsite and offsite wind roses is due to the relative location of the stations, or the data collection and processing methods, or both. Given the differences in the onsite and offsite wind roses and other wind-related data summaries in Section 2.3.2, the changes in the JFD tables in Section 2.3.4 as a result of vector versus scalar wind direction averaging, and the changes in the χ/Q and D/Q values observed due to the different wind direction averaging approaches, it appears to the staff that long-term data representativeness (including resulting χ/Q s and D/Qs for routine releases) is not well established at the CRN Site. Nevertheless, these differences do not exclude the 2011–2013 onsite meteorological data from being used in the atmospheric dispersion models because the collection of meteorological data at the site is still the most accurate way to capture the conditions directly influencing routine airborne releases at the site.

2.3.5.3.4 Diffusion Parameters

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.111 Revision 1 (NRC 1977-TN5887), as a function of atmospheric stability, for its XOQDOQ model runs. The staff evaluated the applicability of the XOQDOQ diffusion parameters (Sagendorf et al. 1982-TN280) and concluded that no unique topographic features preclude the use of the XOQDOQ model for the CRN Site. Therefore, the staff finds that the applicant's use of the diffusion parameter assumptions, as outlined in RG 1.111 Revision 1 (NRC 1977-TN5887), is acceptable.

2.3.5.3.5 Complex Terrain Modeling

As discussed in FSER Section 2.3.2, the CRN Site is located in a region of complex terrain, featuring alternating ridges and valleys. The applicant described the local wind patterns as being influenced by the complex terrain in SSAR Section 2.3.5.3 (TVA 2017-TN5387). The region is prone to up-valley and down-valley flow, along with light winds, especially in the summer and fall seasons, which may lead to short-term increases in pollutant concentration due to pockets of stagnation at the base of nearby hills or near the CRN Site.

Complex terrain sites may need to adjust to a linear trajectory model to represent non-straight-line trajectories—specifically, incorporate adjustment factors for terrain confinement and recirculation effects on annual average dispersion concentrations. These adjustments can be accomplished in two ways, as presented in NUREG/CR-2919, using the XOQDOQ code (Sagendorf et al. 1982-TN280). First, a standard default correction factor that is a function of distance can be applied to the χ/Q and D/Q values for each of the directional sectors. Second, adjustments can be made by comparing results with a variable trajectory model. If the variable trajectory model produces higher concentrations than the straight-line model, the concentration ratio, or adjustment factor, would be used in the straight-line model to correct for nonlinear dispersion effects. The applicant chose to perform a comparison using a variable trajectory model and the NRC-endorsed XOQDOQ model (Sagendorf et al. 1982-TN280). These results are described in the following section.

2.3.5.3.6 Resulting Relative Concentration and Relative Deposition Factors

SSAR Table 2.3.5-10, "χ/Q and D/Q Values for No Decay, Decay, and Undepleted, at Each Receptor Location" (TVA 2017-TN5387), lists the maximum long-term atmospheric dispersion and deposition site characteristic values for the receptors of interest that the applicant derived from their XOQDOQ modeling results. SSAR Tables 2.3.5-6 through 2.3.5-9 also contain the applicant's long-term atmospheric dispersion and deposition estimates for 16 radial sectors at standard distances and distance segments from the site out to 80 km (50 mi) from the proposed facility (TVA 2017-TN5387).

The χ/Q values presented in SSAR Tables 2.3.5-6 through 2.3.5-9 reflect several plume radioactive decay and deposition scenarios (TVA 2017-TN5387). Section C.3 of RG 1.111 Revision 1 (NRC 1977-TN5887) states that radioactive decay and dry deposition should be considered in radiological impact evaluations of potential annual radiation doses to the public, resulting from routine releases of radioactive materials in gaseous effluents. Section C.3.a of RG 1.111 Revision 1 (NRC 1977-TN5887) states that an overall half-life of 2.26 days is acceptable for evaluating the radioactive decay of short-lived noble gases and an overall half-life of 8.00 days is acceptable for evaluating the radioactive decay for all iodines released to the atmosphere. Definitions of the χ/Q categories are as follows:

- Undepleted/No Decay χ/Q values are used to evaluate ground-level concentrations of long-lived noble gases, tritium, and carbon-14. The plume is assumed to travel downwind, without undergoing dry deposition or radioactive decay.
- Undepleted/2.26-Day Decay χ/Q values are used to evaluate ground-level concentrations of short-lived noble gases. The plume is assumed to travel downwind, without undergoing dry deposition, but is decayed, assuming a half-life of 2.26 days, based on the half-life of xenon-133.

- Depleted/8.00-Day Decay χ/Q values are used to evaluate ground-level concentrations of radioiodine and particulates. The plume is assumed to travel downwind, with depletion caused by dry deposition, and is decayed assuming a half-life of 8.00 days, based on the half-life of iodine-131.

Using the information provided by the applicant, including the JFDs of lower-level wind speed (scalar-averaged) and wind direction (vector-averaged), and the atmospheric stability presented in SSAR Tables 2.3.4-2 through 2.3.4-8 (TVA 2017-TN5387), the staff confirmed the applicant's χ/Q and D/Q values by running the XOQDOQ computer code (Sagendorf et al. 1982-TN280) and obtaining similar results (i.e., values on average within about 1 percent).

SSAR Tables 2.3.5-3, "Long-Term Average χ/Q Values at the Exclusion Area Boundary," and 2.3.5-4, "Long-Term Average χ/Q Values at the Low Population Zone," present the long-term average χ/Q values at the EAB and the outer boundary of the LPZ, respectively (TVA 2017-TN5387). These tables provide the resulting χ/Q values for each sector from both XOQDOQ (Sagendorf et al. 1982-TN280) and CALPUFF (EPA 2018-TN6082), as well as the ratio between the two models results. This comparison shows that the χ/Q values derived using the XOQDOQ model range from approximately two times up to two orders of magnitude greater than the values derived using CALPUFF. Based on these results, the staff agrees with the applicant that the XOQDOQ model (Sagendorf et al. 1982-TN280) did not underestimate the annual average χ/Q values at the CRN Site.

In its voluntary submittal of April 9, 2018 (TVA 2018-TN5892), the applicant summarized its comparison of XOQDOQ modeling results using JFDs based on vector-averaged wind directions and scalar-averaged wind speeds (as presented in the SSAR [TVA 2017-TN5387]) and JFDs created using scalar averaging of both wind speed and wind direction measurements. The applicant acknowledged that the routine-release modeling results using scalar-averaged wind directions "are greater in some directions and lower in others." Consequently, the applicant also analyzed doses to the maximally exposed individual and to the population. The applicant stated that "the doses computed using the vector wind direction are greater than those computed using the scalar wind direction input." Therefore, the applicant concluded that "for the Clinch River Site normal dose evaluations…the use of vector wind direction is conservative compared to the use of scalar wind direction." As with the accident-related dispersion modeling, the applicant concluded "that the existing analysis included in the ESPA, which is based on vector wind direction, is conservative and remains the basis of the ESPA."

As mentioned previously, the staff conducted an audit (NRC 2018-TN5893) of the calculation packages that supported the applicant's April 9, 2018 voluntary submittal. The Audit Report (NRC 2018-TN6152) documents the staff's review and conclusion that the applicant's calculations supported its April 9, 2018 submittal and the applicant's position that the doses from airborne accident and normal releases presented in the SSAR (TVA 2017-TN5387), calculated using vector-averaged wind direction data, are bounding.

The audit also showed that sector-specific D/Q values for receptors of interest occur, in many cases, in different sectors as a result of the different wind direction data-averaging approaches. Further, in most cases, the sectors with the maximum D/Q values differ from those implied by the sectors identified in SSAR Table 11.3-2, "Maximum Atmospheric Dispersion and Ground Deposition Factors by Location" (TVA 2017-TN5387). In addition, for two of the receptors of interest (i.e., the nearest beef [meat] animal and vegetable garden), the maximum D/Q value was slightly higher using scalar-averaged wind direction data than using vector-averaged wind

direction data. The significance of these differences from a dose standpoint is evaluated in FSER Section 11.3, which concludes that the doses for the normal gaseous release using vector wind direction averaging are greater than those computed based on scalar-averaged wind directions. Therefore, the staff agrees with the conclusions summarized by the applicant in its April 9, 2018 voluntary submittal and considers the XOQDOQ values in the SSAR (TVA 2017-TN5387) to be conservative and appropriate for this complex terrain site. In light of the foregoing, the staff accepts the long-term χ/Q and D/Q values presented by the applicant.

2.3.5.4 *Conclusion*

As set forth above, the applicant has provided meteorological data, atmospheric dispersion modeling analyses appropriate for the characteristics of the CRN Site, and an evaluation of the potential effects of having used an alternate wind direction data-averaging approach. The staff concludes that representative atmospheric dispersion and deposition conditions have been calculated for specific locations of potential receptors of interest due to routine operational releases to the air. The characterization of atmospheric dispersion and deposition conditions satisfies the criteria described in RG 1.111 (NRC 1977-TN5887) and is appropriate for demonstrating compliance with the numerical guides for doses for any individual located offsite, as contained in 10 CFR Part 50, Appendix I (TN249). The staff reviewed the information provided and, for the reasons given above, concludes that the applicant has established acceptable site characteristics and design parameters that meet the requirements of 10 CFR 100.20(c)(2) (TN282) and 10 CFR 100.21(c)(1) (TN282). Section 2.3.3.4 of this report further discusses the limitation of this conclusion to the CRN Site and to the staff's acceptance of these routine-release χ/Q values.

2.4 Hydrologic Engineering

To ensure that a NPP or NPPs can be designed, constructed, and safely operated on the applicant's proposed CRN Site and in compliance with NRC regulations, the staff evaluated the hydrologic characteristics of the site and surrounding vicinity that may affect the safety of a potential NPP at the site. These site characteristics include the potential for flooding due to precipitation, riverine processes (runoff, dam breach discharge, channel blockage or diversion), coastal effects (storm surges and tsunamis), and associated effects (e.g., from coincident wind waves). In addition, the staff reviewed the maximum elevation of surface water during floods and as combined with other events, associated static and dynamic characteristics, minimum water-surface elevation (WSE) during low water events, maximum elevation of groundwater, and the characteristic ability of the site to attenuate postulated accidental releases of radioactive liquid effluents in groundwater and surface waters. The surface-water hydrologic site characteristics determine the design basis flood (DBF) for the proposed CRN Site, and provide the basis for determining whether flood protection will be required. The groundwater hydrologic site characteristics determine the design basis groundwater loadings and provide the basis for radiological dose analysis for a potential receptor from the postulated accidental release of radioactive liquid effluents in surface waters and groundwater.

The staff prepared FSER Sections 2.4.1 through 2.4.14 in accordance with review procedures described in SRP Sections 2.4.1 through 2.4.14 (NRC 2007/2018-TN5898), using information presented in the applicant's initial SSAR, Revision 0, Section 2.4, "Hydrologic Engineering" (TVA 2016-TN5018), generally available reference materials (e.g., those cited in applicable sections of the SRP), and supplemental information provided by the applicant as a result of audit activities. The SSAR was subsequently updated by TVA to reflect the new information provided to staff (TVA 2017-TN5387) (TVA 2019-TN5855).

2.4.1 Hydrologic Description

The applicant described the CRN Site adjacent to the Clinch River (TVA 2016-TN5018). The plant would use a Clinch River water intake and a river outfall. The applicant proposed that the site would be graded to a new elevation that would be higher than the normal stream surface elevation by approximately 80 ft. The applicant provided the hydrosphere information to describe the upstream and downstream tributaries and dams that could potentially flood the site. The hydrosphere information also includes the surface-water withdrawals for various water supplies and uses within the neighboring areas. The applicant provided an overview describing groundwater conditions on the site and in the surrounding area and summarized information regarding groundwater users. The applicant noted in the SSAR that detailed descriptions of the groundwater conditions, regional and local groundwater resources, and users are provided in SSAR Section 2.4.12.

The SSAR (TVA 2017-TN5387) states that the CRN Site is located on the northern (right) bank of the Clinch River between Clinch River Mile (CRM) 19 and CRM 14.5—a tributary (or "arm") of the Watts Bar Reservoir (Figure 2.4.1-1). River miles are defined as the flow path distance measured from CRM 0, which is the mouth of the Clinch River. SSAR Section 2.4.1 (TVA 2017-TN5387) provides an overview of the hydrologic characteristics and phenomena that have the potential to affect the plant design basis of a reactor technology within the PPE. The applicant stated that designs under consideration within the PPE include the following:

- BWXT mPower™ (Generation mPower LLC design),
- NuScale (NuScale Power, LLC, design),
- SMR-160 (Holtec SMR, LLC, design), and
- Westinghouse SMR (Westinghouse Electric Company, LLC, design).

The hydrologic description of the CRN Site includes the interface of the plant with the hydrosphere, hydrological causal mechanisms, surface-water and groundwater uses, hydrologic data, and alternate conceptual models. The staff review discusses the interface of the plant with the hydrosphere, including descriptions of the site location, major hydrologic features in the site vicinity, surface-water- and groundwater-related characteristics, the proposed water supply to the plant, and any additional information required by the regulations discussed below in the Regulatory Basis section.

2.4.1.1 *Summary of Application*

In SSAR Section 2.4.1, the applicant described the site and stated that all safety-related SSCs would be set above the maximum postulated flood level from the standpoint of hydrologic considerations, and briefly discussed proposed changes to natural drainage features (TVA 2017-TN5387). Because a reactor technology has not yet been selected, final proposed changes to the existing grade, a plant site grading plan, and a drainage design would be evaluated in the COLA.

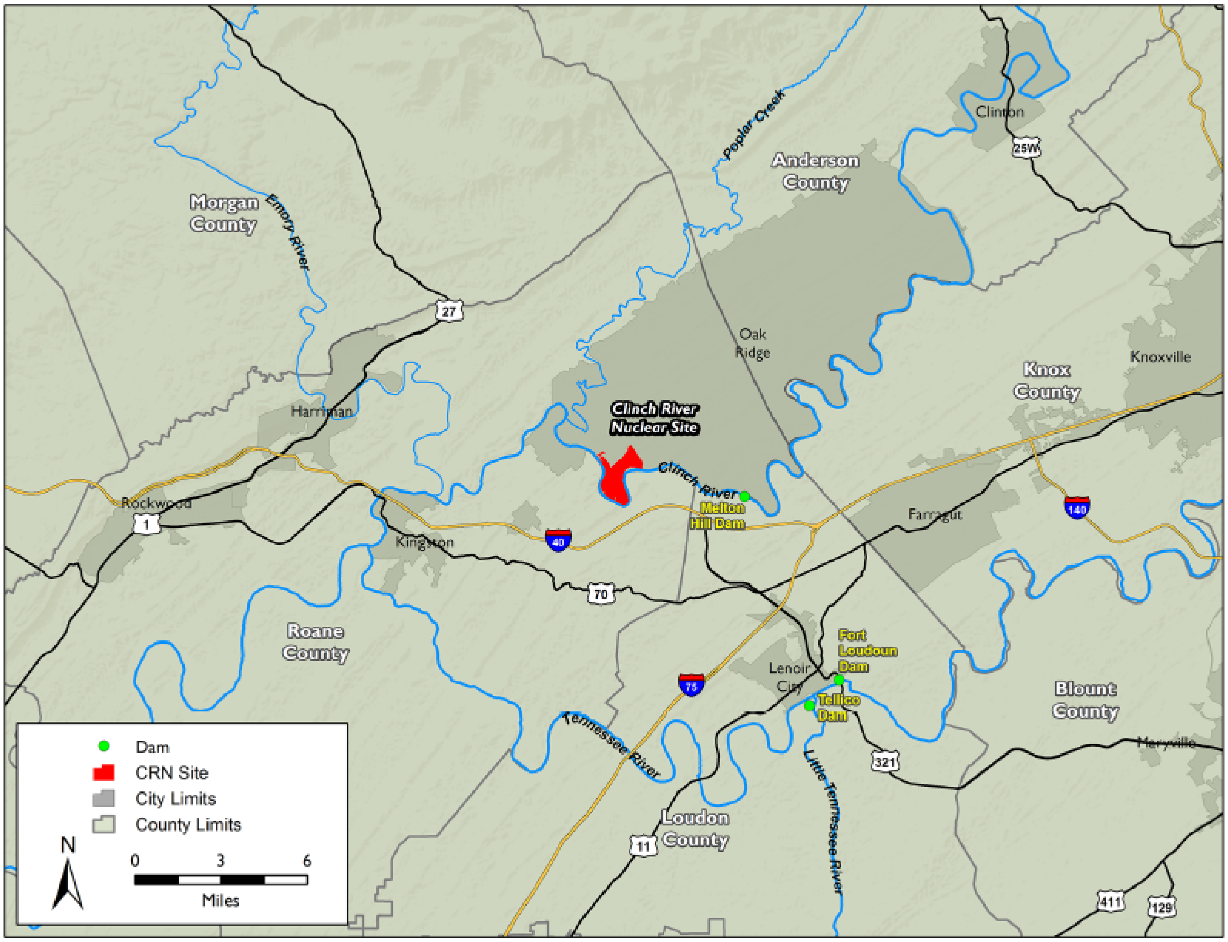

Figure 2.4.1-1 CRN Site Region (reproduced from SSAR Revision 1, Figure 2.4.1-2 [TVA 2017-TN5387]).

2.4.1.2 *Regulatory Basis*

The relevant requirements of NRC regulations for the hydrologic description, and the associated acceptance criteria, are specified in SRP Section 2.4.1, "Hydrologic Description" [NRC 2007/2018-TN5898]).

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

- 10 CFR 52.17(a)(1)(vi), "Contents of applications" (TN251), as it relates to the hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated; and
- 10 CFR Part 100, "Reactor Site Criteria" (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c) (TN282).

The staff also used the appropriate sections of the following RGs for the acceptance criteria identified in NUREG–0800, Section 2.4.1 (NRC 2007/2018-TN5898):

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;
- RG 1.59, "Design Basis Floods for Nuclear Power Plants" (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and
- RG 1.102, "Flood Protection for Nuclear Power Plants" (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.1.3 *Technical Evaluation*

The staff reviewed the information in SSAR Section 2.4.1 (TVA 2017-TN5387) and found that the information in the ESPA acceptably addressed the requirements related to the site's hydrologic description. The staff's technical evaluation of the information included supplemental information provided by the applicant as a result of a site audit the staff conducted as part of the evaluation related to this section (NRC 2018-TN5915). The staff conducted the site audit from April 24–27, 2017, and reviewed the information provided by the applicant during the audit. This information included United States Geological Survey (USGS) topographic maps, topographic maps of the site, available studies and references developed by the applicant, and reports from independent reviews completed by the applicant's contractors. The staff used this information to verify the hydrologic description. The following sections describe the staff's evaluation of the technical information submitted by the applicant.

2.4.1.3.1 Site and Facilities

2.4.1.3.1.1 *Information Submitted by the Applicant*

The applicant proposed a plant location that is on the north bank of the Clinch River (Figure 2.4.1-1) (TVA 2017-TN5387). The location is surrounded by an oxbow bend of the Clinch River path. The oxbow flow bounds the site on the east, south, and west.

The applicant provided elevation information for the site in terms of the North American Vertical Datum of 1988 (NAVD88) and the National Geodetic Vertical Datum of 1929 (NGVD29), as amended by the 1936 South Eastern Supplemental Adjustment (1936 SESA). NGVD29 and the amendment are referred to together as NGVD29 by the applicant and staff. For the CRN Site, the applicant stated that the elevations in NAVD88 equal the elevations in NGVD29 minus 0.371 ft.

The CRN Site PPE specifies that the minimum finished ground elevation in the power block area is 821.0 ft NAVD88 or 821.4 ft NGVD29. This elevation is also referred to as the CRN Site site grade. The applicant-calculated flood surface elevations that were based on the NGVD29 vertical datum, and are consistent with historical records. The local site topography and the site boundary are shown in Figure 2.4.1-2.

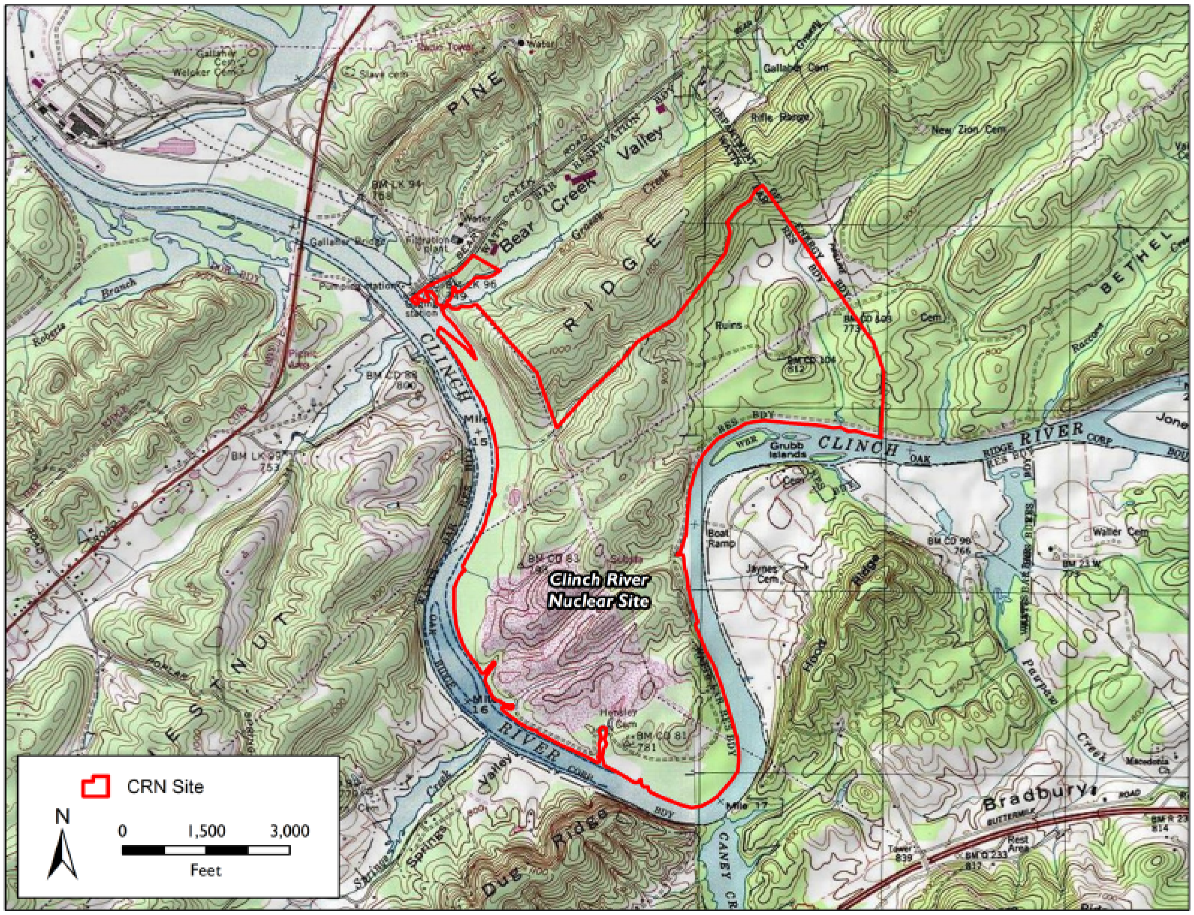

Figure 2.4.1-2 CRN Local Site Boundary and Topography (reproduced from SSAR Revision 1, Figure 2.4.1-3 [TVA 2017-TN5387]).

The applicant stated that the plant facilities, including any entry point to below-grade structures, will be built above the maximum postulated flood event. A specific reactor technology has not been selected for construction at the CRN Site but will be provided with the COLA. Therefore, the applicant described the site hydrology and the principal plant structures in general terms. The general layout of facilities and structures is shown in Figure 2.4.1-3 and includes the locations of intake and discharge structures.

The applicant stated that the source water for the circulating water system and the cooling towers would be the Clinch River. The applicant stated that closed cooling systems would supply internal plant reservoirs. Additionally, the applicant stated that Clinch River water would not be used directly for any safety-related systems. The applicant described the location of the outfall of discharge structure at CRM 15.5 (Figure 2.4.1-3), which is located 2.4 river miles downstream from the water intake.

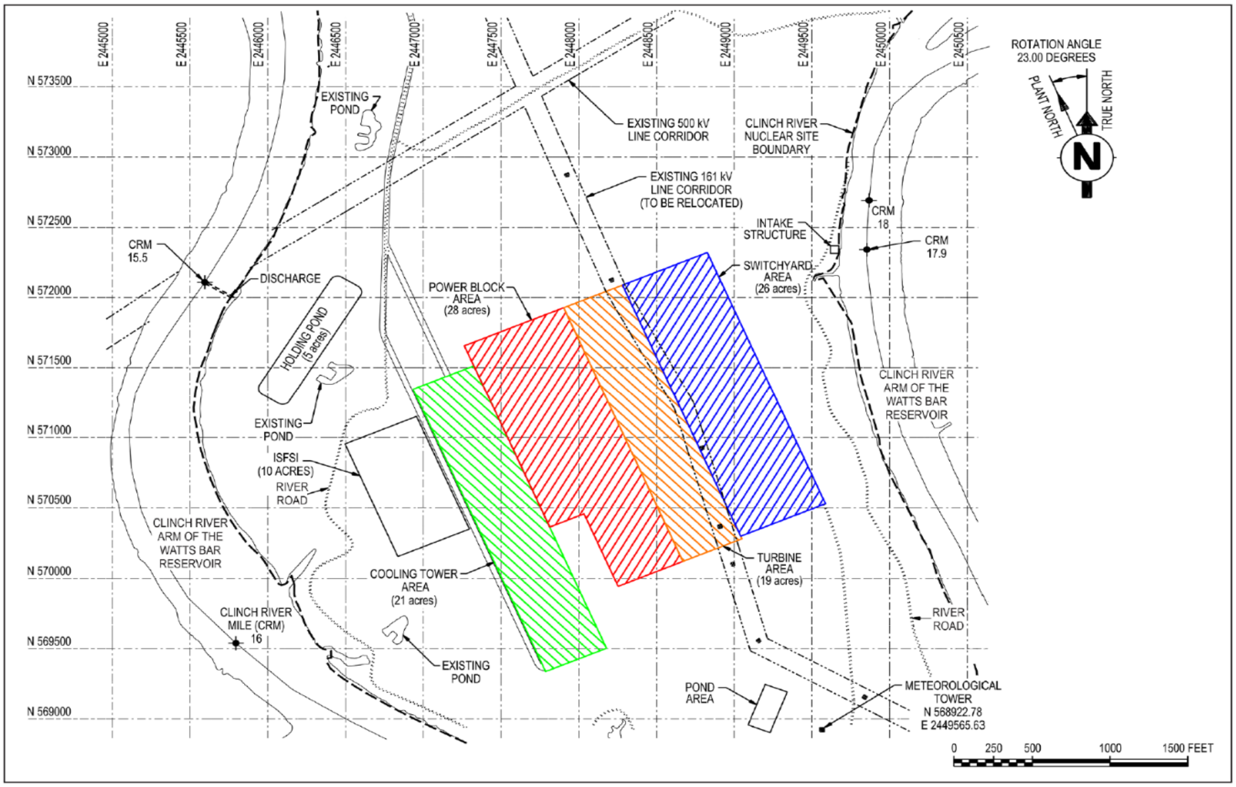

Figure 2.4.1-3 CRN General Layout of Facilities and Structures at the Site (reproduced from SSAR Revision 1, Figure 2.4.11-2 [TVA 2017-TN5387]).

Based on the selected technology, the design of the site grading plan and site drainage will be completed in the COLA. Therefore, the applicant stated that in the COLA they will provide a site grading plan and drainage system that will be designed to route runoff from the local PMP into swales and pipes draining toward the Clinch River.

2.4.1.3.1.2 *Staff's Technical Evaluation*

Using the NOAA vertical datum tool (NOAA 2017-TN6009), the staff found the elevation conversion to NGVD29 ft to be NAVD88 ft plus 0.388 ft, which is consistent with the applicant's value.

The staff compared the summer normal pool elevation of 741 ft NGVD29 and the winter normal pool elevation of 737 ft NGVD29 (Figure 2.4.1-5a) of the Watts Bar Reservoir to the applicant's proposed grade elevation of 821.4 ft NGVD29 (821.0 ft NAVD88), as indicated in Section 2.4.0 of the SSAR (TVA 2017-TN5387). The staff notes that the elevation difference between the CRN Site site grade and the normal WSE of the reservoir near the site is approximately 80 ft.

Based on a review of the material presented by the applicant in SSAR Sections 2.4.1 and 2.4.10 (TVA 2017-TN5387), the staff's observations of the CRN Site during the April 24–27, 2017 site audit (NRC 2018-TN5915), and the supplemental information provided by the applicant, the staff finds that the applicant has acceptably described the hydrologic characteristics of the CRN Site in SSAR Sections 2.4.1 and 2.4.10.

2.4.1.3.2 Hydrosphere

This section describes the hydrosphere conditions in the vicinity of the CRN Site. The applicant categorized the hydrosphere by (1) site location, (2) tributaries, (3) reservoir water flow, (4) reservoir water levels, and (5) water-supply withdrawals. Details associated with these five categories are discussed below.

2.4.1.3.2.1 *Information Submitted by the Applicant*

2.4.1.3.2.1.1 Site Location

The site is located between CRM 19 and CRM 14.5 (Figure 2.4.1-2). Above CRM 16, the upstream drainage area is 3,382 mi^2 (SSAR Section 2.4.1.2.1 [TVA 2017-TN5387]). The applicant stated that the Clinch River's average slope from Norris Dam (CRM 79.8) to CRM 7.0 is approximately 1.5 ft/mi (SSAR Section 2.4.1.2.1 [TVA 2017-TN5387]).

The applicant described the Clinch River path, flowing 350 mi in a southwesterly direction, from the headwaters near Tazewell, Virginia, to its confluence with the Tennessee River at Kingston, Tennessee. The Clinch River flows in the valley between the Cumberland Mountains on the northwest and the Clinch Mountain and Black Oak Ridge on the southeast. The mountain ridges have elevations of up to 4,700 ft NGVD29.

2.4.1.3.2.1.2 Tributaries

The applicant described two large tributaries that contribute flow to the Clinch River: the Powell River, which enters the Clinch River at CRM 88.8, and the Emory River, which enters the Clinch River at CRM 4.4. The Powell River has a drainage area of 938 mi^2, and the Emory River has a drainage area of 865 mi^2. In addition to the two large tributaries, there are seven minor tributaries each having drainage areas more than 5 mi^2 upstream of the CRN Site and downstream of the Norris Dam. Each of the seven minor tributaries has a drainage area that is much less than 800 mi^2.

2.4.1.3.2.1.3 Reservoir Water Flow

The applicant identified three dams that control WSEs at the CRN Site. They are Norris Dam (CRM 79.8) and Melton Hill Dam (CRM 23.1), both upstream from the CRN Site, and Watts Bar Dam at Tennessee River Mile (TRM 529.9), which is downstream from the CRN Site.

(SRI/CEII)[1] Built in the mid-1930s, Norris Dam is a large structure located approximately 62 river miles upstream from the CRN Site. The dam has a maximum height of 265 ft and its overall length is 1,570 ft. The dam has **[[**[redacted]**]]** in two sections, and an ancillary **[[**[redacted]**]]** ft in length. When the water level reaches the top of the spillway gates (1,034 ft NGVD29), Norris Dam will impound approximately 2,552,000 ac-ft of water. When the forebay WSE reaches the dam crest

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[1] In 2003, the Federal Energy Regulatory Commission in 18 CFR Parts 375 (TN5917) and 388 (TN5916) established a procedure for gaining access to Security-Related Information/Critical Energy/Electricity Infrastructure Information (SRI/CEII) that would not otherwise be available under the Freedom of Information Act. The procedure is intended to help keep sensitive infrastructure information out of the public domain, thereby decreasing the likelihood that such information could be used to plan or execute terrorist attacks. In the subsequent narrative, double brackets **[[ ]]** are used to enclose SRI/CEII that is not intended for access by the public.

elevation of 1,061 ft NGVD29, Norris Dam can discharge approximately 344,000 cfs. In addition to its flood control function, Norris Dam provides hydroelectric power production, navigation benefits, dissolved oxygen improvements, and low-flow regulation.

(SRI/CEII) Built in the early 1960s, Melton Hill Dam is located 5.2 river miles upstream from the CRN Site and has a maximum height of 84 ft and an overall length of 1,020 ft. The dam has **[[**[redacted]**]]**, **[[**[redacted]**]]** ft of earthen embankment in **[[**[redacted]**]]**, and concrete lock and power house structures **[[**[redacted]**]]** ft in length. When the forebay water elevation reaches the top of the spillway gates (796 ft NGVD29), Melton Hill Dam will impound approximately 126,000 ac-ft of water. If the forebay water elevation reaches 802 ft NGVD29, the dam can discharge approximately 146,000 cfs. In addition to its navigation and hydroelectric power production functions, Melton Hill Dam regulates low discharge flow requirements.

(SRI/CEII) Built in the early 1940s, Watts Bar Dam is located more than 50 river miles downstream from the CRN Site and its impoundment creates a backwater that extends up to the tailwater of Melton Hill Dam. Watts Bar Dam has a maximum height of 112 ft and a length of approximately 2,960 ft. The dam has **[[**[redacted]**]]** spillway gates, each of which is **[[**[redacted]**]]**-ft wide. The dam has **[[**[redacted]**]]** ft of earthen embankments in **[[**[redacted]**]]** sections and **[[**[redacted]**]]** ft of concrete sections, including the powerhouse, navigation lock, and ancillary structures. When the forebay WSE reaches the top of the spillway gates (745 ft NGVD29), Watts Bar Dam will impound approximately 1,175,000 ac-ft of water. If forebay water elevation reaches 767 ft NGVD29, Watts Bar Dam can discharge approximately 1,144,000 cfs.

The applicant operates many other dams (Figure 2.4.1-4a-b) that can indirectly influence flood levels in the Watts Bar Reservoir and at the CRN Site. These dams are the Fort Loudoun Dam (Tennessee River); the Watauga, South Holston, Boone, Fort Patrick Henry, and Cherokee Dams (Holston River); the Douglas Dam (French Broad River); and the Fontana and Tellico Dams (Little Tennessee River).

The applicant stated that several stream gauges in the vicinity of the CRN Site were operated by the USGS through 1968, and other stream gauges have been operated by the applicant since 1937. In the SSAR, the applicant showed that the average daily discharge at the CRN Site was approximately 4,800 cfs after the completion of Melton Hill Dam in 1963 (TVA 2017-TN5387). Between February and March 1966, there was a 29-day period of no flow below the Melton Hill Dam.

The SSAR states that a Reservoir Operations Study (ROS) was adopted in 2004 and resulted in changes to minimum flow requirements (TVA 2017-TN5387). Appendix A of the ROS shows that for the base case condition the minimum flow from Melton Hill Dam was 400 cfs as a daily average. The ROS indicates there were no changes in the base case minimum flow commitments at Melton Hill Reservoir. The applicant states in the SSAR that 400 cfs is the minimum reservoir-release requirement for the Melton Hill Dam (TVA 2017-TN5387).

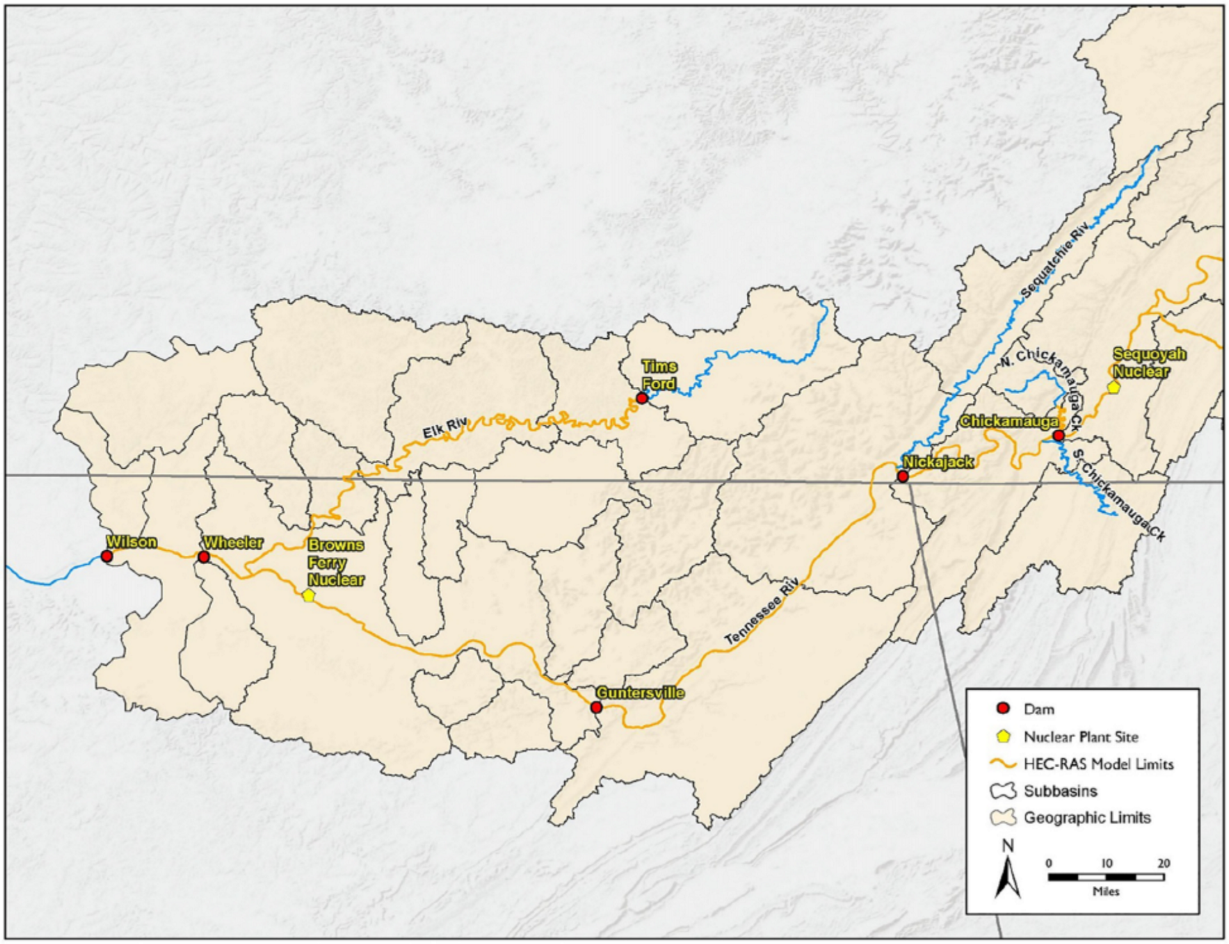


Figure 2.4.1-4a (Sheet 1 of 2) Geographic Map of Tennessee River and its Tributaries, and Location of Dams (reproduced from SSAR Revision 1, Figure 2.4.1-5 [TVA 2017-TN5387])

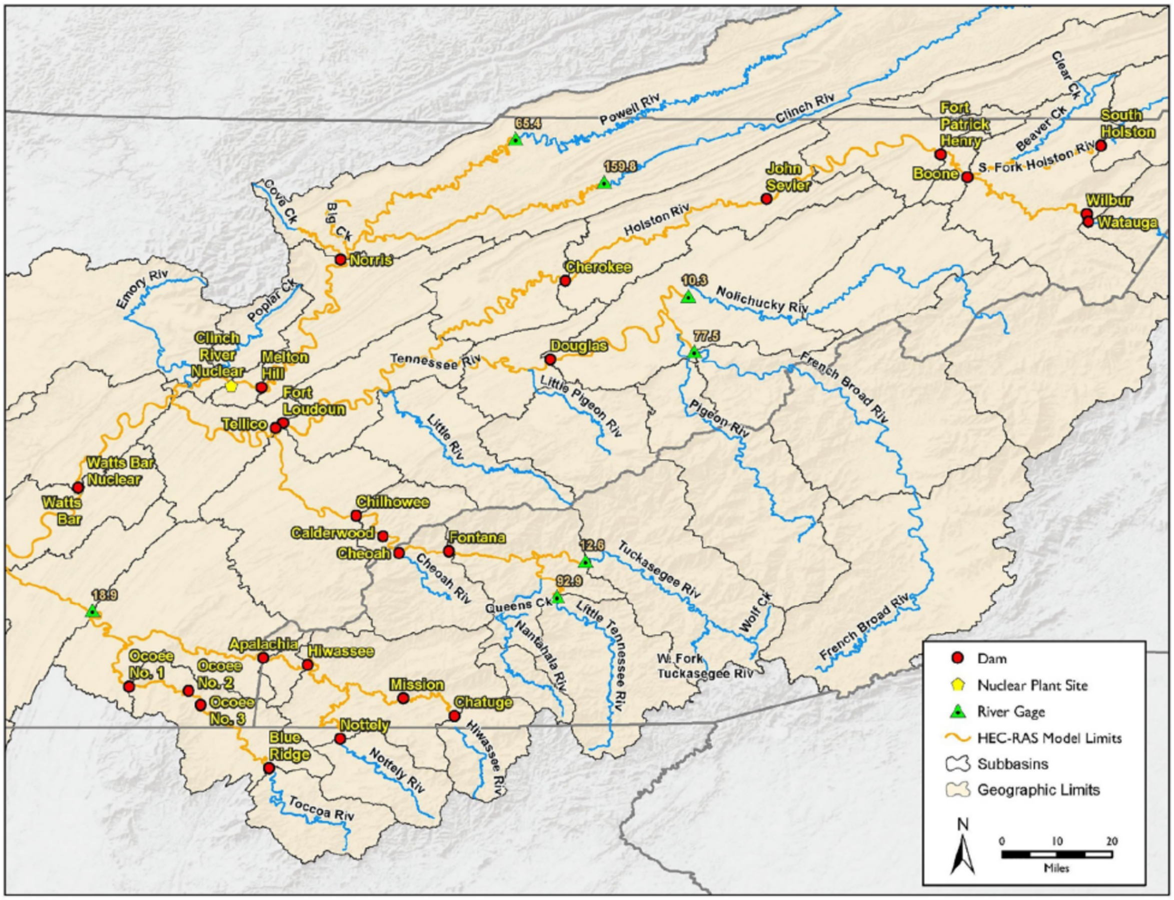


Figure 2.4.1-4b (Sheet 2 of 2) Geographic Map of Tennessee River and its Tributaries, and Location of Dams (reproduced from SSAR Revision 1, Figure 2.4.1-5 [TVA 2017-TN5387])

The applicant stated in the SSAR that since implementation of the ROS during 2004, the monthly average releases from Melton Hill Dam have ranged from a minimum of 589 cfs in November 2008 to a maximum of 14,900 cfs in December 2004 (TVA 2017-TN5387).

2.4.1.3.2.1.4 Reservoir Water Levels

The applicant summarized in the SSAR the reservoir WSEs recorded since completion of Watts Bar Dam in 1942 (TVA 2017-TN5387). The reservoir water level at the Watts Bar Dam located downstream from the CRN Site had a maximum forebay water elevation of 747.4 ft NGVD29, which occurred on May 7, 2003, and a minimum forebay water elevation of 733.7 ft NGVD29, which occurred on March 20, 1945. The Melton Hill Dam located upstream from the CRN Site had a maximum tailwater WSE of 765.1 ft NGVD29, which occurred on April 2, 2000, and a minimum tailwater WSE of 735.0 ft NGVD29, which occurred twice: on January 9, 2002 and December 15, 2005. The seasonal operating curve for Watts Bar, Melton Hill, and Norris Dams are shown respectively in Figure 2.4.1-5a, Figure 2.4.1-5b, and Figure 2.4.1-5c, which provide the months and targeted reservoir levels regulated by the reservoir discharge facilities. Seasonal operating curves are also provided in the SSAR for other dams, including the Fort Loudoun, Tellico, Boone, Cherokee, Douglas, Fontana, Fort Patrick Henry, South Holston, and Watauga Dams (TVA 2017-TN5387), but they are not provided in this FSER.

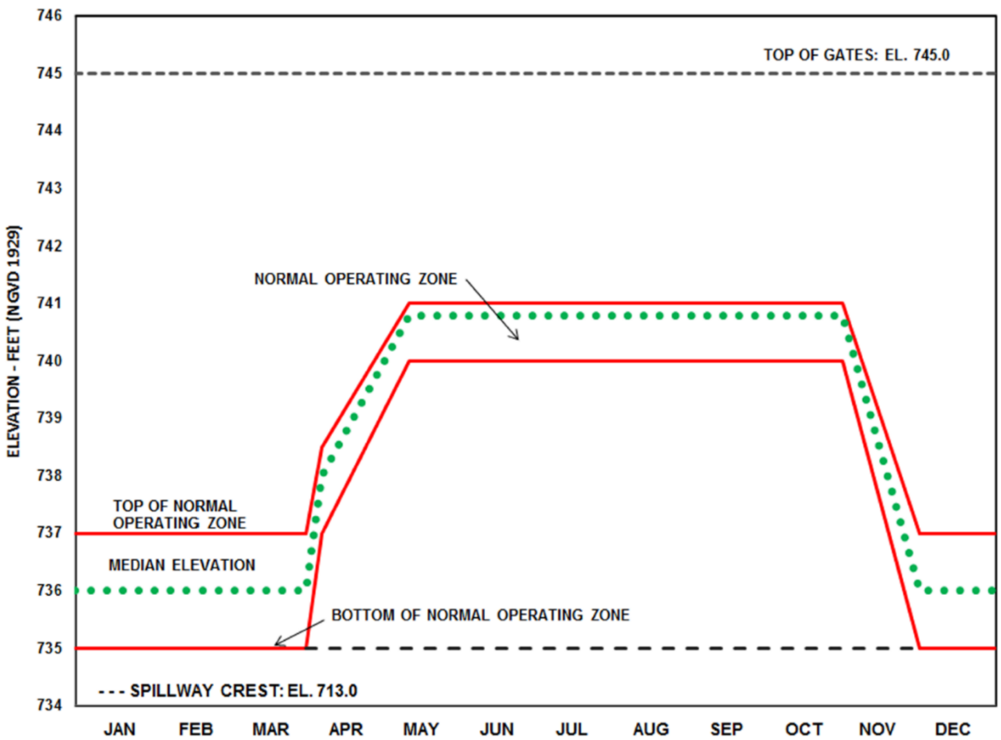


Figure 2.4.1-5a Seasonal Operating Curve for Watts Bar Dam (reproduced from SSAR Revision 1, Figure 2.4.1-6, Sheet 1 of 11 [TVA 2017-TN5387]).

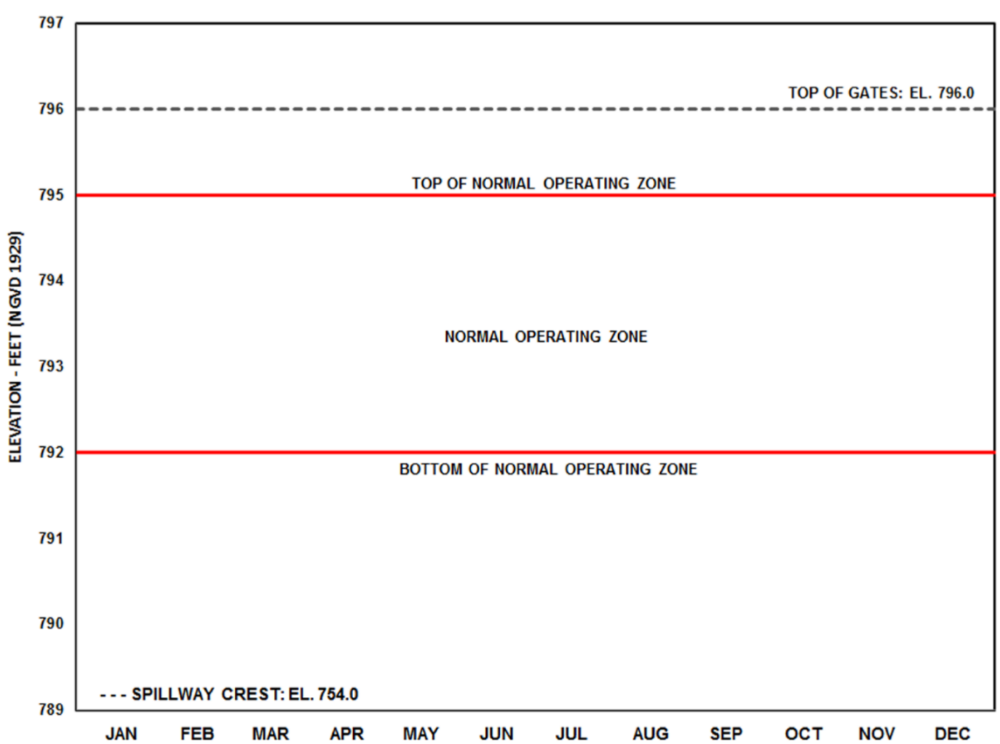


Figure 2.4.1-5b Seasonal Operating Curve for Melton Hill Dam (reproduced from SSAR Revision 1, Figure 2.4.1-6, Sheet 8 of 11 [TVA 2017-TN5387]).

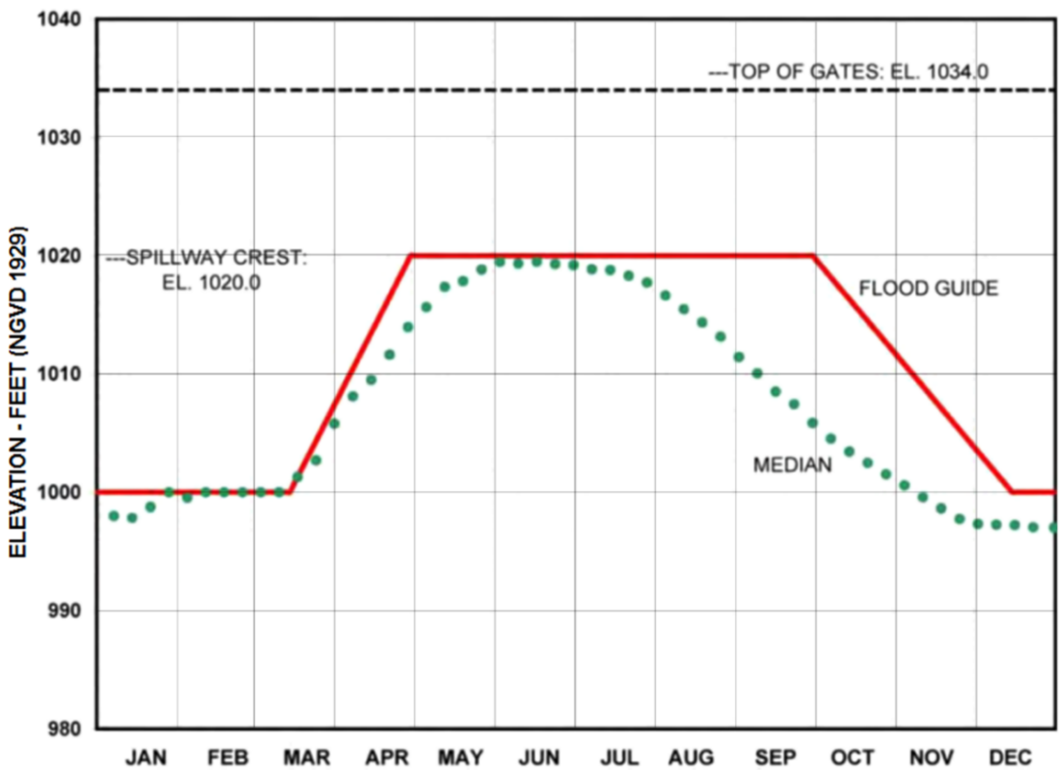


Figure 2.4.1-5c Seasonal Operating Curve for Norris Dam (reproduced from SSAR Revision 1, Figure 2.4.1-6, Sheet 9 of 11 [TVA 2017-TN5387]).

2.4.1.3.2.1.5 Water-Supply Withdrawals

The applicant stated that there are 58 surface water-supply withdrawals within the Clinch River basin (SSAR Table 2.4.1-1 [TVA 2017-TN5387]). Three of these water withdrawals located on the Clinch River downstream from the CRN Site are the (1) Oak Ridge Bear Creek Plant (industrial), which has an intake in the Watts Bar Reservoir; (2) Kingston Fossil Plant (thermoelectric), which has intakes in the Watts Bar Reservoir and the Emory River; and, (3) Kingston Water System (public supply), which has intakes in the Watts Bar Reservoir and the Tennessee River.

During an April 24–27, 2017 audit (NRC 2018-TN5915), the staff discussed the absence of groundwater information in SSAR Section 2.4.1 (TVA 2016-TN5018) with the applicant. The applicant committed to developing and including information about groundwater in this section in a future SSAR revision (TVA 2017-TN5918). The staff reviewed the supplemental information submitted by the applicant (TVA 2017-TN5918), that provided descriptions of groundwater resources and users. The staff subsequently confirmed that this information was included in Revision 1 of the SSAR (TVA 2017-TN5387).

2.4.1.3.2.2 *Staff's Technical Evaluation*

The staff reviewed the applicant's five items included in SSAR Sections 2.4.1.2.1, "Surface Water" and 2.4.1.2.2, "Groundwater" (TVA 2017-TN5387), which include the (1) site location, (2) tributaries, (3) reservoir water flow, (4) reservoir water levels, and (5) water-supply withdrawals. In addition to reviewing these items, the staff examined the completeness of the hydrologic data

for the CRN Site, relevant reservoir operation data, and watershed characteristics. The staff confirmed that the specific data were consistent with data sources, such as basin physiography, regulated discharges from the dams, structural dimensions of the dams, record of peak flood flows, and historical WSEs in the Tennessee River. During the site audit April 24–27, 2017, the staff identified and confirmed various site characteristics that were considered in the applicant's flood analyses (NRC 2018-TN5915).

Based on the information in the SSAR (TVA 2016-TN5018), which was confirmed with information provided during the site audit April 24–April 27, 2017 (NRC 2018-TN5915), as well as the applicant's ROS reports (TVA 2004-TN5919), the staff finds that the applicant acceptably described the hydrosphere for the CRN Site.

2.4.1.4 *Conclusion*

The staff reviewed the ESPA and confirmed that the applicant acceptably described the hydrosphere, and no outstanding information is required to be addressed in the SSAR related to this section. As set forth above, the applicant has provided sufficient information pertaining to the site description. Therefore, the staff concludes that the applicant has met the relevant requirements of 10 CFR 52.17(a)(1) (TN251) and 10 CFR 100.20 (TN282) with respect to the hydrologic description of the site.

2.4.2 Floods

SSAR Section 2.4.2 discusses historical flooding at the proposed site and in the region of the site (TVA 2017-TN5387). The information summarizes and identifies the individual types of flood-producing phenomena, and combinations of flood-producing phenomena, which are considered when establishing the flood design basis for safety-related plant features.

This section provides a review of (1) local flooding on the site and drainage design, (2) stream flooding, (3) surges, (4) seiches, (5) tsunamis, (6) dam failures, (7) flooding caused by landslides, (8) effects of ice formation on water bodies, (9) combined event criteria, (10) other site-related evaluation criteria, and (11) any additional information required by the regulations discussed below in the Regulatory Basis section.

2.4.2.1 *Summary of Application*

In SSAR Section 2.4.2, the applicant addressed the information related to site-specific and regional flood causal mechanisms (TVA 2017-TN5387). The applicant provided reasons for excluding some specific flood events in their detailed flood analysis. The applicant used the detailed flood analysis to determine a worst flooding condition at the CRN Site. Three types of floods were studied and presented in the detailed flood analysis: (1) floods due to PMP coincident with dam failures, (2) floods due to seismic failures of dams coincident with a 25-year or 500-year flood, and (3) floods due to sunny-day failures of dams.

2.4.2.2 *Regulatory Basis*

The relevant requirements of NRC regulations for the identification of floods and flood design considerations, and the associated acceptance criteria, are specified in SRP Section 2.4.2, "Floods" (NRC 2007/2018-TN5898).

The applicable regulatory requirements for considering probable maximum flooding resulting from flood events are set forth in the following:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to the hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated; and
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).

The staff also used the appropriate sections of the following RGs for the acceptance criteria identified in SRP Section 2.4.2 (NRC 2007/2018-TN5898):

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;
- RG 1.59, "Design Basis Floods for Nuclear Power Plants" (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and
- RG 1.102, "Flood Protection for Nuclear Power Plants" (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.2.3 *Technical Evaluation*

The staff reviewed Section 2.4.2 of the SSAR and confirmed that the applicant addressed the appropriate information related to site floods (TVA 2017-TN5387). The staff reviewed the information for this section, including the applicant's SSAR, the information gathered during the site visit (NRC 2018-TN5915), and the applicant's responses to the staff information needs identified in the site audit plan. The staff supplemented this information with other publicly available sources of data during the review. The staff's review areas included the following:

- local site flooding
- stream flooding
- surges and seiches
- tsunamis
- dam failures
- effects of ice formation in water bodies

- channel diversions
- combined events criteria as described in SRP Section 2.4.2
- consideration of other site-related evaluation criteria.

The staff used the information observed during the site visit (NRC 2018-TN5915) to verify the characteristics of important hydrologic features. The staff also performed the site audit to resolve some of the staff's identified information needs. The staff concludes that the applicant provided sufficient details describing the methodology used for surface-water modeling for the flood levels at the site. Sections 2.4.2.3.1 to 2.4.2.3.3 describe the staff's evaluation of the technical information submitted by the applicant.

2.4.2.3.1 Flood History

2.4.2.3.1.1 *Information Submitted by the Applicant*

The applicant provided flood data and flood reports for historical stream floods during the site audit (NRC 2018-TN5915). The data and reports show the flood elevations, based on measured or modeled flood profiles.

SSAR Table 2.4.2-1 provides the record of the elevations of various large flood events in the Clinch River tributary of Watts Bar Reservoir (TVA 2017-TN5387). These flood elevations resulted from natural flow conditions, unregulated by any dams before 1936, and from the flow conditions, regulated by the applicant's dams after 1936. The largest unregulated flood elevation was 767.8 ft NGVD29 at CRM 18.0, which occurred in 1886, and 762.3 ft NGVD29 at CRM 16.0, which occurred in 1867. The largest regulated flood elevation was 748.7 ft NGVD29 at CRM 18.0, which occurred in 2003, and 748.4 ft NGVD29 at CRM 16.0, which occurred in both 1973 and 2003. Both CRM 18.0 and CRM 16.0 are within the CRN Site and near the intake and outlet of the water circulation system (Figure 2.4.1-3). The staff also notes that all historical flood elevations discussed above are well below the CRN Site's minimum finished ground elevation of 821.4 ft NGVD29 (821.0 ft NAVD88) for the power block area.

2.4.2.3.1.2 *Staff's Technical Evaluation*

The staff confirmed the flood historical record with information provided by the applicant during the audit. In addition, the staff has reviewed the applicant's hydrologic modeling analyses used to estimate more recent flood elevations as described in the following sections. Based on this information, the staff finds that the applicant provided appropriate and sufficient information to establish the history of flooding near the CRN Site.

2.4.2.3.2 Flood Design Considerations

2.4.2.3.2.1 *Information Submitted by the Applicant*

In the flood design considerations, the applicant studied three types of events (flood mechanisms) that were used to determine the worst potential flood at the CRN Site. The applicant's three types of events are as follows.

- PMP on critical watersheds with the potential of hydrologic dam failures:

(SRI/CEII) The applicant identified flooding from rivers and streams as the mechanism that produced the most critical flood level calculated at the CRN Site. The critical flood elevation among the PMF events was discussed in SSAR Section 2.4.3 (TVA 2017-TN5387). Based on NOAA HMR-51 (NOAA 1978-TN5942) and HMR-52 (NOAA 1982-TN5943), the applicant determined the critical flood elevation that was computed based on a 7,980 mi^2 PMP event centered at Bulls Gap in the Tennessee River watershed during a March storm. This PMP event produced a peak discharge of 536,000 cfs and a maximum stillwater flood elevation of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) at the CRN Site. The applicant included 2-year wind waves as a potential associated effect on the PMF event. The applicant computed the wind-generated wave height to be **[[**[redacted]**]]** ft above the PMF elevation. Adding the wave height **[[**[redacted]**]]** ft to the maximum stillwater flood elevation of **[[**[redacted]**]]** ft, the applicant gets **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) for the CRN Site. Details of this type of event combined with hydrologic dam failure are discussed in FSER Section 2.4.4.3.5.

- Seismic dam failures with concurrent riverine flooding:

(SRI/CEII) The applicant examined the combined event using JLD-ISG-2013-01 criteria, entitled "Guidance for Assessment of Flood Hazards Due to Dam Failure" (NRC 2013-TN5920), for conditions that could produce a flood elevation potentially affecting the hazard condition. This combined event was the seismic dam failures coincident with a 500-year riverine flood. Combining half of the annual exceedance probability of a 10^{-4} (10,000 year recurrence interval) seismic event with a 500-year flood, the applicant calculated the peak discharge to be 162,000 cfs with a maximum WSE of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) at the CRN Site. This combined event is be discussed in Section 2.4.4.3.2 of this chapter.

- Sunny-day dam failures:

(SRI/CEII) The applicant examined the sunny-day failure of **[[**[redacted]**]]** Dam and a subsequently overtopping failure of **[[**[redacted]**]]** Dam. The applicant showed that this sunny-day failure produced a maximum WSE of **[[**[redacted]**]]** ft NGVD29 at the CRN Site. This sunny-day failure event is discussed in FSER Section 2.4.4.3.5.

In addition to the three types of events described above, the applicant considered the following five flood mechanisms, but did not analyze them:

- surges and seiches (Section 2.4.5)
- landslide-induced tsunamis (Section 2.4.6)
- snow melt and ice jams (Section 2.4.7)
- cooling-water canals and reservoirs (Section 2.4.8)
- channel migration and diversion (Section 2.4.9).

The applicant found that these five types of flood mechanisms were not plausible or were not expected to produce a flood hazard at the CRN Site.

The applicant also discussed the potential for flooding due to local intense precipitation (LIP) events. The applicant calculated the depth of a LIP of 1-hour duration to be 17.4 in. (see Section 2.4.2.3.3). Due to the lack of a specific reactor technology selected for the CRN Site, the applicant did not include a grading plan and a site drainage design. Therefore, the applicant did not provide the flood elevation resulting from a LIP event. The SSAR states that a detailed grading plan and drainage design will be included in the COLA. The applicant indicated in the SSAR that a future drainage design will prevent safety-related SSCs of the plant from flooding (TVA 2017-TN5387).

(SRI/CEII) As described in SSAR Section 2.4.3.5 (TVA 2017-TN5387), the applicant reported that the maximum stillwater flood elevation (MSWFE) for the new plant is **[[**[redacted]**]]** ft NGVD29, which is associated with the PMF from streams and rivers. The DBF level is **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) as described by the applicant in SSAR Section 2.4.3.7 (TVA 2017-TN5387), which is the result of adding a wind-wave height of **[[**[redacted]**]]** ft to **[[**[redacted]**]]**. For context, the CRN PPE states that the minimum site grade elevation in the power block area is elevation 821 ft NAVD88 (821.4 ft NGVD29).

2.4.2.3.2.2 <u>*Staff's Technical Evaluation*</u>

Based on a review of the applicant's information contained in the SSAR (TVA 2017-TN5387), the staff finds that the applicant considered flood-causing phenomena and their combinations that were relevant to the CRN Site.

The staff finds that the applicant's MSWFE due to flooding from streams and rivers as the bounding event is consistent with the historical record and physiography of the Tennessee River basin. The staff finds that the CRN Site minimum site grade elevation of 821.4 ft NGVD29 (821.0 ft NAVD88) precludes impacts on safety-related SSCs from flood hazard scenarios in the Tennessee River basin. Thus, the staff finds that the applicant's historical flood design considerations are acceptable.

The detailed discussion of the staff's evaluation of the applicant's flood design considerations (e.g., including the PMP event, seismic dam failures plus 500-year flood, sunny-day dam failure, and other flooding mechanisms) are addressed in Sections 2.4.3.3.2, 2.4.4.3.3.2, 2.4.4.3.5.2, and 2.4.5.3, etc.

2.4.2.3.3 Effects of Local Intense Precipitation

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

For the CRN Site, the applicant estimated the PMP values and rainfall distributions using the reports prepared by NOAA, including HMR-52 (NOAA 1982-TN5943) and HMR-56 (NOAA 1986-TN5944).

The applicant used the "rough terrain" setting with a corresponding a moisture adjustment factor from HMR-56 (NOAA 1986-TN5944) to estimate the 1-hour precipitation depth of 17.40 in. for the CRN Site. The 17.40 in. are for a 1 mi^2 storm size. In the SSAR supplement, the applicant indicated that three temporal distributions were used to distribute the 17.4 in. (TVA 2017-TN6157) in 5-minute increments for a duration of 1 hour. The temporal distributions were developed and described in the SSAR (TVA 2017-TN5387). The applicant showed the 1-hour precipitation accumulations of three temporal distributions in Table 2.4.2-2 of the SSAR (TVA 2017-TN5387). Each of the three temporal distributions has a different precipitation peak located at the early 20-minute, middle 20-minute, or late 20-minute interval within the total 1-hour duration. This supplemental information was also included in the SSAR (TVA 2017-TN5387).

The applicant noted that neither HMR-52 (NOAA 1982-TN5943) nor HMR-56 (NOAA 1986-TN5944) provided specific guidance for establishing a temporal rainfall distribution in 5-minute increments for a 1-hour duration. The applicant created a temporal distribution for the 1-hour precipitation depth, which is similar to the temporal distribution for a 72-hour precipitation depth arranged in 6-hour increments that were described in the HMR-52 (NOAA 1982-TN5943). The applicant states in the SSAR that additional analyses will be performed for the development of the COLA (TVA 2017-TN5387).

As previously stated, the applicant did not include a site drainage plan for the CRN Site. The SSAR states that the final graded site will take advantage of the topography to facilitate site drainage, and the site drainage plan will be provided in the COLA. The SSAR also states that the site drainage will not be affected by tailwater effects from discharge of surface runoff into the Watts Bar Reservoir (TVA 2017-TN5387). As noted in FSER Section 2.4.1.3.2.1.4, the Watts Barr Reservoir elevation is well below the minimum site grade elevation.

2.4.2.3.3.2 _Staff's Technical Evaluation_

As stated in SRP Section 2.4.2, HMR methods are acceptable for estimating the PMP. Staff independently assessed the 1-hour PMP, 1 mi^2 area using HRM-56 (NOAA 1986-TN5944) methods to obtain the PMP depth of 18.2 in. After using a moisture adjustment factor of 95.6 percent, as provided in HMR-56 Figure 20 (NOAA 1986-TN5944), the staff calculated 17.39 in. for a 1-hour duration, which is negligibly different from the applicant's computed precipitation depth of 17.40 in. for the same rainfall duration. Therefore, the staff determined that the applicant's LIP rate at the CRN Site is reasonable.

The staff found that the applicant's temporal distribution for the 1-hour duration is reasonable. The applicant presented three different temporal precipitation peaks, which are similar to the peaks analyzed in HMR-52 (NOAA 1982-TN5943) for the temporal distribution of a 72-hour PMP.

Based on the above technical evaluation, the staff finds that the applicant has appropriately considered flood-causing phenomena related to LIP for the CRN Site for the ESPA.

Finally, the staff agrees that the site grading plan and stormwater management system related to the local flooding analysis will be specific to the reactor technology. Those design details will not be available until the reactor technology is selected by the COL applicant. Accordingly, the staff identified COL Action Item 2.4-1 to address this future local flooding analysis:

- COL Action Item 2.4-1: An applicant for a COL or CP that references this ESP should design the site grading to provide flooding protection to safety-related structures at the CRN Site based on a comprehensive flood water routing analysis for a local intense precipitation (LIP) event.

2.4.2.4 *Conclusion*

The staff reviewed the ESPA and confirmed that the applicant has demonstrated that flooding has no safety-related impact on the CRN Site, and no outstanding information is required to be addressed in the SSAR related to this section. As set forth above, the applicant has provided sufficient information pertaining to flooding from an LIP. Further, the applicant has considered the most severe natural 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, in establishing site characteristics pertaining to LIP flooding that are acceptable for design purposes. Therefore, the staff concludes that the applicant has met the relevant requirements of 10 CFR 52.17(a)(1) (TN251) and 10 CFR 100.20 (TN282) with respect to determining the acceptability of the site. Because LIP effects are dependent on future side grading and drainage system design, the COL applicant will address COL Action Item 2.4-1.

2.4.3 Probable Maximum Flood on Streams and Rivers

SSAR Section 2.4.3 describes the hydrological site characteristics associated with the PMF on streams and rivers, and combinations of flood-producing phenomena resulting in any potential hazard to the plant's safety-related facilities (TVA 2017-TN5387).

This section provides a review of the following: (1) design basis for flooding in streams and rivers, (2) design basis for site drainage, (3) consideration of other site-related evaluation criteria, and (4) any additional information required by the regulations discussed below in the Regulatory Basis section.

2.4.3.1 *Summary of Application*

(SRI/CEII) In SSAR Section 2.4.3, the applicant addressed information about flooding hazards from streams and rivers (TVA 2017-TN5387). The applicant followed the HMR-41 (NOAA 1965-TN5945), HMR 51 (NOAA 1978-TN5942), HMR-52 (NOAA 1982-TN5943), and HMR-56 (NOAA 1986-TN5944) methods when developing the site-specific PMPs for different sizes of storms. The applicant's PMPs were generated to reflect specific precipitation spatial patterns, the orographic effect on the precipitation, and different storm centers. Through many trials of selecting PMPs and combining them with hypothetical dam failures, the applicant identified a worst flood hazard—a site-specific PMF—that could occur at the CRN Site. Then, the applicant determined the maximum flood elevation would be **[[**[redacted]**]]** ft NVGD29, due to a 7,980 mi^2 PMP combined with dam failures and wind-wave height. This maximum flood elevation is approximately **[[**[redacted]**]]** ft below the site grade elevation 821.4 ft NGVD29 (821.0 ft NAVD88).

2.4.3.2 *Regulatory Basis*

The relevant requirements of NRC regulations for identifying the PMF on streams and rivers, and the associated acceptance criteria, are specified in SRP Section 2.4.3, “Probable Maximum Flood (PMF) on Streams and Rivers” (NRC 2007/2018-TN5898).

The applicable regulatory requirements for identifying the PMF on streams and rivers are set forth in the following:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it sets forth the criteria for determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

The staff also used the appropriate sections of the following RGs for the acceptance criteria identified in SRP Section 2.4.3 (NRC 2007/2018-TN5898):

- RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants” (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;
- RG 1.59, “Design Basis Floods for Nuclear Power Plants” (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and
- RG 1.102, “Flood Protection for Nuclear Power Plants” (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.3.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.4.3 (TVA 2017-TN5387) and confirmed that the information contained in the ESPA addresses the relevant information related to this section. In addition to the systematic review of information provided by the applicant, the staff visited the site during the site audit on April 24–27, 2017, verified the location and elevation of important streams and hydrologic features, and supplemented this information with other publicly available sources of data (NRC 2018-TN5915). The review topics included the following:

- design basis for flooding in streams and rivers
- combined events criteria
- design basis for site drainage
- consideration of other site-related evaluation criteria.

As discussed in FSER Section 2.4.2.4, the potential for flooding due to LIP and associated surface-water drainage systems will be evaluated in the COLA after a reactor technology is selected.

2.4.3.3.1 Watershed Characteristics

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

As presented in the SSAR to describe the watershed characteristics, the applicant divided the Tennessee River watershed into 65 sub-basins above Wilson Dam (TVA 2017-TN5387). The total watershed area of the applicant's hydrologic model is 30,747 mi^2 including 65 sub-basins. The delineated sub-basins are depicted below in 1. The applicant delineated each sub-basin according to watershed topography and stream gauge locations. Wilson Dam is located at the outlet of Sub-basin No. 69 (Figure 2.4.3-1). Directly above the CRN Site are Sub-basin Nos. 33 and 34. The Norris Dam upstream from the CRN Site is located at the outlet of Sub-basin No. 26. Melton Hill Dam is located in Sub-basin No.27 upstream from the CRN Site. The major downstream flow control is at Watts Bar Dam, located at the outlet of Sub-basin No. 37. The other sub-basins are in the downstream of the CRN Site or in the tributary watersheds of the Tennessee River. The applicant established hydrologic parameters for each sub-basin and used rainfall rate as input for the watershed hydrologic simulations.

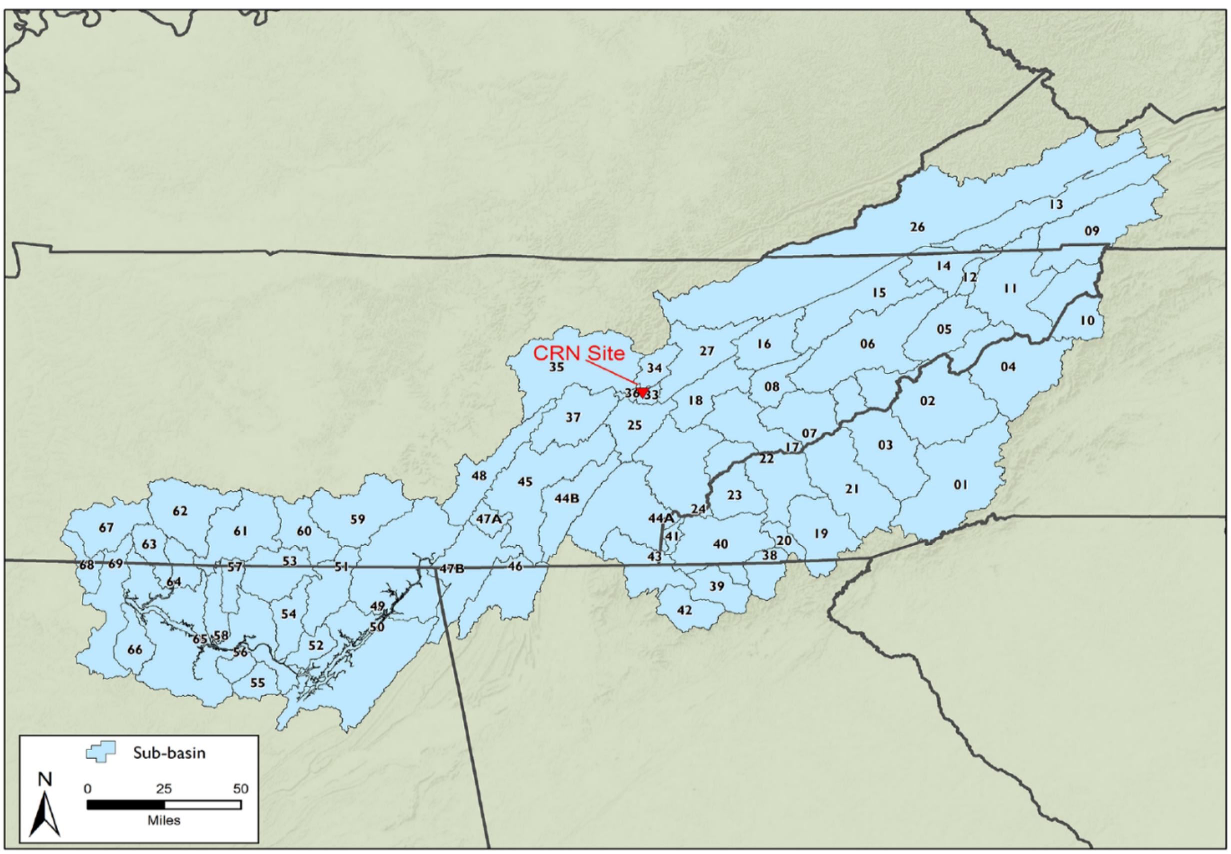


Figure 2.4.3-1 Tennessee River Watershed Sub-basins Used by the Applicant for Hydrologic Analysis (reproduced from SSAR Revision 1, Figure 2.4.3-1 [TVA 2017-TN5387]).

2.4.3.3.1.2 *Staff's Technical Evaluation*

The staff reviewed the sub-basin information by comparing the topography map published by the USGS (2017-TN6174) to the applicant's sub-basin map. The staff found that the applicant's choice of sub-basins is acceptable because the sub-basins were delineated based on the basin ridges and stream flow outlets and stream gauge locations. The staff also reviewed the applicant's description of sub-basin sizes and found that the sizes are compatible with the staff's measurements using geographic information system (GIS) tools. The staff used ArcHydro tools (ESRI 2013.-TN6176) within the GIS software to check the applicant's sub-basin mapping against USGS digital elevation models (DEMs) (USGS 2017-TN6175) within a portion of the area above Chattanooga, Tennessee. The staff previously evaluated the relevant hydrologic parameters for the watershed during a technical review in 2014 for the Watts Bar Nuclear Power Plant License Amendment Request (NRC 2015-TN5921). Based on the current review of the USGS topography maps and the comparison to the technical review in 2014, the staff finds that the applicant provided the most recently available information for the watershed characteristics.

2.4.3.3.2 Probable Maximum Precipitation

2.4.3.3.2.1 *Information Submitted by the Applicant*

To consider the flood hazards at the CRN Site caused by severe meteorological conditions, the applicant adopted the methodologies addressed in HMR-41 (NOAA 1965-TN5945), HMR-51 (NOAA 1978-TN5942), HMR-52 (NOAA 1982-TN5943), and HMR-56 (NOAA 1986-TN5944) to compute the PMP.

The applicant presented four groups of candidate storms in SSAR Section 2.4.3.2 for computing the PMP (TVA 2017-TN5387). Among the candidate storms, the applicant searched for one storm that could create a maximum flood level at the CRN Site. The four groups of candidate storms included the following:

1. A storm center in 3,382 mi^2 of the watershed area above the CRN Site, developed according to HMR-51 (NOAA 1978-TN5942) and HMR-52 (NOAA 1982-TN5943), which provide the guidance applicable for the generalized PMP in the watershed areas east of the 105th meridian and the watershed areas from 10 mi^2 to 20,000 mi^2 in the United States.
2. A storm center in 2,912 mi^2 of the watershed area above Norris Dam, developed according to HMR-56 (NOAA 1986-TN5944), which provides the guidance applicable for watershed areas less than 3,000 mi^2 in the Tennessee River watershed.
3. A storm center in 469 mi^2 of the watershed area between Norris Dam and the CRN Site, developed according to the guidance of HMR-56 (NOAA 1986-TN5944).
4. A storm center at Bulls Gap or at Sweetwater in the 7,980 mi^2 of watershed area above the Chickamauga Dam and below the major tributary storage dams, or a storm center in the 21,400 mi^2 of watershed area above Chattanooga, developed according to HMR-41 (NOAA 1965-TN5945), which provides the guidance applicable for the basin areas larger than 3,000 mi^2 in the Tennessee River watershed.

To develop the first candidate storm covering the 3,382 mi^2 watershed as indicated for group No. 1 above, the applicant located the centroid of the watershed on Figures 18 through 47 in HMR-51 (NOAA 1978-TN5942) to create storm depth-area-duration (DAD) curves. The storm areas of the DAD curves range from 10 mi^2 to 20,000 mi^2, and the storm durations of the curves range from 6 to 72 hours. The applicant assigned the interpolated precipitation depths from

those DAD curves to the isohyet lines of a standard storm pattern quoted from HMR-52 (NOAA 1982-TN5943). The isohyet lines form a total storm area in an elliptical shape and provide the spatial distribution of the storm over the 3,382 mi^2 watershed. By orienting the axis of the elliptical storm area and trying smaller and larger total storm areas, the applicant identified a critical 6,500 mi^2 storm area that could produce the maximum precipitation over the 3,382 mi^2 watershed. The applicant used the isohyets of the 6,500 mi^2 storm area to compute the sub-basin average precipitations that would be carried later into a hydrologic modeling as the input data for computing the PMF elevation at the CRN Site.

To generate the second and third candidate storms over watershed areas less than 3,000 mi^2 as indicated above for group Nos. 2 and 3, the applicant used the HMR-56 method (NOAA 1986-TN5944), which is similar to the procedure for developing the first candidate storm. The applicant included the second and third candidate storms to maximize the uncontrolled discharges from Norris Dam and Melton Hill Dam, and to evaluate the potential flood hazard for the CRN Site.

In the fourth group of candidate storms, the applicant followed the HMR-41 method (NOAA 1965-TN5945) to generate three storms. Two storms are over the watershed areas of 7,980 mi^2 either centered at Bulls Gap or Sweetwater above Chickamauga Dam. Another storm is over 21,400 mi^2 above Chattanooga.

All the above candidate storms were 9-day events, which would occur over the time sequence of a 3-day antecedent storm to saturate the watershed, followed by a 3-day dry interval, and then the 3-day main storm. The applicant assigned the rainfall depth of a 3-day antecedent storm to have a uniform areal distribution over the watershed area above Guntersville Dam that was equal to 30 percent of the areal average rainfall depth of a 3-day main storm when the storm belonged to the first three groups of candidate storms, including the storms over the different watershed sizes 3,382 mi^2, 2,912 mi^2, and 469 mi^2. The applicant used 40 percent of the areal average rainfall depth of a 3-day main storm as the 3-day antecedent storm rainfall depth when the storm belonged to the fourth group of candidate storms. The fourth group of candidate storms are those over the watershed sizes of 7,980 mi^2 and 21,400 mi^2. The applicant assigned the temporal rainfall distribution of the 3-day main storm in accordance with methods in HMR-52 (NOAA 1982-TN5943), HMR-41 (NOAA 1965-TN5945), or HMR-56 (NOAA 1986-TN5944), depending on the method applicable to the different storm candidates. As presented in the SSAR, the applicant formulated the temporal distribution by setting the group of the four greatest 6-hour increments of the 72-hour rainfall in the middle, the group of the four smallest 6-hour increments at the end, and the group of median four 6-hour increments at the beginning (TVA 2017-TN5387). With this formulation, the applicant could have the heaviest rainfall depth occur in the second day of the 3-day main storm. The applicant used the HMR procedures to set the temporal distributions for the 3-day antecedent storms. The applicant assigned the temporal distribution of 3-day antecedent storms to be the same pattern of the 3-day main storm.

Among all candidate storms, the applicant found that the 7,980 mi^2 storm centered at Bulls Gap in March could generate the worst flood condition at the CRN Site. The applicant stated that this 7,980 mi^2 storm event would have 17.02 in. of areal average rainfall depth over the watershed above Watts Bar Dam for the 3-day main storm. This event would also provide 6.00 in. of areal average rainfall depth over the watershed area above Guntersville Dam for the 3-day antecedent storm.

2.4.3.3.2.2 *Staff's Technical Evaluation*

In addition to reviewing the four groups of candidate storms, the staff reviewed the applicant's PMP computational steps that followed HMR guidance. The staff notes that the applicant's first candidate storm covering a 3,382 mi^2 watershed was one of the candidate storms in the Clinch River watershed and was generated by the procedures described in HMR-51 (NOAA 1978-TN5942) and HMR-52 (NOAA 1982-TN5943). HMR-51 and HMR-52 are applicable to the Clinch River watershed in the areas east of the 105th meridian, but are not applicable where orographic effects are significant. Because the terrain variation in the Clinch River watershed may have significant orographic effects on the PMP, the staff checked the appropriateness of using HMR-51 and HMR-52 to compute the precipitation for the first candidate storm. The staff finds that the applicant's justification of using HMR-51 (NOAA 1978-TN5942) and HMR-52 (NOAA 1982-TN5943) for estimating the first storm over the 3,382 mi^2 watershed is based on the Addendum to HMR-45 (NOAA 1969-TN5946), which states that the ridges within the Clinch River watershed are relatively low and generally parallel to the direction of inflow of moisture during extreme storms. The Addendum also states that topographic effects within the Clinch River basin are minimal and were not applied when determining rainfall volume or distribution. Therefore, the staff considers that the applicant's use of HMR-51 (NOAA 1978-TN5942) and HMR-52 (NOAA 1982-TN5943) for the PMP computation of the 3,382 mi^2 watershed is acceptable without considering the topographic effects when computing the PMP for the first candidate storm.

Based on calculations provided by the applicant, the staff noted that the applicant developed DAD curves for sub-basins and considered the Terrain Adjustment Factor (TAF) in the PMP computations when using HMR-56 (NOAA 1986-TN5944) and HMR-41 (NOAA 1965-TN5945) for the second through fourth groups of candidate storms. The TAF, as described in HMR-56 (NOAA 1986-TN5944), can be used to adjust the computed PMP according to the percentages of rough, smooth, and intermediate terrain in the sub-basins. The staff finds that the non-mountainous flat area or the low ridge area, such as the Clinch River watershed, does not need the TAF as described in the HMRs. The staff also finds that the applicant followed the HMRs to consider the TAF, except when HMR-51 (NOAA 1978-TN5942) and HMR-52 (NOAA 1982-TN5943) were used. The staff concludes the applicant's PMP was reasonably computed to represent a critical precipitation pattern because the results were generated using the HMR TAF and in accordance with HMR guidance.

The staff checked the applicant's areal average 72-hour PMP depth centered at Bulls Gap over the watershed above Watts Bar Dam. The staff calculated the areal average 72-hour PMP of 17.05 in. for the 3-day main storm (72-hour PMP) above Watts Bar Dam, which is a minimally different than the applicant's calculated 17.02 in. The staff also checked the applicant's calculated antecedent rainfall depth by calculating an areal average PMP of 5.95 in., above Guntersville Dam for the 3-day antecedent storm, which is negligibly different than the applicant's 6.00 in. The staff selected Guntersville Dam (see Figure 2.4.1-4b, Sheet 2 of 2) for checking the areal average of antecedent rainfall depth because the dam approximates the outer isohyet boundary of the storm pattern. Based on a comparison of the minimal differences between the applicant's and the staff's calculations, the staff determined that the applicant acceptably computed the spatially averaged PMP of 17.02 in. for the 3-day main storm (72-hour PMP) over the watershed area above Watts Bar Dam and 6.00 in. for the 3-day antecedent storm over the watershed area above Guntersville Dam. The staff also confirmed that the applicant's 72-hour PMP depth for each sub-basin shown in Table 2.4.3-2 of the SSAR (TVA 2017-TN5387) matched the applicant's calculations reviewed during the audit (NRC 2018-TN5915).

The staff used HMR-41 guidance (NOAA 1965-TN5945) and calculated the temporal PMP distribution of the main storm (72-hour PMP) over the watershed area above the Watts Bar Dam and found negligible differences in the applicant's temporal PMP distribution, as shown in SSAR Table 2.4.3-3 (TVA 2017-TN5387). Due to these small differences, the staff determined that the temporal PMP values shown in SSAR Table 2.4.3-3 are reasonable.

The staff reviewed the applicant's calculations for the four groups of candidate storms provided by the applicant. The staff reviewed the applicant's calculations and information provided in SSAR Section 2.4.3.2 (TVA 2017-TN5387), and the staff determined that the applicant's temporal rainfall distributions were acceptable.

The staff noted that the current PMP isohyet patterns of the fourth group of candidate storms for the 7,980 mi^2 and 21,400 mi^2 watersheds are similar to the PMP isohyet patterns reviewed by the NRC staff in 2014 and 2015 (NRC 2015-TN5921) for the Watts Bar Nuclear Power Plant License Amendment Request. The staff also notes that the applicant used similar parameters and steps for computing the storms over the 7,980 mi^2 and 21,400 mi^2 watersheds that were examined by the NRC staff in the previous review of the Watts Bar Nuclear Power Plant License Amendment Request (NRC 2015-TN5921).

The staff noted that the applicant's computed PMP for the storm over the 7,980 mi^2 watershed above Chickamauga Dam is a controlling storm when compared to the other candidate storms described in SSAR Table 2.4.3-1 (TVA 2017-TN5387). The controlling storm could generate a maximum flood elevation at the CRN Site in the Watts Bar Reservoir's upstream area, as described in FSER Section 2.4.3.3.5.

2.4.3.3.3 Precipitation Losses

2.4.3.3.3.1 *Information Submitted by the Applicant*

The applicant assumed no precipitation losses for surface runoff computations equivalent to 100 percent of the precipitation transformed into surface runoff.

2.4.3.3.3.2 *Staff's Technical Evaluation*

Precipitation losses typically occur during rainfall events. These losses are the result of natural soil absorption, the filling up of surface depressions, vegetal interception, and other factors. The staff considers the applicant's assumption of no precipitation losses, which directly converts all precipitation to surface runoff, to be acceptable because it is a conservative assumption.

2.4.3.3.4 Runoff and Stream Course Models

The evaluation of the Runoff and Stream Course Models is provided in FSER Sections 2.4.3.3.4.1 to 2.4.3.3.4.4, which describe the runoff model, stream course model extent, stream course geometry development and calibration, and design storm implementation, respectively.

2.4.3.3.4.1 *Runoff Model*

2.4.3.3.4.1.1 Information Submitted by the Applicant

The applicant developed a rainfall-runoff model using Spreadsheet (TVA 2016-TN6156) to convert rainfall discussed in SSAR Section 2.4.3.4.1 (TVA 2017-TN5387) into surface runoff

using the unit hydrograph method for all the sub-basins (Figure 2.4.3-1) in the Tennessee River watershed.

The applicant derived unit hydrographs based on the flood record between 1940 and 1973. The applicant followed a reverse process called deconvolution (Newton and Vineyard 1967-TN6126) to derive the unit hydrographs. When a sub-basin lacked rainfall-runoff data, the applicant derived synthetic unit hydrographs from the available data for other sub-basins that have similar hydrologic characteristics.

The applicant validated the unit hydrographs that could reproduce the rainfall-runoff results of large storms recorded from 1997 through 2007. When large storm data were not available in this period for some sub-basins, the applicant either used the data back to 1985 or routed the computed runoff to a downstream point where the data were available for validation. The applicant provided the validated unit hydrographs for the sub-basins above Chickamauga Dam.

Due to the nonlinearity between the effective rainfall depth and the surface runoff during an extreme large flood, such as a PMF, the applicant increased the validated unit hydrograph peak by 20 percent and decreased the time-to-peak by one-third. The applicant used the adjusted unit hydrographs (TVA 2016-TN6156) to calculate the surface runoffs of hypothetical storms at the outlets of the sub-basins above Wilson Dam. Each sub-basin, including sub-basin Nos. 1 through 65 (Figure 2.4.3-1), has its own adjusted unit hydrograph. The applicant treated the sub-basin Nos. 66 through 69 as a reservoir area. Thus, the surface runoff hydrographs for sub-basin Nos. 66 through 69 were calculated by multiplying the sub-basin area by the rainfall intensity without using the unit hydrograph method.

In SSAR Section 2.4.3.3, the applicant set no precipitation losses for any of the PMP events (TVA 2017-TN5387). The applicant used zero-loss of rainfall depths and the adjusted unit hydrographs to generate the surface runoff hydrographs for a PMP event.

In addition, the applicant considered that the reservoir volumes of many small dams could become non-detainable flows if the small dams were assumed to fail during a PMP event. The applicant counted these non-detainable flows from the small dams as additional surface runoff flows and identified approximately 700 dams in the Tennessee River watershed above Wheeler Dam. The applicant used the list of the National Inventory of Dams (NID) to acquire the storage volumes of the 700 dams. The NID is maintained by the U.S. Army Corps of Engineers (USACE). Not counting the reservoir storage effect of the 700 small dams, the applicant simply converted the storage volumes into rectangular hydrographs of surface runoffs with 6-day flow durations. All the rectangular hydrographs in the different sub-basins have a starting day of 1 day after the peak rainfall of the antecedent storm. For a demonstration, the applicant included the rectangular hydrographs that were added to the discharges at Norris Dam, Melton Hill Dam, and Watts Bar Dam in the Figures 2.4.3-18, 19, and 20 of the SSAR (TVA 2017-TN5387). As demonstrated in Figures 2.4.3-18 through 20 of the SSAR, the applicant directly added the rectangular hydrographs as input data to the applicant's surface runoff model (TVA 2016-TN6156).

2.4.3.3.4.1.2 Staff's Technical Evaluation

The staff reviewed the peak flows, peaking times, and unit volumes of the applicant's unit hydrographs presented in the Figure 2.4.3-17 of the SSAR (TVA 2017-TN5387). By reviewing the details of the unit hydrograph development during the NRC audit (NRC 2018-TN5915), the

staff confirmed that the applicant's unit hydrographs had been updated and validated by comparing simulated results to several storm events from 1997 through 2007.

The sub-basin unit hydrographs and their validations are discussed in the April 2017 audit summary report (NRC 2018-TN5915). The staff found that the applicant used acceptable methodologies and procedures to derive and validate the unit hydrographs because the applicant used common practices in hydrologic engineering that are consistent with NRC guidance. The staff reviewed the applicant's detailed validations of unit hydrographs, including the selected large storms, the stream base-flow separation, and the computations of effective rainfalls that were generated from the observed precipitations and the Antecedent Precipitation Index method (Linsley et al. 1982-TN6030). The staff examined the comparison between the applicant's simulated surface runoff hydrographs and the observed stream flow hydrographs.

Based on the staff's review of the applicant's results for unit hydrograph validation, the staff confirmed that the applicant's unit hydrographs can be used to reproduce the recorded large floods and to reflect the current watershed characteristics acceptably. The staff also finds that the reproduced flow rates or flow elevations by the unit hydrographs are within small variances when compared to the recorded flow rates or flow elevations of the storm events. Therefore, the staff considers the applicant's unit hydrographs acceptable.

The staff noted that the applicant's rectangular-shaped hydrographs, treated as additional surface runoffs to the sub-basins, were obtained by converting the small reservoir storage volumes of the NID into surface runoffs. The staff concludes the rectangular-shaped hydrographs are acceptable because the applicant conservatively converted the storage volumes into the rectangular hydrographs with no consideration of flow attenuation between the NID dams and the sub-basin outlets. The staff observed that Figures 2.4.3-18 through 20 of the SSAR (TVA 2017-TN5387) indicate that, compared to the PMF flows, the rectangular-shaped hydrographs would not be significant inflows to the reservoirs.

The staff reviewed the applicant's runoff model and confirmed that the nonlinearity of the unit hydrographs was included as recommended by NUREG/CR-7046 (Prasad et al. 2011-TN2031). Therefore, the staff confirmed the applicant's spreadsheet runoff model contains nonlinearity that can be further used to generate surface runoff values with relevant PMP events.

The staff determined that the applicant's computation of surface runoffs resulting from a PMP event was conservative because the applicant-computed surface runoffs were developed based on rainfall depth without any reduction of infiltration loss, without considering peak flow attenuation of rectangular hydrographs converted from NID storage volumes, and without considering lag times between the rainfall events and surface runoffs for instantaneous runoffs created for Sub-basins 66 through 69. More detailed information about the stream course models and design storm implementation is presented in Sections 2.4.3.3.4.2 through 2.4.3.3.4.4 below.

2.4.3.3.4.2 *Stream Course Model Extent*

2.4.3.3.4.2.1 Information Submitted by the Applicant

The applicant used the calibrated Hydrologic Engineering Center-River Analysis System (HEC-RAS) model (USACE 2010-TN4128) to simulate the flood profiles that connected in the main river channel and many other tributary channels in the Tennessee River watershed (TVA 2016-TN6156). The flood profiles converge to the downstream end at Wilson Dam, which is the outlet

of Sub-basin No. 69 (Figure 2.4.3-1). The upstream boundaries of the HEC-RAS model were located at various control points, including upstream dams and reservoirs, critical stream gauge stations, confluences of tributaries or rivers, and hydraulic control structures. Details of the upstream boundary points of the HEC-RAS model are shown in Figure 2.4.1-4a-b. These upstream points receive inflows from the surface runoff hydrographs that were generated by the applicant's runoff model described in FSER Section 2.4.3.3.4.1. The applicant stated that dams and reservoirs modeled below the Chickamauga Dam (Figure 2.4.1-4b, Sheet 2 of 2) would have little effect on the predicted flood profiles at the CRN Site. The Chickamauga Dam is located immediately downstream of Watts Bar Dam.

2.4.3.3.4.2.2 Staff's Technical Evaluation

The staff reviewed the upstream boundary and hydrologic control points in the HEC-RAS model. The staff examined the applicant's inflows stored in the HEC's Data Storage System (HEC-DSS) files (TVA 2016-TN6156), which were consistent with the output data stored in the spreadsheet of the applicant's runoff model. Based on the staff review and examination of the inflow files, the staff finds that the applicant acceptably set up the upstream boundary and control points. The staff notes that the HEC-DSS files meet both the HEC-RAS model input and input format requirements (USACE 2010-TN4128).

In accordance with the HEC-RAS computational results, the staff agrees with the applicant's conclusion that floods occurring downstream of the Watts Bar Dam or Chickamauga Dam would have minimal effect on water levels near the CRN Site.

2.4.3.3.4.3 *Stream Course Model Geometry Development and Calibration*

2.4.3.3.4.3.1 Information Submitted by the Applicant

The applicant developed elevation-storage relationships for main-stem reservoirs, using reservoir-level storage information and sediment range survey maps. The reservoir elevation-storage relationships are for uses in the HEC-RAS model. The applicant also measured the reservoir areas on the composite maps consisting of USACE survey maps, the applicant's land maps, USGS topographic maps, and the applicant's navigation maps. The applicant used the measured reservoir areas above the projected flood elevation to extend the range of elevation-storage relationships when extension was needed.

In addition to the reservoir elevation-storage relationships, the applicant developed stream channel profiles and effective flow areas of the main stem and tributaries, which would be used in the HEC-RAS model. The applicant developed the channel profiles and effective stream flow areas from the cross-section data of the applicant's historical hydrology model, USACE hydrographic survey data, aerial photos, and the Digital Terrain Model (DTM) data of water-surface topography.

The channel profiles in the HEC-RAS model above Watts Bar Dam included major hydraulic structures and stream gage stations (TVA 2016-TN6156). The main stem and tributaries upstream from Watts Bar Dam include the Little Tennessee River, Clinch River, French Broad River, and Holston River (Figure 2.4.1-4a, Sheet 1 of 2.)

The applicant also extended the cross-section areas to be large enough to contain the PMF for flow simulations in the HEC-RAS model. The extended cross sections include off-channel ineffective flow areas that allow reach storage volumes to closely replicate the reservoir

elevation-storage relationships. The average overbank-flow lengths were also considered with the off-channel ineffective flow areas to compute the reach storage volume. The applicant also simulated the complex off-channel volumes by adding flow cross sections with lateral discharge structures that connected to the designated flood plains. The applicant provided examples of the replicated reach storage volumes as shown in Figures 2.4.3-22 through 2.4.3-24 of the SSAR (TVA 2017-TN5387). To replicate the reservoir volume needed in the constricted flow areas of the reaches, the applicant augmented ineffective off-channel flow areas in the specific stream cross sections to increase reach volume by using the triangulated irregular network file of the related reservoir and channel.

After setting up the stream geometric data in the HEC-RAS model (USACE 2010-TN4128), the applicant calibrated the hydraulic parameters in the model by selecting the two largest flood events, which occurred in March 1973 and May 2003.

The applicant separated three sequential segments of the Clinch River and calibrated the Clinch River as a portion of the HEC-RAS model. The downstream segment is from the Clinch River mouth at river mile 0.0 to its upstream Melton Hill Dam at river mile 23.1. The middle segment is from Melton Hill Dam to Norris Dam at river mile 79.8. The upstream segment stretches from Norris Dam to the reservoir upstream limit at river mile 153.6. The downstream and middle segments were calibrated with March 1973 and May 2003 events that were the same events used to calibrate the main stem of the Tennessee River. The upstream segment, consisting of two tributaries, was calibrated with 2002 and 2003 flood events, as well as with Federal Emergency Management Agency flood profiles. The applicant also calibrated the other sequential segments of the Tennessee River in the HEC-RAS model. In each segment, the upstream boundary conditions were the observed discharges at upstream dams and the downstream boundary conditions were the observed headwater elevations at downstream dams. The applicant calibrated the HEC-RAS model to replicate the flood events in segments by adjusting hydraulic parameters, including the friction coefficient of the flow, and by checking ineffective flow areas and reservoir storage volumes. The adjustments of the hydraulic parameters were iterative during the calibration process until they could make the peak flood elevation difference from the observed flood elevation within a range from 0.5 to 1.5 ft at the headwater levels of the dams. The applicant presented the calibration results of the Clinch River in Figures 2.4.3-10 through 2.4.3-15 in the SSAR (TVA 2017-TN5387) as a portion of the HEC-RAS model calibrations. After calibrations, the applicant combined all the Clinch River segments with other segments in the Tennessee River watershed into one model. The applicant later used the calibrated HEC-RAS model (TVA 2016-TN6156) to simulate the stream flows and reservoir volume changes in the Tennessee River watershed (see FSER Sections 2.4.3.3.5 and 2.4.3.3.6).

As requested by the staff during the audit (NRC 2018-TN5915), the applicant added stream cross sections and analyzed the backwater effect caused by a high flow constriction at the Tennessee State Highway 58 (TN 58) Bridge, located about 2 mi downstream from the CRN Site, and provided supplemental data, including the reduced intervals between stream cross sections and the TN 58 Bridge (TVA 2017-TN6155; TVA 2017-TN6159) that could be used as geometry files for the HEC-RAS model. To validate the configuration of the TN 58 Bridge, the applicant provided the bridge profile and plan shown in the SSAR supplements (TVA 2017-TN6157). The applicant used these geometry files (TVA 2017-TN6155, TVA 2017-TN6159) in the sensitivity study of backwater effects on the flood elevation changes. The applicant provided the sensitivity study result in the SSAR (TVA 2017-TN5387) and indicated minimal changes of the flood elevations adjacent to the CRN Site.

2.4.3.3.4.3.2 Staff's Technical Evaluation

The staff noted that the applicant used available data acquired from Federal and State government agencies to develop and validate the elevation-storage relationship of main-stem reservoirs as shown in the SSAR (TVA 2017-TN5387). The staff also noted that the applicant developed stream cross sections based on the applicant's previous hydrologic model and validated the stream cross sections with the reliable data provided by Federal government agencies. The staff concludes that the applicant data sources used in both developing the reservoir elevation-storage relationship and deriving the stream cross sections are acceptable, because the data sources are reliable and generated by government agencies.

The staff used GIS tools to extract stream cross sections from USGS topographic maps and USGS DTM files. The staff finds that the extracted cross sections are consistent with the applicant's cross sections above normal flow elevations shown in the HEC-RAS model (TVA 2016-TN6156). Based on the geometric consistency of the comparisons, the staff concludes that the applicant's stream cross sections are acceptably used in the HEC-RAS model to represent the stream geometry.

The staff examined the applicant's reservoir volume calculations in which the applicant used reservoir surface areas and elevations to calculate incremental and cumulative volumes of reservoir storage. Based on the staff's comparisons between the USGS contour maps and the evaluations used in the applicant's calculations, the staff confirmed that the elevation-storage relationship shown in the HEC-RAS model reasonably represents the field conditions of the reservoirs. The staff determined that the reservoir elevation-storage data are valid and acceptably used in the HEC-RAS model to represent the field conditions because the applicant validated the elevation-storage relationship with various reliable data sources, including those from government agencies as described in the SSAR (TVA 2017-TN5387).

The staff reviewed the effective flow areas determined by the applicant from the validated stream geometry in the HEC-RAS model and reviewed the hydraulic parameters used in the model (TVA 2016-TN6156, TVA 2017-TN6155, TVA 2017-TN6159). Based on the review, the staff found that (1) the applicant's HEC-RAS model setup and the effective flow areas were based on reliable topographic data; (2) the applicant's hydraulic parameters were calibrated within a reasonable range when compared to the values of the HEC-RAS Reference Manual (USACE 2016-TN5947); and (3) the calibrated peak elevations remain higher than the observed elevations by 0.5 to 1.5 ft. With those findings, the staff determined that the applicant's HEC-RAS model was acceptably calibrated and that the HEC-RAS model (USACE 2016-TN5947) is applicable for PMF simulations.

The staff also noted that the applicant simulated a series of reach volumes using the HEC-RAS model under the steady-state flat-pool storage condition to replicate a reservoir volume in the HEC-RAS model. For confirmation, the staff calculated the reservoir volumes under the steady-state flat-pool simulation using the staff's spreadsheets and obtained results similar to those described by the applicant. Based on the similarity of the staff's results relative to the applicant's demonstrations shown in the SSAR (TVA 2017-TN5387), the staff determined that the applicant-determined stream reaches acceptably represent the reservoirs in the HEC-RAS model.

The staff noted that the applicant provided a statement to include a sensitivity study result regarding the backwater effect on the CRN Site when the TN 58 Bridge was added to the HEC-RAS model for PMF simulations. Using the applicant's bridge geometry data (TVA 2017-

TN6159), including the bridge profile and plan, the staff calculated PMF elevations of various locations to confirm the applicant's conclusion that there were minimal increases in the PMF elevations. The staff's calculated PMF elevations show a minimal increase in the PMF elevation at the CRN Site when the bridge is included in the HEC-RAS model. Therefore, the staff determined that accounting for the bridge does not substantially affect the PMF elevations and that including the bridge in the PMF simulation is unnecessary.

In addition to the reservoirs and streams being established in the HEC-RAS model, reservoir operational guides are other dominant factors that affect the PMF simulation in the HEC-RAS model. The operational guides are described in detail in Section 2.4.3.3.4.4 below.

2.4.3.3.4.4 *Design Storm Implementation*

2.4.3.3.4.4.1 Information Submitted by the Applicant

To control floods, the applicant implemented flood operational guides for the reservoirs in the Tennessee River watershed. The floods controlled by the operational guides can be the outcomes of various seasonal design storms, such as a PMP event that occurs in March. The flood operational guides for warm seasons are different from the ones for cold seasons. The applicant used SSAR Figure 2.4.3-4 (TVA 2017-TN5387) as an example to demonstrate the complexity of operational guides for controlling reservoir headwater levels in March and June at Norris Dam. Using the diagram shown in SSAR Figure 2.4.3-4 (TVA 2017-TN5387), the applicant explained the steps for managing flow discharges between 4,500 cfs and 24,000 cfs, as well as headwater levels between 1,005 ft and 1,034 ft. SSAR Figure 2.4.3-4 shows the primary guide curve to be used to raise the reservoir level when flood flows enter the reservoir, and the recovery curve to be used to draw down the reservoir level when the flood flows recede (TVA 2017-TN5387). The applicant also indicated that 1,034 ft was the upper limit of the operational guides for Norris Dam. The applicant provided transition conditions to extend the limit of flood operational guides into dam rating curves when the reservoir headwater exceeds 1,034 ft. The submergence effects between the reservoir headwater and tailwater were included in the dam rating curves.

Because Melton Hill Dam is not for flood control, a simple flood operational guide for all seasons was provided in SSAR Figure 2.4.3-5 (TVA 2017-TN5387). For Watts Bar Dam, the applicant showed different and complex flood operational guides in SSAR Figure 2.4.3-6 (TVA 2017-TN5387).

The flood operational guides and the dam rating curves were both scripted as computer program lines embedded as portions of "HEC-RAS unsteady flow rules" in the applicant's HEC-RAS model. During a flood profile simulation, the applicant's scripted "HEC-RAS unsteady flow rules" can be executed to compute the reservoir outflows by following the dam rating curves or the operational guides. The computations were incorporated with the reservoir headwater and tailwater levels. The applicant used the median or normal pool level of a season as the initial reservoir water elevations to start the flood profile simulation in the HEC-RAS model (USACE 2016-TN5947).

For the hypothetical dam breach during various design storms, the applicant scripted other program lines embedded in the "HEC-RAS unsteady flow rules" to compute the breach flows. These scripted program lines describe weir flow equations and dam breach parameters. The applicant adopted the weir flow equation to calculate the breach outflows when the geometrical breach section did not reach the channel bottom. If the breach section reached the channel

bottom, the applicant calculated the outflow by the unsteady flow equations formulated in the HEC-RAS model. FSER Sections 2.4.4 and 2.4.4.3.2 provide details regarding potential dam failures and dam breach parameters, respectively.

2.4.3.3.4.4.2 Staff's Technical Evaluation

The staff reviewed the numerical values of the flood operational guides and dam rating curves (TVA 2016-TN6158). By examining the numerical values, the staff finds that the relationship between the headwater levels at dams and discharges from dams can reflect the flood operational guides and dam rating curves. The staff confirms that the numerical values match the computational results of the applicant's HEC-RAS model (TVA 2016-TN6156).

The staff reviewed weir flow equations and their coefficients that described dam rating curves that were used in the applicant's HEC-RAS model. The staff confirms that the weir flow equations are used in standard engineering applications and that the coefficients of the equations are within a standardized range.

The staff noted that "HEC-RAS unsteady flow rules" is one of the programming functions in the HEC-RAS model, and that it allows users to prescribe unsteady flow rules according to dam rating curves or flood operational guides. The staff reviewed the unsteady flow rules embedded in the applicant's HEC-RAS model and found that the unsteady flow rules matched the applicant's flood operational guides and the applicant's dam rating curves. To examine the tailwater submergence effects on the applicant's dam rating curves, the staff checked the model by increasing the tailwater elevations at Melton Hill Dam. Based on the checks, the staff found that the applicant's dam rating curves embedded in the "HEC-RAS unsteady flow rules" can respond to the tailwater submergence effects. The staff finds that the dam rating curves generated by the applicant's HEC-RAS model for Norris, Melton Hill, and Watts Bar Dams match the diagrams shown in SSAR Figures 2.4.3-7 through 2.4.3-9 (TVA 2017-TN5387).

Based on the staff's examinational results described above, the staff considers that the dam rating curves and the flood operational guides were appropriately represented with the applicant's HEC-RAS model simulations.

For the other dam rating curves related to dam failures, the staff reviewed the applicant's dam breach parameters that were used in the HEC-RAS model and the applicant's computed breach outflows that were generated from the HEC-RAS model (USACE 2016-TN5947). Regarding the dam breach parameter, the staff confirms that the applicant used the acceptable methods described in JLD-ISG-2013-01, "Guidance for Assessment of Flooding Hazards Due to Dam Failure" (NRC 2013-TN5920) to develop the breach depth, width, and side slope (the staff's evaluation of the dam breach parameters are described in FSER Section 2.4.4.3.3). Regarding the computed breach outflows, the staff compared the applicant's computed results from the spreadsheets (TVA 2016-TN6158) and the computed breach outflows from the HEC-RAS model (TVA 2016-TN6158). Based on the consistency between the spreadsheets and the HEC-RAS results, the staff determined that the applicant's weir flow equations and the applicant's weir flow discharge coefficients for dam breach outflows were acceptably used and embedded in the HEC-RAS model.

2.4.3.3.5 Probable Maximum Flood Flow

2.4.3.3.5.1 Information Submitted by the Applicant

(SRI/CEII) The applicant included the prescribed reservoir operational guides and the established dam rating curves in the HEC-RAS model (USACE 2016-TN5947) to compute the flood elevations of various storm events. The applicant compared the computed flood elevations of various storms, including the 7,980 mi^2, 21,400 mi^2, 3,382 mi^2, 2,912 mi^2, and 469 mi^2 storms. Based on the comparison shown in Table 2.4.3-1 of the SSAR supplement (TVA 2017-TN6157), the applicant stated that the maximum flood elevation at the CRN Site (described in FSER Section 2.4.3.3.6) was the result of the 7,980 mi^2 storm as a PMP event, in which the storm center was set at Bulls Gap and assumed to occur in March. The applicant presented the calculated PMF elevation, **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88), and the maximum flood flow, 536,000 cfs, in SSAR Figure 2.4.3-3 (TVA 2017-TN5387). This PMP event could cause overtopping flows, as described in FSER Section 2.4.4.3.4. The applicant selected the normal reservoir levels in March as the initial pool conditions according to the applicant's flood operational guides to match the timing of the 7,980 mi^2 PMP occurrence. For the other storm events, the applicant set the normal reservoir levels in June as initial conditions to match the timing of the other storm occurrences. All reservoir normal levels in June would be at their highest elevations of the year according to the applicant's flood operational guides.

(SRI/CEII) The applicant performed a sensitivity study, assuming all the discharge gates were inoperable for **[[**[redacted]**]]** Dam and reducing the gate discharge rate of **[[**[redacted]**]]** Dam during the 7,980 mi^2 storm. The sensitivity study showed that overtopping failures of both the **[[**[redacted]**]]** Dam and its downstream **[[**[redacted]**]]** Dam would occur due to the assumption. With these overtopping failures, the applicant indicated that the flood elevation at the CRN Site would increase by **[[**[redacted]**]]** ft above the **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88). The elevation of **[[**[redacted]**]]** ft NGVD29 is the result under the condition of all gates being operable during the 7,980 mi^2 storm. The applicant noted the assumption of inoperable gates is unrealistic because the reliability of the discharge gates is monitored by daily operation. The applicant stated that the TVA has the means and resources to resolve any gate operation issues.

2.4.3.3.5.2 Staff's Technical Evaluation

The staff reviewed the applicant's calibrated HEC-RAS model (TVA 2016-TN6156) and supporting calculations provided during the NRC's safety audits (April through October 2017). The staff's review items included the applicant's model setup, stream augment sections for ineffective flows, the geometry of stream cross sections, energy loss coefficients of stream flows, the unsteady flow rules, inflow data as input to the model, storage volumes of the reservoirs, and distances between the stream cross sections within the flood plain. In the above review items, the staff noted a warning message produced by the HEC-RAS model for additional stream cross sections between the CRN Site and the Melton Hill Dam. To resolve the warning message, the staff interpolated additional cross sections. Based on the results of the applicant's sensitivity study, the staff confirms that the addition of stream cross sections eliminates the warning message and has a minimal impact on the flood elevation at the CRN Site.

(SRI/CEII) The staff reviewed the applicant's various storm events as inputs to the applicant's HEC-RAS models. The staff notes that the applicant necessarily adjusted some hydraulic parameters and changed the inputs in the HEC-RAS model to satisfy the requirements of the hydraulic condition

changes. For example, discharge gates off and on, dam breach parameters, and dam failure timing needed to be changed to describe dam failure conditions in different storm events. The staff reviewed the flood profiles resulting from the (1) 7,980 mi^2 storm, (2) 21,400 mi^2 storm, (3) 3,382 mi^2 storm, (4) 2,912 mi^2 storm, and (5) 469 mi^2 storm. Based on a comparison of the applicant's simulation results, the staff confirms that the calculated PMF elevation is **[[**[redacted]**]]** ft NGVD29 (shown in SSAR Figure 2.4.3-3 [TVA 2017-TN5387]) at the CRN Site as a result of the 7,980 mi^2 storm.

(SRI/CEII) The staff reviewed the applicant's calculation package for the sensitivity study for which the applicant hypothetically set all spillway gates of **[[**[redacted]**]]** Dam to be inoperable and reduced the gate discharge rate of **[[**[redacted]**]]** Dam by 20 percent during the 7,980 mi^2 storm. The staff finds that applicant's dam failure timing and dam breach cross sections shown in the calculation package are reasonable. The staff confirms that the calculation is acceptable and the applicant's MSWFE is **[[**[redacted]**]]** ft above the calculated flood elevation of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88), which is the result of the inoperable spillway gates at **[[**[redacted]**]]** Dam and 20 percent discharge reduction at **[[**[redacted]**]]** Dam.

2.4.3.3.6 Water-Level Determinations

2.4.3.3.6.1 *Information Submitted by the Applicant*

(SRI/CEII) The applicant indicated that the calculated PMF elevation at the CRN Site is **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88). This elevation is below the applicant's MSWFE of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88). To define the MSWFE, the applicant has added **[[**[redacted]**]]** ft above **[[**[redacted]**]]** ft as the margin for future changes.

2.4.3.3.6.2 *Staff's Technical Evaluation*

(SRI/CEII) The staff evaluated the applicant's HEC-RAS model and the flood profiles generated from the applicant's HEC-RAS model. The staff finds that the applicant's MSWFE of **[[**[redacted]**]]** ft was well established above all calculated flood elevations. Additionally, the staff considers that the backwater effect due to the Tennessee Highway 58 Bridge, which is approximately 2 mi downstream from the CRN Site (TVA 2017-TN6159, TVA 2017-TN6155) as described in Section 2.4.3.3.4.3, and the assumption of inoperable discharge gates at **[[**[redacted]**]]** and **[[**[redacted]**]]** Dams as described in Section 2.4.3.3.5, are both bounded by the MSWFE for the CRN Site.

(SRI/CEII) Without including the wind-wave effect, the staff confirms that the **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) is the MSWFE, which provides a **[[**[redacted]**]]** ft margin above the calculated PMF elevation of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88).

2.4.3.3.7 Coincident Wind-Wave Activity

2.4.3.3.7.1 *Information Submitted by the Applicant*

The applicant provided the 2-year wind-generated wave height under the controlling PMF generated by the 7,980 mi^2 storm, in which the storm center was set at Bulls Gap and to occur in March. The summary of the applicant's coincident wind-wave information in this section is similar to FSER Section 2.4.4.3.8.1.

The applicant stated that because Melton Hill Dam would be overtopped during the controlling PMF event, the wind-generated waves at the dam site were not calculated. At the Norris Dam, the applicant computed the wave height and provided information to demonstrate sufficient margin exists to prevent overtopping of the structure.

2.4.3.3.7.2 _Staff's Technical Evaluation_

The staff's evaluation for the wind-generated wave height is described in Section 2.4.4.3.8. The staff reviewed the headwater level (1,056 ft NGVD29) plus the wind-wave height at Norris Dam. By comparing them with the embankment top elevation at 1,065 ft NGVD29, the staff confirmed that the 3-foot freeboard of Norris Dam and the embankment height are sufficient to prevent overtopping during the controlling PMF event.

2.4.3.4 *Conclusion*

The staff reviewed the ESPA and confirmed that the applicant has demonstrated that the PMF on streams and rivers has no safety-related impact on the CRN Site, and no outstanding information is required to be addressed in the SSAR related to this section. As set forth above, the applicant has presented and substantiated information to establish the site description. Further, the applicant has considered the most severe natural 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, in establishing site characteristics pertaining to the PMF on streams and rivers that are acceptable for design purposes. Therefore, the staff concludes that the applicant has met the relevant requirements of 10 CFR 52.17(a)(1) (TN251), 10 CFR 100.20 (TN282) and 10 CFR 100.23(d) (TN282) with respect to determining the acceptability of the site.

2.4.4 Potential Dam Failures

SSAR Section 2.4.4 addresses potential dam failures to ensure that any potential hazard to safety-related structures due to the failure of onsite, upstream, and downstream water control structures is considered in the plant design (TVA 2017-TN5387). As described in SSAR Section 2.4.1.1, the applicant stated that internal plant reservoirs will be used as part of closed cooling systems. Therefore, the potential for onsite flooding due to onsite cooling-water storage structures was not evaluated.

This section presents a review of the following areas related to dam failures: (1) flood waves resulting from severe dam breaching or failure, including those due to hydrologic failure, those routed to the site, and the resulting highest WSE that may result in the flooding of SSCs important to safety; (2) failures of dams in the path to the plant site caused by the failure of upstream dams due to earthquakes and the effect of the highest WSE at the site under the failure conditions; (3) dynamic effects of dam failure-induced flood waves on SSCs important to safety; (4) effects of sediment deposition or erosion during dam failure-induced flood waves that may result in the blockage or loss of function of SSCs important to safety; and (5) any additional information required by the regulations discussed in the Regulatory Basis section (Section 2.4.4.2).

2.4.4.1 *Summary of Application*

In SSAR Section 2.4.4, the applicant addressed the site-specific information for potential dam failures (TVA 2017-TN5387). Approximately 700 dams were counted above Wheeler Dam in the Tennessee River watershed. More specifically, within the areas upstream and downstream from the CRN Site, two major dams—Norris and Melton Hill Dams—regulate stream flow that passes around the site. The other upstream and downstream dams in the tributaries may have either backwater effects or may contribute minor flows to the site. Therefore, dam failures and cascading dam failures were considered in the applicant's analyses. No safety-related water storage structures would be constructed on the site. Therefore, the potential failure of onsite water control or storage facilities was not evaluated. There are no plans to construct dams and reservoirs that could adversely affect flood levels at the CRN Site. In summary, the areas for review in this FSER section include flood waves from hypothetical severe breaching of upstream dams, simultaneous dam failures due to storm events or seismic events, and effects of sediment deposition. Details of relevant flood hazards due to a potential dam failure are provided in the staff's technical evaluation below.

2.4.4.2 *Regulatory Basis*

The relevant requirements of NRC regulations for the identification of floods, flood design considerations, and potential dam failures, and the associated acceptance criteria, are specified in SRP Section 2.4.4, "Potential Dam Failures" (NRC 2007/2018-TN5898).

The applicable regulatory requirements for identifying the effects of dam failures are set forth in the following:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it sets forth the criteria for determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

The staff also used the appropriate sections of the following RGs for the acceptance criteria identified in SRP Section 2.4.4 (NRC 2007/2018-TN5898):

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;
- RG 1.59, "Design Basis Floods for Nuclear Power Plants" (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and
- RG 1.102, "Flood Protection for Nuclear Power Plants" (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.4.3 *Technical Evaluation*

The staff reviewed the information in SSAR Section 2.4.4 (TVA 2017-TN5387). The staff confirmed that the applicant addressed information related to the flood elevation and site characteristics associated with the most severe plausible dam failure event. The staff's technical review of SSAR Section 2.4.4 included an independent review of the applicant's information and technical computations (TVA 2017-TN6155, TVA 2016-TN6158) for the HEC-RAS model simulations. In Sections 2.4.4.3.1 through 2.4.4.3.6, below, the staff describes the technical evaluation in sequence by following the applicant's section titles provided in SSAR Section 2.4.4 (TVA 2017-TN5387).

2.4.4.3.1 Dam and Reservoir Description

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

(SRI/CEII) The applicant followed NRC guidance (JLD-ISG-2013-01, "Interim Staff Guidance for Assessment of Flooding Hazards Due to Dam Failure" [NRC 2013-TN5920]) and adopted the American National Standards Institute/American Nuclear Society (ANSI/ANS-2.8) 1992 Standards methods when screening single or multiple hypothetical dam failures that would potentially impact the plant site [ANSI/ANS 1992-TN6150]). According to the reservoir storage volumes and dam locations, the applicant first identified 11 dams upstream from Watts Bar Dam that might potentially cause a flood elevation at the site. The 11 dams are as follows: **[[**

1. [redacted]
2. [redacted]
3. [redacted]
4. [redacted]
5. [redacted]
6. [redacted]
7. [redacted]
8. [redacted]
9. [redacted]
10. [redacted]
11. [redacted]**]]**.

Among the 11 dams, **[[**[redacted]**]]** Dam is located **[[**[redacted]**]]** river miles upstream from the plant site, while **[[**[redacted]**]]** Dam is farther upstream and **[[**[redacted]**]]** river miles from **[[**[redacted]**]]** Dam. These two dams have direct impacts on the plant site. The other nine dams listed above are distributed either downstream or in watersheds adjacent to the plant site (Figure 2.4.1-4a,b of this report). The other dams (Nos. 3 through 11) do not have a direct impact on the plant site, but they contribute stream flows to the downstream Watts Bar Dam. The applicant stated that contributing flows from the 11 dams to the downstream Watts Bar Dam can produce a backwater effect on the CRN Site. The reservoir elevation-storage relationship for each of the 11 dams plus Watts Bar Dam is shown in Figure 2.4.4-1 (12 sheets) of the SSAR (TVA 2017-TN5387). More details about the development of the elevation-storage relationship are addressed in Section 2.4.3.3.4.3. The applicant provided the seasonal operational curve for each of the 12 dams (SSAR Figure 2.4.1-6 [TVA 2017-TN5387]) to illustrate that the reservoir levels are controlled and adjusted during flood or normal status in different months.

2.4.4.3.1.2 _Staff's Technical Evaluation_

(SRI/CEII) The staff determined that the applicant has followed the current NRC guidance ("Interim Staff Guidance for Assessment of Flooding Hazards Due to Dam Failure," [NRC 2013-TN5920]) and the recommended procedures (ANSI/ANS-2.8 1992 Standards) for evaluating the dams that may influence flood levels at the CRN Site. Based on review of the applicant's supporting information, including the calculation package provided during the NRC audit performed in April 2017, the staff notes that the applicant chose the HEC-RAS model (USACE 2016-TN5947) to further analyze breach outflow from the 11 dams. Based on the NRC staff's review of the applicant's calculation package TVA 2017-TN6155, TVA 2016-TN6158), including examination of the dam locations and the reservoir storage volumes of the 11 dams, the staff determined that the 11 dams are acceptable for dam breach outflow analysis. The staff noted that the applicant conservatively assumed the **[[**[redacted]**]]** Dam would not fail under any conditions in order to create the maximum backwater effect during the flood event at the CRN Site.

2.4.4.3.2 Dam Failure Permutations

2.4.4.3.2.1 _Information Submitted by the Applicant_

To calculate maximum water level, peak flow, and velocities at the CRN Site for any postulated dam failures, the applicant used the HEC-RAS model (USACE 2016-TN5947). The dam breach parameters of the postulated dam failure, including the timing of instantaneous dam failure, breach configuration, and breach size, were scripted in the unsteady flow rules embedded in the HEC-RAS model (USACE 2016-TN5947).

The applicant organized the 11 dams into three different failure modes: (1) hydrologic failure, (2) seismic failure, and (3) sunny-day failure. These dam failure modes are described in Sections 2.4.4.3.3 through 2.4.4.3.5, respectively.

(SRI/CEII) The SSAR includes discussion of the analyses of the stabilities of concrete dams and earthen embankments (TVA 2017-TN5387). When the stability of the concrete section or its embankment was outside of the acceptance criteria, the dam or the embankment was assumed to fail. The concrete dams were evaluated for overturning and for horizontal sliding resistances. The post-earthquake earth embankment stability was examined for potential soil-wedge sliding on the embankment slope without overtopping flows. The applicant stated that sediment deposition from the hypothetical dam failures of upstream **[[**[redacted]**]]** and **[[**[redacted]**]]** Dams would not reach plant grade at the CRN Site.

2.4.4.3.2.2 _Staff's Technical Evaluation_

The applicant postulated three dam failure modes for the flood hazard evaluation. The staff determined that the applicant followed the TVA's current dam stability criteria and adopted the USACE design standards to determine the dam and embankment stability. The staff noted that the applicant also used NRC guidance (NRC 2013-TN5920, NRC 1977-TN5913) and acceptable standards (ANSI/ANS 1992) to evaluate the dam failure modes that would create breach outflows resulting from either seismic or storm events. Based on the review of the applicant's HEC-RAS model, the staff confirms that the applicant's HEC-RAS model reflects the dam failure modes that were acceptably analyzed using standard methodology and procedures.

The staff concurred that the applicant evaluated overturning and sliding resistances to determine the stability of concrete dams and used the soil-wedge sliding method to justify the

stability of soil embankments. Because the applicant's evaluation and method are common and standard in the engineering practices, the staff concluded that the determination of dam stability is acceptable.

2.4.4.3.3 Seismic Dam Failure Analysis

2.4.4.3.3.1 *Information Submitted by the Applicant*

A seismic dam failure was defined by the applicant as a dam failure caused by a 10,000-year seismic event coincident with a 25-year flood, or a half-10,000-year seismic event coincident with a 500-year flood. For the seismic dam failure, the applicant considered two critical seismic events. One is a half-10,000-year Douglas-centered seismic event coincident with a 500-year flood. The other is a 10,000-year Fort Loudoun-centered seismic event in combination with a 25-year flood. The applicant adopted 1.1 as a lowest bounding factor of safety and used it to justify the post-earthquake embankment failure. For a safety factor of less than 1.1, the applicant provided further rationale indicating that the post-earthquake embankment will not fail when the embankment deformation is less than both 2 ft and the half filter zone thickness inside the earth embankment. The applicant also examined the dams for determination of an individual failure or a group of multiple failures due to two critical seismic events.

(SRI/CEII) The applicant found **[[**[redacted]**]]** Dam would fail due to either the half-10,000-year Douglas-centered seismic event coincident with a 500-year June flood, or the 10,000-year Fort Loudoun-centered seismic event coincident with a 25-year June flood. Under the same seismic events and the coincident floods, the applicant also found **[[**[redacted]**]]** Dam would not fail. Both dams are located upstream of the CRN Site. The other dams are outside the Clinch River watershed, but the applicant included them in the seismic dam failure analysis.

The applicant calculated inflows to dams at their upstream interest points for 500-year and 25-year floods that included base flows occurring in June, which are due to higher summer pool elevations. The applicant derived its own scaled hydrograph method to develop the hydrographs for 500-year and 25-year floods. The scaled hydrograph method used daily flow records between 1903 and 2013 to calculate 25-year or 500-year maximum accumulated flow volumes for each duration from 1 to 5 days. The applicant used these accumulated flow volumes as target volumes to adjust the surface runoff volumes generated by unit hydrograph method using 25-year and 500-year storms of the published National Weather Service Atlas 14 data (Bonnin et al. 2006-TN6029). After the volume adjustment, the 25-year and 500-year hydrographs were used as inflow hydrographs to the dams.

(SRI/CEII) For small dam failures, the applicant included the corresponding dams listed in the NID and calculated the peak outflows for these failed dams using the Froehlich method (Froehlich 1995-TN6104). These outflows were added to the coincident 500-year and 25-year floods. The applicant set the peak time at 20 minutes for each outflow hydrograph and routed these outflows to upstream interest points of the HEC-RAS model. These outflow hydrographs were added to the upstream interest points at the boundary of the HEC-RAS model as input data for simulating seismic dam failure flows in the watershed. The applicant showed that the half-10,000-year Douglas-centered seismic event coincident with the 500-year flood is a controlling event for the CRN Site. The simulated peak water elevation of the seismic dam failure scenario coincident with a 500-year flood event is **[[**[redacted]**]]** ft at the CRN Site.

2.4.4.3.3.2 _Staff's Technical Evaluation_

The staff noted that the applicant followed NRC guidance using the simplified volume method to identify 11 dam failures that were potentially critical to the plant site. The staff reviewed the applicant's procedures and methods for calculating the 500-year and 25-year floods. The staff noted the computational results of the 500-year and 25-year floods are acceptable because they are based on 110 years of stream flow data from 1903 to 2013. Furthermore, the staff finds that the applicant adopted the Froehlich method (Froehlich 1995-TN6104) to estimate the outflows of dam failures listed in the NID. The Froehlich method is commonly used and accepted in dam safety design and hydrological engineering practice (NRC 2013-TN5920). The staff examined the applicant's HEC-RAS model (TVA 2016-TN6158) for the seismic failures and confirmed that the computed flood elevation is reasonable for the plant site. Based on the reviews and examinations, the staff confirmed that the applicant's Douglas-centered seismic event coincident with a 500-year flood is reasonable as the controlling event for seismic failures of the dams.

(SRI/CEII) The staff confirmed that the applicant applied a widely used and standard method to calculate potential soil-wedge sliding for embankment stability. The staff concluded that the applicant's lowest factor of safety 1.1 for post-earthquake embankment stability is reasonable because the factor is larger than 1 and complies with the applicant's dam safety standards. The staff did not review the structural computations related to dam stability with respect to seismic events because the flood hazard resulting from the seismic failures of the dams is below the peak water elevation associated with the PMF flood event scenario. Based on examination of the applicant's hydraulic calculations (TVA 2016-TN6158), the staff confirmed that the maximum flood elevation, after considering multiple seismic dam failure scenarios at the CRN Site, is elevation **[[**[redacted]**]]** ft NGVD29.

2.4.4.3.4 Hydrologic Failure Analysis

2.4.4.3.4.1 _Information Submitted by the Applicant_

(SRI/CEII) Hydrologic failure occurs when a dam cannot sustain the external loads during a flood event produced by rainfall, snowmelt, or a combination thereof. The most common failure modes associated with hydrologic dam failure include overtopping, structure overstressing, and embankment surface erosion due to high velocity flow or wave action. For concrete sections of dams, including spillways and lock gates, the applicant evaluated structural stability with respect to critical headwater elevation levels and tailwater conditions. The applicant investigated the 11 dams listed in FSER Section 2.4.4.3 and found that the 7 dams listed below would fail: **[[**

1. [redacted]
2. [redacted]
3. [redacted]
4. [redacted]
5. [redacted]
6. [redacted]
7. [redacted]**]]**.

(SRI/CEII) Although the **[[**[redacted]**]]** Dam would likely fail, the applicant assumed it would never fail during the flood event simulation to maximize the backwater flood elevation at the CRN Site. After including the seven dams listed above, the applicant added nine other dams to the list of assumed dam failures. The following dams and their embankments were assumed to totally and instantaneously fail during the PMF event: **[[**

1. [redacted]
2.
3.
4.
5.
6.
7.
8.
9.]].

(SRI/CEII) Of the earth embankments adjoining any of the 11 potentially failing dams listed in FSER Section 2.4.4.3, the applicant considered that an overtopping flow over the embankment and the flow erosion on the embankment slope could reduce the embankment stability. The applicant evaluated the following earth embankments of the dams for a PMF event and determined that the following embankments would fail: **[[**

1. [redacted]
2.
3.
4.
5.
6.
7.

]].

The applicant applied the Von Thun and Gillette method (Von Thun and Gillette 1990-TN6127) for calculating breach parameters at embankments smaller than the cross section of the channel (**[[**[redacted]**]]** Dam embankment failure for No. 7 above). Although the **[[**[redacted]**]]** Dam would likely fail, the applicant assumed its embankment would not fail to maximize flood elevation at the CRN Site. Finally, the applicant allowed the maximum (total) breach cross section to coincide with the downstream channel cross-section width for embankment failures Nos. 1 through 6.

(SRI/CEII) Including the above hydrologic failures of seven concrete dams, nine unevaluated dams, and seven embankments of dams, the applicant applied the HEC-RAS model (USACE 2016-TN5947) to compute the PMF elevation at the CRN Site. The computed peak elevation during the PMF and dam failure event is **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) without addition of coincident wind waves (see FSER Section 2.4.4.3.8). The controlling rainfall event used to generate the PMF (see FSER Section 2.4.3.3.5) is the 7,980 mi^2 March PMP with the storm centered at Bulls Gap.

2.4.4.3.4.2 *Staff's Technical Evaluation*

The staff noted that the applicant maximized the potential effects of dam failure on the plant site by synchronizing the critical failure timing with the peak headwater level, and conservatively assuming the instantaneous failure of dams or embankments. The staff reviewed the applicant's calculation packages (TVA 2016-TN6156) of the flood-routing model HEC-RAS for the hydrologic failures and examined the computational procedures and results. Based on reviewing the HEC-RAS model shown in the calculation package, the staff accepted the computed flood elevation as the result of PMF simulation that included coincident hydrologic dam failures.

(SRI/CEII) The staff confirmed that the HEC-RAS simulation assumed failure of the seven concrete dams, nine unevaluated dams, and seven embankment dams listed above. Among those dam failures, the staff tested the sensitivity response of the HEC-RAS model by arbitrarily changing dam failure or non-failure conditions. The staff selected **[[**[redacted]**]]** for the test because they detain and control large flood volumes. Based on the testing results, the staff determined that during the PMP event when setting **[[**[redacted]**]]** embankment dams either to fail or not fail, the flood elevation increases from the **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) at the CRN Site are within **[[**[redacted]**]]** ft. The **[[**[redacted]**]]** ft tolerance is acceptable when compared to the **[[**[redacted]**]]** ft margin that is between the PMF elevation of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) and the proposed grade elevation 821.4 ft NGVD29 (821.0 ft NAVD88) at the CRN Site.

(SRI/CEII) Further, the staff tested the sensitivity of the HEC-RAS model results and assumed a failure of the upstream **[[**[redacted]**]]**. Similar to the applicant's assumption, the staff's sensitivity test assumed the **[[**[redacted]**]]** would not fail in order to maximize the backwater effect at the CRN Site. The staff's sensitivity test results in a **[[**[redacted]**]]** increase above the applicant's peak elevation of **[[**[redacted]**]]**, which is well below the CRN grade elevation of 821.4 ft NGVD29 (821.0 ft NAVD88).

The staff confirmed that the applicant acceptably used the Von Thun method to determine the breach parameters because the applicant scripted Von Thun's breach equations in the HEC-RAS model. The staff confirms that Von Thun's calculation procedures (Von Thun and Gillette 1990-TN6127) are acceptable (NRC 2013-TN5920).

2.4.4.3.5 Failure by Other Methods

2.4.4.3.5.1 *Information Submitted by the Applicant*

(SRI/CEII) Dam failures not associated with a concurrent extreme flood or seismic event may arise from a variety of causes. A sunny-day failure is a hypothetical failure mode resulting from the breach of the postulated weakest portion of a specific dam during sunny-day (or fair-weather) conditions. Dams in a hypothetical sunny-day failure mode are classified by the applicant as dam failures by other methods. The applicant found that the most likely sunny-day failure of **[[**[redacted]**]]** Dam would be the **[[**[redacted]**]]** of the dam. The failure has the potential to affect the plant site, and could result in a subsequent overtopping failure of **[[**[redacted]**]]** Dam. These sequential failures of the **[[**[redacted]**]]** and **[[**[redacted]**]]** Dams in sunny-day conditions would produce a flood elevation of **[[**[redacted]**]]** at the plant site.

2.4.4.3.5.2 *Staff's Technical Evaluation*

(SRI/CEII) The staff reviewed the applicant's HEC-RAS model (TVA 2016-TN6158) for the sunny-day failure. The staff examined the initial reservoir level in the model, the **[[**[redacted]**]]** Dam rating curve for the **[[**[redacted]**]]** failure, and the unsteady flow rules embedded in the model. From the HEC-RAS modeling results, the staff notes that the computed flood elevation at the plant site is **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88). Based on the initial reservoir level, dam rating curve, and unsteady flow rules, the staff confirms the computed flood elevation of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) is reasonable and acceptable.

2.4.4.3.6 Unsteady Flow of Potential Dam Failures

2.4.4.3.6.1 *Information Submitted by the Applicant*

To simulate the floods due to the postulated dam failure in three different modes (seismic, hydrologic, and sunny day), the applicant provided the HEC-RAS models (TVA 2016-TN6156 for hydrological failure and TVA 2016-TN6158 for seismic and sunny-day failures) for NRC review. To create a HEC-RAS model for dam failure simulations, the applicant modified the input parameters in the HEC-RAS model that was used for the stream flood simulation (see Section 2.4.3.4 of the SSAR [TVA 2017-TN5387]). The following input parameters were necessarily modified for various dam failure modes: (1) initial reservoir level, (2) reservoir inflows, (3) breach flows with breach configuration, and (4) the scripted instantaneous dam failure at specific timings. The breach configuration and dam failure timing were scripted in the unsteady flow rules that were embedded in the HEC-RAS model. For any earth embankment failure, the Von Thun and Gillette method (Von Thun and Gillette 1990-TN6127) was scripted in the unsteady flow rules.

2.4.4.3.6.2 *Staff's Technical Evaluation*

The staff reviewed the input parameters used to modify the numerical simulations among the three dam failure modes scripted in the HEC-RAS model. The staff determined that the input parameters and data used for the dam failures are acceptable and reasonable because the inputs reflect both of the operation rules prior to dam failure and the Von Thun formula (Von Thun and Gillette 1990-TN6127) after the dam breach. The staff confirmed that the applicant's dam failure modeling is acceptable because the applicant added the dam failure modeling as components to the original HEC-RAS model that was calibrated using historical flood records.

2.4.4.3.7 Water Level

2.4.4.3.7.1 *Information Submitted by the Applicant*

The flood elevations at the CRN Site resulting from the three dam failure modes computed by the HEC-RAS models (TVA 2016-TN6156 for hydrological failure and TVA 2016-TN6158 for seismic and sunny-day failures) are summarized in Table 2.4.4-1 below.

(SRI/CEII) **Table 2.4.4-1 Summary of Flood Elevations at the CRN Site (CRM 17.9)**

Dam Failure Modes	CRN Site Maximum Stillwater Elevation (Clinch River Mile 17.9)	Comments
Hydrologic Failure	**[[**[redacted]**]]** ft NGVD29[(a)]	The 7,980 mi^2, Bull Gap centered, PMF March event plus multiple dam failures **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) is the SSAR Table 2.0-1 maximum stillwater flood elevation (MSWFE) for the CRN Site including a safety margin **[[**[redacted]**]]** ft above the hydrologic failure stillwater elevation.

(SRI/CEII)

Dam Failure Modes	CRN Site Maximum Stillwater Elevation (Clinch River Mile 17.9)	Comments
Seismic Failure	**[[**[redacted]**]]** NGVD29 (**[[**[redacted]**]]** ft NAVD88)	Douglas Center seismic event coincident with a 500-year flood event
Sunny-Day Failure	**[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88)	**[[**[redacted]**]]** of **[[**[redacted]**]]** Dam and the whole **[[**[redacted]**]]** Dam fails upstream from CRN

(a) SSAR Section 2.4.3.6 (TVA 2017-TN5387).

2.4.4.3.7.2 _Staff's Technical Evaluation_

The staff reviewed and examined the applicant's HEC-RAS models. Based on the staff's examination of the model, the staff confirms that the model acceptably generated the flood profiles of the different dam failure modes. The staff also determined that the applicant-calculated flood elevations resulting from the three dam failure modes are reasonable.

2.4.4.3.8 Coincident Wind Wave

2.4.4.3.8.1 _Information Submitted by the Applicant_

(SRI/CEII) The applicant followed the computational procedures of the USACE Coastal Engineering Manual (USACE 2002-TN6031) to compute the water wave height induced by the wind. The applicant addressed the wind-generated wave effect on the maximum stillwater elevation, which is associated with the PMF event (see SSAR Section 2.4.3.6 [TVA 2017-TN5387]). The wind-generated waves associated with the PMF event were treated as one of the associated effects of the flood hazard for the plant site. The applicant analyzed available wind data from 2000 to 2014 from the neighboring meteorological stations at Huntsville in Alabama, Asheville, North Carolina, as well as Chattanooga, Knoxville, and the Tri-Cities in Tennessee. Based on the recorded wind data, the applicant developed the statistic wind speed with the average period of a 2-year occurrence for the plant site. The applicant's computational results show that the 2-year wind speed over a water surface is 33 mph, and that the critical fetch distance of the wind over water surface is 4.25 mi, measured along a prevailing direction from the plant site to the PMF inundation boundary. The applicant used the computed wind speed associated with the wind duration and the fetch distance to determine that the wind-wave height would be **[[**[redacted]**]]** ft at the plant site. Linearly adding the wind-wave height to the PMF's MSWFE results in a total flood elevation at the plant site that is **[[**[redacted]**]]** ft above NGVD29. This maximum flood elevation **[[**[redacted]**]]** ft NGVD29) is well below the site grade elevation of 821.4 ft NGVD29 (821.0 ft NAVD88). Therefore, the applicant stated that the maximum flood event, including coincident wind-generated waves, would not inundate the plant site.

2.4.4.3.8.2 _Staff's Technical Evaluation_

The staff reviewed the applicant's computational procedures for the wind-generated wave height, including wave runup and wind setup, and examined the intermediate results of the calculations. The staff finds that the wind-wave computations are complete and acceptable because the applicant followed NRC guidance (NRC 2012-TN5948) and NRC-recommended methodologies (Prasad et al. 2011-TN2031), and followed the USACE design manual (USACE 2002-TN6031). The staff examined the fetch distance in the prevailing wind direction shown in

(SRI/CEII) the SSAR Figure 2.4.3-16 (TVA 2017-TN5387). Based on the staff's examination of the inundation area and the prevailing wind direction, the staff confirms that the applicant's fetch distance of 4.25 mi is reasonable. Based on a review of the applicant's analysis, the staff notes that the applicant's computed maximum elevation of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) at the plant site results from the MSWFE of **[[**[redacted]**]]** ft plus the coincident wind-wave height of **[[**[redacted]**]]** ft. The staff notes that this flood elevation is well below the site grade elevation of 821.4 ft NGVD29 (821.0 ft NAVD88). Therefore, the staff concludes that the plant would not be inundated by the dam failure flood event including coincident wind-wave effects.

2.4.4.3.9 Erosion and Deposition Effects

2.4.4.3.9.1 *Information Submitted by the Applicant*

(SRI/CEII) The applicant assumed the erodible material would be transported by breach outflows from all the earthen embankments and saddle dams above the Watts Bar Dam. The erodible volume was calculated to be 200,000,000 yd^3 or approximately 124,000 ac-ft. Assuming that the erodible material would completely deposit in the downstream Watts Bar Reservoir reducing the existing reservoir volume, the applicant computed the increase in reservoir level to be less than **[[**[redacted]**]]** ft. This increased level of **[[**[redacted]**]]** ft is far below the CRN Site site grade elevation by **[[**[redacted]**]]** ft. Based on the computed reservoir volume reduction and the reservoir-level increase, the applicant showed the insignificant effect of the erodible material with respect to flood events on the CRN Site.

2.4.4.3.9.2 *Staff's Technical Evaluation*

(SRI/CEII) The staff noted that the CRN Site is above the normal reservoir water-surface level by approximately 80 ft, and above the MSWFE **[[**[redacted]**]]** ft NGVD29) by **[[**[redacted]**]]** ft. Based on the applicant's **[[**[redacted]**]]** increase in the reservoir level, the staff notes that the erodible material would have an insignificant impact on the flood elevation at the CRN Site.

Because the reactor technology PPE proposed by the applicant for the CRN Site would not rely on the Clinch River as a safety-related water source, the staff confirms that the erosion and deposition would have no effect on safety-related conditions at the CRN Site.

2.4.4.4 *Conclusion*

The staff reviewed the ESPA and confirmed that the applicant demonstrated that floods due to dam failures would have no adverse impacts on the CRN Site, and no outstanding information is required to be addressed in the SSAR related to this section. As set forth above, the applicant has provided sufficient information pertaining to potential dam failures. Further, the applicant has considered the most severe natural 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, in establishing site characteristics pertaining to potential dam failures that are acceptable for design purposes. Therefore, the staff concludes that the applicant has met the requirements 10 CFR 52.17(a) (TN251), 10 CFR 100.20 (TN282), and 10 CFR 100.23(d) (TN282) related to dam failures.

2.4.5 Probable Maximum Surge and Seiche Flooding

This section addresses the probable maximum surge and seiche flooding to ensure that any potential hazard to the safety-related SSCs at the proposed site were appropriately considered in compliance with NRC regulations.

This section presents the evaluation of the following topics based on data provided by the applicant in the SSAR (TVA 2017-TN5387) and information available from other sources: (1) the probable maximum hurricane (PMH) that causes the probable maximum surge as it approaches the site along a critical path at an optimum rate of movement, (2) probable maximum wind storm (PMWS) from a hypothetical extratropical cyclone or a moving squall line that approaches the site along a critical path at an optimum rate of movement, (3) a seiche near the site and the potential for seiche wave oscillations at the natural periodicity of a water body that may affect the elevations of the floodwater surface near the site or cause a low WSE affecting safety-related water supplies, (4) wind-induced wave runup under PMH or PMWS winds, (5) effects of sediment erosion and deposition during a storm surge and seiche-induced waves that may result in blockage or loss of function of SSCs important to safety, (6) the potential effects of seismic and non-seismic information about the postulated design bases and how they relate to a surge and seiche in the vicinity of the site and the site region, and (7) any additional information required by the regulations discussed below in the Regulatory Basis section.

2.4.5.1 *Summary of Application*

In SSAR Section 2.4.5, the applicant addressed information related to probable maximum surge and seiche flooding in terms of impacts on structures and water supply.

2.4.5.2 *Regulatory Basis*

The relevant requirements of NRC regulations about the effects of a probable maximum storm surge, and the associated acceptance criteria, are specified in SRP Section 2.4.5, “Probable Maximum Surge and Seiche Flooding” (NRC 2007/2018-TN5898).

The applicable regulatory requirements for identifying surge and seiche hazards, design considerations, and the associated acceptance criteria, are set forth in the following:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it sets forth the criteria for determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

The staff also used appropriate sections of the following RGs for the acceptance criteria identified in SRP Section 2.4.5 (NRC 2007/2018-TN5898):

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;
- RG 1.59, "Design Basis Floods for Nuclear Power Plants" (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and
- RG 1.102, "Flood Protection for Nuclear Power Plants" (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.5.3 *Technical Evaluation*

The staff reviewed the information in SSAR Section 2.4.5 (TVA 2017-TN5387). The staff's review confirmed that the information in the ESPA addresses the probable maximum surge and seiche flooding. The staff's technical review of this section includes an independent review of the applicant's information in the SSAR.

This section describes the staff's evaluation of the technical information presented in SSAR Section 2.4.5 (TVA 2017-TN5387).

2.4.5.3.1 Information Submitted by the Applicant

SSAR Section 2.4.5 states that storm surge is not a plausible flood hazard mechanism for the CRN Site because the site, located on the Clinch River tributary of Watts Bar Reservoir, is approximately 1,580 river miles from the Gulf of Mexico (TVA 2017-TN5387). The SSAR also notes the proposed CRN Site site grade elevation is approximately 80 ft above the normal pool elevation (741 ft NGVD29) of the Clinch River tributary of Watts Bar Reservoir, implying that any possible surge would be well below the site.

As for a seismic seiche recorded in the Tennessee River valley area, the SSAR stated that the seiche amplitude is very small (TVA 2017-TN5387). Based on the analyses by the USGS after the March 27, 1964 earthquake in Alaska, the SSAR reported that the maximum seiche on reservoirs was 0.6 ft at gauges in Kentucky and a maximum of 0.1 ft at gauges in Tennessee (TVA 2017-TN5387). Consequently, the applicant concluded that the size of an earthquake-generated seiche would be small. The SSAR states that the CRN Site is within an Eastern Tennessee Seismic Zone (USGS 2014-TN6177), but that no significant seiches due to earthquake activity in the Tennessee River valley have been recorded. The SSAR also states that there is no evidence of landslide-induced seiches and that the slopes around the CRN Site are stable (TVA 2017-TN5387).

The SSAR also examines possible wind-generated seiches and states that there is no flood hazard from this mechanism due to the limited fetch (4.25 mi) and a large elevation difference of 79 ft between the normal pool and CRN Site site grade elevation (TVA 2017-TN5387).

2.4.5.3.2 Staff's Technical Evaluation

The staff examined the surge and seiche information provided in SSAR Section 2.4.5 (TVA 2017-TN5387). Consequently, the staff finds that the applicant provided sufficient and acceptable evidence in the SSAR to support the insignificant impact of surges or seiches on the CRN Site. As the staff noted in FSER Section 2.4.1.3.1.2, the CRN Site is approximately 80 ft above the normal pool elevation of the Clinch River tributary of Watts Bar Reservoir. Therefore, based on the staff's examinations, and the approximately 80 ft of marginal difference between the site grade elevation and the normal reservoir level, the staff concurs with the applicant's assessment that storm surge and seiche motion in the lakes, reservoirs, and ponds in the Tennessee River watershed should produce minimal water-level changes and are not plausible flood hazard mechanisms for the CRN Site.

2.4.5.4 *Conclusion*

The staff concludes that the applicant's identification and consideration of the surge and seiche hazards set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.20(c) (TN282), and 10 CFR 100.23(d) (TN282). The staff also confirms that storm surge and seiche motion in the Clinch River tributary of Watts Bar Reservoir are not a plausible external flooding hazard mechanism at the CRN Site.

2.4.6 Probable Maximum Tsunami Hazards

This section addresses the hydrological design basis developed to ensure that any potential tsunami hazards to the SSCs important to safety are considered in the plant design.

This section presents the staff's review of the flood levels caused by postulated tsunami wave-forming scenarios. The specific areas of the review include the description of the probable maximum tsunami (PMT), historical tsunami records, source generator characteristics, tsunami analyses, tsunami water levels, hydrograph and harbor or breakwater influences of a tsunami-like wave, and its effects on safety-related facilities.

2.4.6.1 *Summary of Application*

In SSAR Section 2.4.6, the applicant provided site-specific information about potential tsunami effects on the CRN Site (TVA 2017-TN5387).

2.4.6.2 *Regulatory Basis*

The relevant requirements of NRC regulations for the consideration of PMT hazards, design considerations, and the associated acceptance criteria, are specified in SRP Section 2.4.6, "Probable Maximum Tsunami Hazards" (NRC 2007/2018-TN5898).

The applicable regulatory requirements for identifying PMT hazards are as follows:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it sets forth the criteria for determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

The related acceptance criteria are as follows:

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;
- RG 1.59, "Design Basis Floods for Nuclear Power Plants" (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and
- RG 1.102, "Flood Protection for Nuclear Power Plants" (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.6.3 *Technical Evaluation*

The staff reviewed the information in SSAR Section 2.4.6 (TVA 2017-TN5387), and confirmed that the information in the ESPA addresses the relevant information related to the PMT. The staff's technical review of this section included an independent review of the applicant's information in the SSAR. This section describes the staff's evaluation of the technical information in SSAR Section 2.4.6 (TVA 2017-TN5387).

2.4.6.3.1 Information Submitted by the Applicant

As stated in the SSAR, the CRN Site lies more than 300 mi from the nearest seacoast (TVA 2017-TN5387).

As discussed in SSAR Section 2.5.3, there is no evidence of Quaternary tectonic deformation near the site and the potential for tectonic fault rupture is minimal (TVA 2017-TN5387). Consequently, there is little likelihood of triggering a tsunami from vertical ground motion in the Watts Bar Reservoir adjacent to the CRN Site. Also, there is evidence of one small and shallow landslide found within the site location. A tsunami hazard was also considered at Norris and Melton Hill Dams and is considered bounded by possible dam failures considered in SSAR Section 2.4.4 (TVA 2017-TN5387). Because the CRN Site site grade elevation is approximately 80 ft above the normal pool elevation of the Watts Bar Reservoir near the site, the site inundation potential from a landslide-induced tsunami is negligible.

2.4.6.3.2 Staff's Technical Evaluation

The staff reviewed the hydrologic and geological information provided in the SSAR (TVA 2017-TN5387). The staff also examined USGS topographic maps (USGS 2017-TN6175) in the vicinity of the CRN Site and noted steep bluffs on the opposite side of the Clinch River tributary of Watts Bar Reservoir. However, no very large slides or slumps are apparent in these topographic data. The staff concurs with the assessment in the SSAR that the flood hazard from tsunamis is negligible.

2.4.6.4 *Conclusion*

The staff concludes that the tsunami hazard is negligible at the proposed CRN Site. Therefore, the staff finds that the identification and consideration of the tsunami hazards set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.20(c) (TN282), and 10 CFR 100.23(d) (TN282).

2.4.7 Ice Effects

SSAR Section 2.4.7 addresses ice effects to ensure that safety-related facilities and water supply are not affected by ice-induced hazards (TVA 2017-TN5387).

The specific areas of review are as follows: (1) regional history and types of historical ice accumulations (e.g., ice jams, wind-driven ice ridges, floes, frazil ice formation); (2) potential effects of ice-induced, high- or low-flow levels on safety-related facilities and water supplies; (3) potential effects of a surface ice sheet to reduce the volume of available liquid water in safety-related water reservoirs; (4) potential effects of ice to produce forces on, or cause blockage of, safety-related facilities; (5) potential effects of seismic and non-seismic data on the postulated worst-case icing scenario for the proposed plant site; and (6) any additional information required by the regulations discussed below in the Regulatory Basis section (Section 2.4.7.2).

2.4.7.1 *Summary of Application*

In SSAR Section 2.4.7, the applicant evaluated potential ice effects at the proposed plant location, including the review of ice formations or ice jams; modeling of combined events to ensure protection of the safety-related facilities from ice-affected floods; and mitigation to protect safety-related structures from ice. Analysis of ice effects at the proposed plant included review of historic winter conditions and the simulation of flooding due to an upstream ice jam break.

2.4.7.2 *Regulatory Basis*

The relevant requirements of the NRC regulations for identifying ice effects and the associated acceptance criteria are in SRP Section 2.4.7, “Ice Effects” (NRC 2007/2018-TN5898).

The applicable regulatory requirements for identifying ice effects are set forth in the following:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c) (TN282).

The staff also used the appropriate sections of the following RGs for the acceptance criteria identified in SRP Section 2.4.7 (NRC 2007/2018-TN5898):

- RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants” (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;

- RG 1.59, “Design Basis Floods for Nuclear Power Plants” (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and
- RG 1.102, “Flood Protection for Nuclear Power Plants” (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.7.3 *Technical Evaluation*

The staff reviewed the information in SSAR Section 2.4.7 (TVA 2017-TN5387), and confirmed that the information in the ESPA addresses the relevant information related to the site ice effects.

Sections 2.4.7.3.1 through 2.4.7.3.6 below provide the staff’s evaluation of the technical information presented in SSAR Section 2.4.7 (TVA 2017-TN5387).

2.4.7.3.1 Historical Ice Accumulation

2.4.7.3.1.1 *Information Submitted by the Applicant*

The applicant examined the temperature records from 1871 to the present (NOAA 2014-TN6178) to determine the minimum temperature in the region. The lowest air temperature of -24° Fahrenheit (F) occurred in January 1985. The SSAR indicates that the lowest recorded water temperature in the Watts Bar Reservoir for the periods of 1942 to 1953 and 1967 to 1973 was 39 F in January 1970 (TVA 2017-TN5387).

As reported in the SSAR, the USACE Ice Jam Database (1780 through February 7, 2014) had one ice jam event on the Clinch River in 1940 near Clinton, located 15 mi upstream of the CRN Site (TVA 2017-TN5387). The ice obstruction was in place from January 22 through February 6, 1940. According to the SSAR, 5 in. thick ice was the record in Chattanooga, Tennessee, apparently during this same period (TVA 2017-TN5387). Also, according to the SSAR, since the first historical record of freezing conditions in 1796, the Tennessee River has frozen more than 16 times and had floating ice 6 other times. The most severe event was in January 1918; it featured an ice jam height of 10 ft in some places (TVA 2017-TN5387).

Based on the historical data, the applicant maintains that the flood hazard from ice jams is not credible.

2.4.7.3.1.2 *Staff’s Technical Evaluation*

The staff reviewed historical temperature records and determined the applicant’s characterization to be reasonable and acceptable for representation of potential surface and frazil ice formation. Although ice jam flooding has occurred upstream of the CRN Site, the staff reviewed the Cold Region Research and Engineering Laboratory Ice Jam Database (USACE 1999-TN6179), and concurs with the applicant’s assessment that an ice-induced flood hazard is not physically credible because of the 80 ft difference in normal pool elevations and the site grade, as previously noted in Section 2.4.1.3.1. The staff determined that the applicant’s review and characterization of the historical record are acceptable.

2.4.7.3.2 High and Low Water Levels

2.4.7.3.2.1 *Information Submitted by the Applicant*

Although the site grade plans have not been developed, the SSAR considers the possibility of blockage of the drainage system due to freezing conditions (TVA 2017-TN5387). However, the SSAR notes that the drainage system (culverts, catch basins, and storm drains) are all assumed to be blocked and that because the proposed site grade elevation is above the natural grade, there is a sufficient hydraulic gradient for site drainage (TVA 2017-TN5387).

(SRI/CEII) The SSAR includes a brief analysis of a hypothetical ice dam just upstream of the CRN Site (TVA 2017-TN5387). A maximum elevation of 771 ft NGVD29 (770.6 ft NAVD88) is assumed, which is the maximum design elevation of the **[[**[redacted]**]]** Dam tailwater and the maximum known flood elevation (from March 1886). The storage created by such a hypothetical ice dam is bounded by storage behind **[[**[redacted]**]]** Dam as well as by storage behind **[[**[redacted]**]]** Dam. Accordingly, the effect of a breach of such a hypothetical ice dam would be bounded by failure of Norris Dam.

Consideration of a hypothetical ice dam downstream of the CRN Site was also included in the SSAR (TVA 2017-TN5387). The SSAR assumes a hypothetical ice dam forms at Watts Bar Dam and builds up to the top of earthen embankments at approximately 772 ft NGVD29. This would produce a water level at the CRN Site that is approximately 30 ft higher than the summer normal pool water level. With the site grade at 821 ft NGVD29 (821.0 ft NAVD88), there is more than 40 ft of freeboard available before inundating the site. Consequently, the flood hazard from a downstream ice dam is negligible.

Section 2.4.7.2 of the SSAR stated that low water considerations do not apply to the CRN Site because the reactor technology PPE does not rely on an external water source for safety-related and risk-significant water supply (TVA 2017-TN5387).

2.4.7.3.2.2 *Staff's Technical Evaluation*

(SRI/CEII) The staff examined the hypothetical cases of upstream and downstream ice dams and the flood hazard they could produce. The staff finds the SSAR assessment, which was based on comparing the water volumes retained by a hypothetical ice dam upstream of the CRN Site, to be appropriate. For the upstream ice dam case, an ice dam failure would be bounded by **[[**[redacted]**]]** Dam upstream sunny-day failures because the retention volume behind the ice dam would be significantly less than the volume of the **[[**[redacted]**]]** Dam. For a downstream ice dam, the elevation of the CRN Site site grade above the Clinch River precludes inundation.

Based on the staff's review of the topography of the site location, the staff's review of the Cold Region Research and Engineering Laboratory Ice Jam Database (USACE 1999-TN6179), and the applicant's reasonable application of conservative ice jam analyses, the staff concludes that ice jams would have no high water safety-related impacts on the water-supply intake or the water supply for the CRN Site. Based on the reactor technology PPE not relying on an external water source for safety-related and risk-significant water supply to the CRN Site, the staff concludes that ice jams would also have no low water safety-related impacts. The staff finds the applicant's analysis acceptable.

2.4.7.3.3 Ice Sheet Formation

2.4.7.3.3.1 *Information Submitted by the Applicant*

The SSAR states that the reactor technology PPE considered for the CRN Site does not require that external water supply be provided to SSCs important to safety or open storage of water supply for safety-related uses (TVA 2017-TN5387). Hence, ice sheet formation would not affect SSCs important to safety.

The SSAR stated the maximum ice sheet thickness at the CRN Site is approximately 11 in. as calculated from data according to the peak accumulated freezing degree-days (TVA 2017-TN5387).

2.4.7.3.3.2 *Staff's Technical Evaluation*

Because the SSAR states that the proposed reactor technology PPE does not require safety-related cooling water from the Clinch River (TVA 2017-TN5387), the staff concludes that any ice sheet formation on the Clinch River would not affect site safety. The staff finds the computed ice sheet thickness acceptable, because the computations were based on 65 years of meteorological data. The staff reviewed the applicant's use of the USACE (2004-TN6180) methods for computing the ice thickness based on the meteorological data and found the applicant's use of the methodology acceptable.

2.4.7.3.4 Potential Ice-Induced Forces and Blockages

2.4.7.3.4.1 *Information Submitted by the Applicant*

The SSAR states that the CRN Site does not have SSCs important to safety that could be affected by ice-induced forces or blockages (TVA 2017-TN5387).

2.4.7.3.4.2 *Staff's Technical Evaluation*

Because the reactor technology PPE considered for the CRN Site does not rely on an external safety-related water supply, the staff concludes that ice sheet formation would have no safety-related impact.

2.4.7.3.5 Consideration of Other Site-Related Evaluation Criteria

2.4.7.3.5.1 *Information Submitted by the Applicant*

The SSAR states that there is no additional information to indicate that other icing scenarios would occur that are more severe than the scenarios already examined above (TVA 2017-TN5387).

2.4.7.3.5.2 *Staff's Technical Evaluation*

The staff finds the SSAR assessment (TVA 2017-TN5387) acceptable based on the applicant's description of the proposed site climatology and meteorological assessment.

2.4.7.3.6 Consideration of Cold-Region Hydrology

2.4.7.3.6.1 *Information Submitted by the Applicant*

As noted in the SSAR, the CRN Site is not subject to cold-region conditions, such as permafrost (TVA 2017-TN5387). The precipitation events, including rain-on-snow or snowmelt, for local site drainage from LIP and site inundation from flooding of streams and river are discussed in SSAR Sections 2.4.2 and 2.4.3, respectively (TVA 2017-TN5387).

2.4.7.3.6.2 *Staff's Technical Evaluation*

The staff finds the SSAR assessment (TVA 2017-TN5387) acceptable based on the applicant's description of the proposed site climatology and meteorological assessment.

2.4.7.4 *Conclusion*

The staff reviewed the ESPA and confirmed that the applicant has demonstrated that the ice effects have no safety-related impact on the CRN Site, and no outstanding information is required to be addressed in the SSAR related to this section. As set forth above, the applicant has provided sufficient information pertaining to ice effects. Therefore, the staff concludes that the applicant has met the requirements concerning ice effects with respect to 10 CFR 52.17(a)(1)(vi) (TN251) and 10 CFR 100.20(c) (TN282). Further, the applicant has considered the most severe natural 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, in establishing site characteristics pertaining to ice effects that are acceptable for design purposes.

2.4.8 Cooling-Water Canals and Reservoirs

The cooling-water canals and reservoirs used to transport and impound water supplied to the SSCs important to safety are reviewed to verify their hydraulic design basis. The specific areas of review are as follows: (1) design bases postulated and used by the applicant to protect structures such as riprap, inasmuch as they apply to safety-related water supply; (2) design bases of canals pertaining to capacity, protection against wind waves, erosion, sedimentation, and freeboard and the ability to withstand a PMF (surges, etc.), inasmuch as they apply to a safety-related water supply; (3) design bases of reservoirs pertaining to capacity, PMF design basis, wind-wave and runup protection, discharge facilities (e.g., low-level outlet, spillways), outlet protection, freeboard, and erosion and sedimentation processes inasmuch as they apply to a safety-related water supply; and (4) potential effects of seismic and non-seismic information about the postulated hydraulic design bases of canals and reservoirs for the proposed plant site.

2.4.8.1 *Summary of Application*

In SSAR Section 2.4.8 (TVA 2016-TN5018), the applicant addresses the cooling-water canals and reservoirs used to transport and impound water supplied to the safety-related SSCs. This section of the report presents an evaluation of the design basis for the capacity and operating plan for safety-related cooling-water canals and reservoirs.

2.4.8.2 *Regulatory Basis*

The relevant requirements of NRC regulations for the cooling-water canals and reservoirs, and the associated acceptance criteria, are specified in SRP Section 2.4.8, "Cooling Water Canals and Reservoirs" (NRC 2007/2018-TN5898).

The applicable regulatory requirements for describing cooling-water canals and reservoirs are set forth in the following:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it sets forth the criteria for determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

The staff also used the appropriate sections of the following RGs for the acceptance criteria identified in SRP Section 2.4.8 (NRC 2007/2018-TN5898):

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;
- RG 1.59, "Design Basis Floods for Nuclear Power Plants" (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and
- RG 1.102, "Flood Protection for Nuclear Power Plants" (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.8.3 *Technical Evaluation*

The staff reviewed the information in SSAR Section 2.4.8 (TVA 2016-TN5018), and confirmed that the information in the ESPA addresses the relevant information related to the site cooling-water canals and reservoirs. The staff's technical review of this section included an independent review of the applicant's information in the SSAR. The staff supplemented this information with other publicly available sources of data. The staff's technical review of this section described below includes an independent review of the applicant's information provided in the SSAR (TVA 2016-TN5018).

2.4.8.3.1 Information Submitted by the Applicant

The SSAR states that the proposed reactor technology PPE at the CRN Site does not rely on the Clinch River tributary of the Watts Bar Reservoir as a safety-related water supply (TVA 2016-TN5018). The CRN Site does not have a cooling-water canal or reservoirs. The applicant does not propose any safety-related canals or reservoirs used to transport or impound plant cooling water.

2.4.8.3.2 Staff's Technical Evaluation

The staff reviewed SSAR Section 2.4.8 (TVA 2016-TN5018). The staff confirmed that the information in the ESPA addresses the relevant information related to this section and is sufficient and appropriate. The staff concludes that because there are no safety-related reservoirs or canals proposed for the reactor technology PPE, SSAR Section 2.4.8 (TVA 2016-TN5018) is not applicable to the CRN Site.

2.4.8.4 *Conclusion*

The staff reviewed the ESPA and confirmed that there are no safety-related cooling-water reservoirs or canals proposed for the reactor technology PPE. No outstanding information was required and no updates to the SSAR were needed for this section.

2.4.9 Channel Diversions

This section of the FSER evaluates the applicant's plant and essential water supplies to ensure that they will not be adversely affected by stream or channel diversions. The evaluation includes stream channel diversions away from the site (which may lead to a loss of safety-related water) and stream channel diversions toward the site (which may lead to flooding). This section also reviews the applicant's proposal to ensure that alternate water supplies are available to safety-related equipment, if needed.

This section of the report presents an evaluation of the following specific areas:

- historical channel migration phenomena including cutoffs, subsidence, and uplift;
- regional topographic evidence that suggests a future channel diversion may or may not occur (used in conjunction with evidence of historical diversions);
- thermal causes of channel diversion, such as ice jams, which may result from downstream ice blockages that may lead to flooding from backwater or upstream ice blockages that can divert the flow of water away from the intake;
- potential for forces on safety-related facilities or the blockage of water supplies resulting from channel migration-induced flooding (flooding not addressed by hydrometeorologically induced flooding scenarios in other sections);
- potential for channel diversion by human-induced causes (i.e., land-use changes, diking, channelization, armoring, or failure of structures);
- alternate water sources and operating procedures;
- potential effects of seismic and non-seismic information about the postulated worst-case channel diversion scenario for the proposed plant site; and
- any additional information required by the regulations discussed below in the Regulatory Basis section.

2.4.9.1 *Summary of Application*

The applicant described the potential hazards of channel diversions in SSAR Sections 2.4.9.1 through 2.4.9.7 (TVA 2016-TN5018). Based on the reactor technology PPE for the CRN Site, there is no need for external water sources to supply the safety-related cooling systems. Consequently, a loss of water supply due to channel diversions would not affect the safety-related cooling system. The applicant also considered the potential for a flood from a channel

diversion by reviewing hydrologic, hydraulic, climatic, topographic and geologic evidence, and anthropogenic impacts near the CRN Site. The applicant concluded that channel diversions would not cause flooding at the CRN Site.

2.4.9.2 *Regulatory Basis*

The relevant requirements of NRC regulations for channel diversions, and the associated acceptance criteria, are specified in SRP Section 2.4.9, "Channel Diversions" (NRC 2007/2018-TN5898).

The applicable regulatory requirements for identifying and evaluating channel diversions are set forth in the following:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it sets forth the criteria for determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

The staff also used the appropriate sections of the following RGs for the acceptance criteria identified in SRP Section 2.4.9 (NRC 2007/2018-TN5898).

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;
- RG 1.59, "Design Basis Floods for Nuclear Power Plants" (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and
- RG 1.102, "Flood Protection for Nuclear Power Plants" (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.9.3 *Technical Evaluation*

The staff reviewed the information in SSAR Section 2.4.9 (TVA 2016-TN5018). The staff's review confirmed that the information in the ESPA addresses the relevant information related to channel diversions. The staff's technical review of this section includes an independent review of the applicant's information in the SSAR (TVA 2016-TN5018). The staff supplemented this information with other publicly available sources of data.

2.4.9.3.1 Historical Channel Diversions

2.4.9.3.1.1 *Information Submitted by the Applicant*

The applicant examined the recent (2013) and historic (1935, 1953, and 1968) USGS topographic maps, presented in SSAR Section 2.4.9, Figures 2.4.9-1 through 2.4.9-4, for changes in Clinch River channel locations and found little change in the channel over the period (TVA 2016-TN5018). Several Clinch River flood events occurred in 1957, 1962, 1963, 1973, and 1977 at USGS stream gauge (03528000) near Tazewell, Tennessee, with no recorded change in river location.

As described in Section 2.4.9.1 of the SSAR (TVA 2016-TN5018), the age and morphology of the Clinch River terraces date back many thousands of years into the Pleistocene, which indicates a stable landscape. Material in the Clinch River floodplain has been dated to approximately 2,500 years before the present. A diversion of the Clinch River around St. Paul, Virginia, to prevent flooding of the town is reported in the SSAR (TVA 2016-TN5018). According to the SSAR, the diversion required blasting of solid rock to construct a new channel. Shoreline erosion by various means (boat traffic, wind waves, etc.) is described as being local in nature and readily mitigated, and hence has a negligible influence on bank stability.

2.4.9.3.1.2 *Staff's Technical Evaluation*

The staff examined the most current USGS topographic maps for the CRN Site (USGS 2017-TN6182) and compared them to the USGS quadrangle maps of Bethel Valley and Elverton, Tennessee, published in 1935 (USGS 2017-TN6181). The staff noted that the USGS quadrangle maps published in 1935 can present the original stream course of the Clinch River at the CRN Site because Norris Dam—a flood control dam upstream from the CRN Site—was completed in March 1936. Based on the staff's examinations and comparisons of maps, the staff confirmed that no change in location of the Clinch River channel is evident in these records.

The staff also examined other geologic information provided in the SSAR (TVA 2016-TN5018). The staff also noted the shoreline erosion prevention program is implemented as part of TVA's Shoreline Management Policy (TVA 1999-TN6187). Based on the above information, the staff determined that the applicant's evaluation is acceptable.

2.4.9.3.2 Regional Topographic Evidence

2.4.9.3.2.1 *Information Submitted by the Applicant*

The region around the CRN Site consists of ridges and valleys formed by folding and faulting of the sedimentary strata. The major rivers of the area are thought to be stable and older than the current valley and ridge formation, because they cut through ridges as they formed (SSAR Section 2.4.9.2 [TVA 2016-TN5018]).

The region around the CRN Site and the Clinch River tributary of Watts Bars Reservoir has a moderate susceptibility for landslides with a low incidence rate, as shown in SSAR Figure 2.4.9-5 (TVA 2016-TN5018). The applicant considered the potential for large-scale slope failure to be negligible.

2.4.9.3.2.2 *Staff’s Technical Evaluation*

The staff examined the geologic information provided in the SSAR (TVA 2016-TN5018). Based on the topographic map, geologic evidence of stable stratigraphy not being prone to landslides, stable stream course, and the USGS landslide incidence and susceptibility map provided by the applicant, the staff determined that that a channel diversion could be reasonably excluded as a flood-causing mechanism at the CRN Site.

2.4.9.3.3 Ice Causes

2.4.9.3.3.1 *Information Submitted by the Applicant*

Ice effects are discussed in SSAR Section 2.4.7, “Ice Effects” (TVA 2016-TN5018). Upstream and downstream river ice blockages would not be a threat to safety-related or risk-significant site SSCs.

2.4.9.3.3.2 *Staff’s Technical Evaluation*

SSAR Section 2.4.7 discusses the potential for an ice jam or blockage to cause flooding at the CRN Site (TVA 2016-TN5018). The staff finds the applicant’s evaluation of the potential for ice to induce a channel diversion to be acceptable. The staff concludes that river blockage could not inundate the CRN Site.

2.4.9.3.4 Flooding of Site Due to Channel Diversions

2.4.9.3.4.1 *Information Submitted by the Applicant*

Based on examinations in SSAR Sections 2.4.9.1 through 2.4.9.3, the applicant stated that there is no credible evidence that flooding as the result of channel diversions could occur that would affect safety at the CRN Site (TVA 2016-TN5018).

2.4.9.3.4.2 *Staff’s Technical Evaluation*

Based on the staff’s evaluations described in FSER Sections 2.4.9.3.1 through 2.4.9.3.3, the staff concludes that there is no credible evidence for channel diversions.

2.4.9.3.5 Human-Induced Causes of Channel Diversion

2.4.9.3.5.1 *Information Submitted by the Applicant*

Norris Dam provides flood protection in downstream areas, while Melton Hill Dam is run-of-the-river dam that provides no flood protection. The SSAR states that with the presence of the dams, the channels tend to be stabilized because sediment transport through the river system is reduced by the dams (TVA 2016-TN5018). The dam system reduces floods and the associated sediment transport and bank erosion that would otherwise be caused by relatively large floods. Failure of the upstream dams is examined in SSAR Section 2.4.4 (TVA 2016-TN5018). According to the applicant, the site is not affected by flood-waters from such potential dam failures, and diversion is not likely even with high flows and velocities. The applicant concludes that diversion of the Clinch River due to dam operations or dam failure is highly unlikely.

2.4.9.3.5.2 *Staff's Technical Evaluation*

(SRI/CEII) The staff reviewed the information provided by the applicant and examined potential dam failures as described in FSER Section 2.4.4. The dam failures with a PMF event produce the PMF elevation of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) at the CRN Site, which is far below the proposed site grade elevation of 821.4 ft NGVD29 (821.0 ft NAVD88). Thus, the staff concludes the CRN Site could not be inundated by channel diversion flooding.

2.4.9.3.6 Alternative Water Sources

2.4.9.3.6.1 *Information Submitted by the Applicant*

The SSAR states that the reactor technology PPE for the CRN Site does not rely on a water source for safety-related purposes from the Clinch River tributary of Watts Bar Reservoir (TVA 2016-TN5018).

2.4.9.3.6.2 *Staff's Technical Evaluation*

The staff determined that the applicant's evaluation of alternate water sources is acceptable, because the reactor technology PPE for the CRN Site does not rely on a water source from the Clinch River for safety-related purposes.

2.4.9.3.7 Consideration of Other Site-Related Evaluation Criteria

2.4.9.3.7.1 *Information Submitted by the Applicant*

The applicant provides no additional considerations related to channel diversions.

2.4.9.3.7.2 *Staff's Technical Evaluation*

(SRI/CEII) The staff finds that the applicant's computed PMF elevation of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) is well below the proposed site grade elevation of 821.4 ft NGVD29 (821.0 ft NAVD88). Therefore, the CRN Site cannot be inundated by channel diversions in the region, and additional considerations related to channel diversions are not needed.

2.4.9.4 *Conclusion*

The staff reviewed the ESPA and confirmed that the applicant has demonstrated that channel diversions have no impact on the CRN Site, because the reactor technology PPE does not rely on safety-related water supply from the Clinch River, and no outstanding information is required to be addressed in the SSAR related to this section. As set forth above, the applicant has provided information pertaining to channel diversions showing that channel diversion above the CRN Site is not likely. Further, the applicant has considered the most severe natural 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, in establishing site characteristics pertaining to channel diversions that are acceptable for design purposes. Therefore, the staff concludes that the applicant has met the requirements regarding channel diversions in 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.20 (TN282), and 10 CFR 100.23(d) (TN282).

2.4.10 Flooding Protection Requirements

This section considers and reviews the locations and elevations of safety-related facilities and structures that require protection from flooding. These requirements are then compared with DBF conditions to determine whether flood effects need to be considered in the plant's design or emergency procedures. The specific areas of review are as follows:

- safety-related facilities exposed to flooding,
- type of flood protection (e.g., "hardened facilities," sandbags, flood doors, bulkheads) provided to the SSCs exposed to floods,
- emergency procedures needed to implement flood protection activities and warning times available for their implementation reviewed by the organization responsible for reviewing issues related to plant emergency procedures,
- potential effects of seismic and non-seismic information about the postulated flooding protection for the proposed plant site, and
- any additional information required by the regulations discussed below in the Regulatory Basis section.

2.4.10.1 *Summary of Application*

In SSAR Section 2.4.10, the applicant addressed the need for site-specific information about flood protection requirements (TVA 2016-TN5018).

2.4.10.2 *Regulatory Basis*

The relevant requirements of NRC regulations and the associated acceptance criteria for flood protection are specified in SRP Section 2.4.10, "Flooding Protection Requirements" (NRC 2007/2018-TN5898).

The applicable regulatory requirements for identifying and evaluating flood protection are set forth in the following:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it sets forth the criteria for determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site

The staff also used the appropriate sections of the following RGs for the acceptance criteria identified in SRP Section 2.4.10 (NRC 2007/2018-TN5898):

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the UHS will be available where needed;

  RG 1.59, "Design Basis Floods for Nuclear Power Plants" (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that natural flooding phenomena that could potentially affect the site have been appropriately identified and characterized; and RG 1.102, "Flood Protection for Nuclear Power Plants" (NRC 1976-TN5914), as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site.

2.4.10.3 *Technical Evaluation*

The staff reviewed information in SSAR Section 2.4.10 (TVA 2016-TN5018) and confirmed that the information in the ESPA addresses the necessary information related to flooding protection requirements. The staff's technical review of this section includes an independent review of the applicant's information presented in SSAR Section 2.4.10 (TVA 2016-TN5018).

2.4.10.3.1 Information Submitted by the Applicant

Subsequent to selection of a reactor technology, the applicant would design the final site grading, including slopes and diversion ditches, to drain runoff resulting from an LIP away from safety-related SSCs into swales and pipes toward the Clinch River (which surrounds the CRN Site on three sides). These site drainage systems will be designed to prevent the flooding of safety-related SSCs if the LIP event occurs. SSAR Section 2.4.2.3 stated the requirements for the site grading plan will be provided in the COLA. SSAR Section 2.4.2.3 also stated that a fully effective drainage system would be designed at the COL stage (TVA 2016-TN5018). Potential flooding at buildings due to an LIP event and associated effects is dependent on the final plant grading plan and storm drainage design that will be determined during the development of the COLA.

(SRI/CEII) In addition to the LIP flood hazard, the SSAR identified an MSWFE of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88) (TVA 2016-TN5018). The applicant stated in SSAR Table 2.0-1 that the site characteristic flood elevation is **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88), which is the MSWFE plus wave height **[[**[redacted]**]]** ft (TVA 2016-TN5018). This flood event does not include the potential for flooding caused by a LIP event and associated site drainage.

2.4.10.3.1 Staff's Technical Evaluation

The staff reviewed the information submitted by the applicant related to flood protection at the CRN Site. Because the SSAR Table 2.0-2 site-related design parameter minimum site grade is an elevation of 821.4 ft NGVD29 (821.0 ft NAVD88) (TVA 2016-TN5018), flood protection requirements are not applicable for the SSAR Table 2.0-1 site characteristic maximum flood.

Because the potential for flooding caused by a LIP event would be evaluated, and the CRN Site grading plan would be finalized, in the COLA, the staff includes COL Action Item 2.4-2:

COL Action Item 2.4-2: An applicant for a COL or CP referencing this this ESP should address whether the local flood elevation exceeds the site grade elevation and whether the local flood elevation justifies flood protection measures to prevent flooding of any safety-related structures, systems and components (SSCs). If so, the applicant should address necessary flooding protection for safety-related SSCs based on the flooding event and associated effects.

2.4.10.4 *Conclusion*

The staff reviewed the ESPA and confirmed that no outstanding flood protection information is required to be addressed in the SSAR related to this section. As set forth above, the applicant has provided sufficient information pertaining to flood protection. The staff concludes that the applicant has provided sufficient information pertaining to flood protection to satisfy the requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.20(c) (TN282) and 10 CFR 100.23(d) (TN282). The COL applicant will address COL Action Item 2.4-2.

2.4.11 Low Water Considerations

This section addresses natural events that may reduce or limit the available safety-related cooling-water supply (TVA 2016-TN5018). The applicant ensures that an acceptable water supply will exist to shut down the plant under conditions requiring safety-related cooling.

This section of the report provides an evaluation of the following specific areas:

- low water conditions due to the worst drought considered reasonably possible in the region;

the effects of low WSEs caused by various hydrometeorological events and a potential blockage of intakes by sediment, debris, littoral drift, and ice possibly affecting the safety-related water supply;

- the effects of low water on the intake structure and pump design bases in relation to the events described in SSAR Sections 2.4.7, 2.4.8, 2.4.9, and 2.4.11 (TVA 2016-TN5018), which includes the consideration of the range of water supply required by the plant (including minimum operating and shutdown flows during anticipated operational occurrences and emergency conditions) compared to water-supply availability (considering the capability of the UHS to provide acceptable cooling water under conditions requiring safety-related cooling); and
- any additional information required by the regulations discussed below in the Regulatory Basis section.

2.4.11.1 *Summary of Application*

In SSAR Section 2.4.11, the applicant addressed the impacts of low water on safety-related water supply (TVA 2016-TN5018).

2.4.11.2 *Regulatory Basis*

The relevant requirements of NRC regulations and the associated acceptance criteria for low water considerations are specified in SRP Section 2.4.11, “Low Water Considerations” (NRC 2007/2018-TN5898).

The applicable regulatory requirements for identifying and evaluating low water considerations are set forth in the following:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrologic features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it sets forth the criteria for determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

The staff also used the appropriate sections of the following RGs for the acceptance criteria identified in SRP Section 2.4.11 (NRC 2007/2018-TN5898).

- RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907), as it relates to providing high assurance that the water sources relied on for the sink will be available where needed; and
- RG 1.59, "Design Basis Floods for Nuclear Power Plants" (NRC 1977-TN5913), as supplemented by best current practices, as it relates to providing assurance that post-flood-waves causing low water level phenomena that could potentially affect the site have been appropriately identified and characterized.

2.4.11.3 *Technical Evaluation*

By reviewing the information in SSAR Section 2.4.11 (TVA 2016-TN5018), the staff confirmed that the information in the ESPA addresses the relevant information related to low water considerations. The staff's technical review of this section includes an independent review of the applicant's information in the SSAR (TVA 2016-TN5018). The staff also supplemented this information with other publicly available sources of data.

This section describes the staff's evaluation of the technical information presented in SSAR Section 2.4.11 (TVA 2016-TN5018).

2.4.11.3.1 Information Submitted by the Applicant

The reactor technology PPE for the CRN Site does not rely on water supply from the Clinch River tributary of Watts Bar Reservoir to support safety-related SSCs.

The Clinch River tributary of Watts Bar Reservoir is anticipated to supply normal cooling water with a peak withdrawal rate of about 30,708 gpm, equal to 68 cfs. That normal cooling-water supply provides makeup water to maintain the cooling system supply following evaporation and blowdown losses from a mechanical draft cooling-tower system. Return flow from the normal water system to the Clinch River tributary of Watts Bar Reservoir would be via a discharge structure, with a peak discharge of about 17,900 gpm, equal to 40 cfs. This results in a consumptive water use of approximately 12,808 gpm, equal to 28.5 cfs.

2.4.11.3.2 Staff's Technical Evaluation

According to SSAR Sections 2.4.1.1 and 2.4.11 (TVA 2016-TN5018), the staff notes that the makeup water for normal cooling operations comes from the Clinch River tributary of Watts Bar Reservoir. The potable and other water are supplied from the Oak Ridge Department of Public

Works. The staff finds the applicant's information acceptable for evaluating non-safety-related water supply. FSER Sections 2.4.11.3.3 through 2.4.11.3.6 are related to evaluating these makeup water needs.

2.4.11.3.3 Low Flow in Rivers and Streams

2.4.11.3.3.1 *Information Submitted by the Applicant*

The SSAR notes that in the Clinch River tributary of Watts Bar Reservoir the flow is regulated primarily by releases from Melton Hill Dam and the water level is regulated by Watts Bar Dam (TVA 2016-TN5018). Therefore, the operation of both dams, addressed separately below, can affect the surface-water elevation in the Clinch River near the site.

2.4.11.3.3.1.1 Melton Hill Dam

According to the SSAR (TVA 2016-TN5018), Melton Hill Dam is operated for several purposes: navigation, hydroelectric power production, water supply, water quality and aquatic ecology enhancement, and recreation (but not for flood control because of its limited capacity). The dam has a minimum daily-average release requirement of 400 cfs for downstream water-supply and water-quality enhancement. The SSAR supplements (TVA 2017-TN6171) indicated that the occurrence of the minimum release flow (400 cfs) continuously for an extended period is infrequent in the historical record. Periods of zero flow from Melton Hill Dam do occasionally occur. Since the adoption of the ROS policy in 2004 (TVA 2004-TN5919), the frequency of zero-flow days has been 0.06 percent.

2.4.11.3.3.1.2 Watts Bar Dam

According to the SSAR (TVA 2016-TN5018), Watts Bar Dam is operated for several purposes: navigation, flood control, hydroelectric power production, water supply, water quality, aquatic ecology, and recreation. Watts Bar Dam has a minimum flow daily-average release requirement of 1,200 cfs for downstream water-supply and water-quality management (TVA 2004-TN5919). Watts Bar Reservoir is managed at two normal operating pool levels corresponding to winter (normal minimum level) and summer (normal maximum level). The normal minimum level is maintained in the winter to provide flood storage because most flooding events occur in the winter. The normal summer level is 6 ft higher than the winter level.

The primary inflows to Watts Bar Reservoir are the releases from Fort Loudoun Dam and flow from the Clinch River at Melton Hill Dam. The primary outflows from Watts Bar Reservoir are releases from hydroelectric power generation, water supply to the Watts Bar NPP for condenser cooling water, and flood flow releases.

The SSAR analyzes the effects on water level of the Watts Bar Reservoir based on a set of conservative assumptions that only include (1) an inflow from minimum flow release from Melton Hill Dam; (2) outflows from consumptive uses, evaporation, and Watts Bar Dam minimum flow requirements; and (3) the Watts Bar Reservoir stage-storage curve (TVA 2016-TN5018).

2.4.11.3.3.2 *Staff's Technical Evaluation*

There are no safety-related water-supply needs for the reactor technology PPE at the CRN Site. The SSAR states that 30,708 gpm (68 cfs) represents the water needs for non-safety-related purposes, primarily for condenser cooling water for normal operations (TVA 2016-TN5018).

The staff notes that the needs (68 cfs) are less than 400 cfs of minimum release flow from Melton Hill Dam under drought conditions. The 400 cfs is a minimum release flow based on the installation of an upstream bypass at the Melton Hill Dam to maintain hydrothermal requirements for operation of the proposed units. The staff notes that the operating pool levels of Watts Bar Reservoir used for the drought condition analysis are illustrated in Figure 2.4.1-5a. Based on the availability of minimum release flow from Melton Hill Dam and the Watts Bar Reservoir level during drought conditions, the staff confirmed that this low-flow study for non-safety-related water supply is acceptable. This minimum release flow frequency for drought conditions (TVA 2017-TN6171) is included in the SSAR revisions.

Based on the staff's review of the information as updated in the SSAR (TVA 2017-TN5387), and the NRC Site Audit Summary Report (NRC 2018-TN5915), the staff determined that the applicant's low-flow information was reasonable for use in analyzing the non-safety-related water supply.

2.4.11.3.4 Low Water from Surges, Seiches, or Tsunamis

2.4.11.3.4.1 *Information Submitted by the Applicant*

SSAR Section 2.4.11.2 states that the CRN Site does not rely on the Clinch River for safety-related water-supply purposes (TVA 2016-TN5018). SSAR Sections 2.4.5, 2.4.6, and 2.4.7 discuss surges and seiches, tsunamis, and ice jams, and the applicant concludes that these hazard mechanisms could not affect safety-related SSCs at the CRN Site (TVA 2016-TN5018).

2.4.11.3.4.2 *Staff's Technical Evaluation*

Based on the previous review of SSAR Sections 2.4.5, 2.4.6, and 2.4.7 (TVA 2016-TN5018), the staff finds the applicant's information acceptable.

2.4.11.3.5 Historical Low Water

2.4.11.3.5.1 *Information Submitted by the Applicant*

According to SSAR Section 2.4.11.3 (TVA 2016-TN5018), the drought of 1986 to 1987 was the most severe recorded in the State of Tennessee. Water-level records for that severe drought period for Watts Bar Reservoir show that the water level did not drop below 735 ft NGVD29 (734.6 ft NAVD88), as discussed in SSAR Section 2.4.11.1.2 (TVA 2016-TN5018). SSAR Figure 2.4.11-3 shows the annual minimum water levels between 1943 and 2012 in Watts Bar Reservoir.

2.4.11.3.5.2 *Staff's Technical Evaluation*

The staff determined that the applicant used a sufficient period of annual low-flow record to identify and analyze the low-flow conditions.

2.4.11.3.6 Future Controls

2.4.11.3.6.1 *Information Submitted by the Applicant*

SSAR Section 2.4.11.4 states that the technology of the CRN Site does not rely on water supply from the Clinch River for safety-related purposes (TVA 2016-TN5018). Additionally, the SSAR states that the applicant would control any future water uses of the Clinch River arm of the

Watts Bar Reservoir, and future users would need to account for the surface-water use of the CRN Site (TVA 2016-TN5018).

2.4.11.3.6.2 *Staff's Technical Evaluation*

Because the applicant's reactor technology PPE does not require an external water supply to protect SSCs important to safety, the staff determined the applicant's assessment of future controls is acceptable.

2.4.11.3.7 Plant Requirements

2.4.11.3.7.1 *Information Submitted by the Applicant*

The applicant cites SSAR Section 2.4.11.3 (TVA 2016-TN5018), in which an analysis of water availability during a drought is evaluated. That analysis concluded that reservoir operations would maintain sufficient water levels to operate the CRN Site intake.

2.4.11.3.7.2 *Staff's Technical Evaluation*

Because the applicant's reactor technology PPE does not require an external water supply to protect SSCs important to safety, the staff determined that the applicant's assessment of plant requirements is acceptable.

2.4.11.3.8 Heat Sink Dependability Requirements

2.4.11.3.8.1 *Information Submitted by the Applicant*

SSAR Section 2.4.11.6 states that the reactor technology PPE for the CRN Site does not rely on water from the Clinch River for safety-related purposes (TVA 2016-TN5018).

2.4.11.3.8.2 *Staff's Technical Evaluation*

Because the reactor technology PPE does not require an external water supply to protect SSCs important to safety, the staff determined that the applicant's assessment of the heat sink dependability is acceptable.

2.4.11.4 *Conclusion*

The staff reviewed the ESPA and confirmed that the applicant has demonstrated that the low water considerations have no safety-related impact on the CRN Site, because the UHS for the CRN Site does not rely on the Clinch River, and no outstanding information is required to be addressed in the SSAR related to this section. As set forth above, the applicant provided sufficient information pertaining to low water considerations. Further, the applicant has considered the most severe natural 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, in establishing site characteristics pertaining to low water that are acceptable for design purposes. Therefore, the staff concludes that the applicant has met the requirements related to low water considerations with respect to 10 CFR 52.17(a)(vi) (TN251) and 10 CFR 100.20(c) (TN282).

2.4.12 Groundwater

SSAR Section 2.4.12, “Groundwater,” describes the hydrogeological characteristics of the site. One objective of groundwater investigations and monitoring at this site is to evaluate the effects of groundwater on plant foundations (TVA 2016-TN5018). The evaluation is performed to assure that the maximum groundwater elevation remains below the PPE design parameter value. Other objectives are to examine whether groundwater provides any safety-related water supply, determine whether dewatering systems are required to maintain groundwater elevation below the required level, measure characteristics and properties of the site needed to develop a conceptual site model of groundwater movement, and estimate the direction and velocity of movement of potential radionuclide contaminants.

The section presents an evaluation of the following specific areas:

- identification of the aquifers, types of onsite groundwater use, sources of recharge, present withdrawals, and known and likely future withdrawals, flow rates, travel time, gradients (and other properties that affect the movement of accidental contaminants in groundwater), groundwater levels beneath the site, seasonal and climatic fluctuations, monitoring and protection requirements, and manmade changes that have the potential to cause long-term changes in local groundwater regime;
- effects of groundwater levels and other hydrodynamic effects of groundwater on the design bases of plant foundations and other SSCs important to safety;
- reliability of groundwater resources and related systems used to supply safety-related water to the plant;
- reliability of dewatering systems to maintain groundwater conditions within the plant’s design bases;
- potential effects of seismic and non-seismic information about the postulated worst-case groundwater conditions for the proposed plant site; and
- any additional information required by the regulations discussed below in the Regulatory Basis section.

2.4.12.1 *Summary of Application*

In SSAR Section 2.4.12.1 (TVA 2016-TN5018), the applicant addressed groundwater conditions in terms of their effects on site structures and the water supply, as follows:

- The applicant described geologic formations, and regional and local groundwater aquifers, sources, and sinks.
- The applicant stated that there are no current or projected groundwater uses for the CRN Site.
- The applicant described dewatering that would be required during construction. Because of the proposed plant grade elevation, no dewatering would be required when the plant is operational.
- The applicant described the historical, present and projected future regional use relying on reports and databases of the TVA, DOE, Tennessee Department of Environment and Conservation (TDEC), the EPA, and the USGS.

- The applicant described water levels and flow directions both regionally and onsite. The applicant provided groundwater-level contour maps of the site and regional maps showing major hydrologic features.
- The applicant described regional and onsite field investigations and studies used to characterize aquifer parameters, the groundwater flow system, and hydrostatic loading.

2.4.12.2 *Regulatory Basis*

The relevant requirements of NRC regulations for groundwater, and the associated acceptance criteria, are described in SRP Section 2.4.12, "Groundwater" (NRC 2007/2018-TN5898).

The applicable regulatory requirements are set forth in the following:

- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it relates to determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.
- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The staff also used the acceptance criteria identified in SRP Section 2.4.12 (NRC 2007/2018-TN5898):

- Local and Regional Groundwater Characteristics and Use: The applicant should supply a complete description of regional and local groundwater characteristics and groundwater use, groundwater monitoring and protection requirements, and any manmade changes that have the potential to affect regional groundwater characteristics over a long period of time.
- Effects on Plant Foundations and other SSCs Important to Safety: The applicant should supply a complete description of the effects of groundwater-surface elevations and other hydrodynamic effects on the design bases of plant foundations and other SSCs important to safety.
- Reliability of Groundwater Resources and Systems Used for Safety-Related Purposes: The applicant should supply a complete description of all SSCs important to safety that depend on groundwater, as well as data and analysis regarding the reliability of the groundwater source.
- Reliability of Dewatering Systems: The applicant should supply a complete description of the site dewatering system, including its reliability to maintain the groundwater conditions within the groundwater design bases of SSCs important to safety.
- Consideration of Other Site-Related Evaluation Criteria: The applicant should supply an assessment of the potential effects of the postulated worst-case scenario related to groundwater effects for the proposed plant site.

2.4.12.3 *Technical Evaluation*

The staff reviewed the information in SSAR Section 2.4.12, which included the applicant's supplemental information related to the hydrogeologic site characterization (TVA 2017-TN5387), and confirmed that the information in the ESPA addresses the relevant information related to the groundwater considerations. The staff's technical review of this section includes an independent review of the applicant's information in the SSAR (TVA 2017-TN5387) and the applicant's responses to the staff's requests for supplemental information as cited in the NRC CRN Site Audit Summary Report (NRC 2018-TN5915). The staff supplemented this information with other publicly available sources of data and information.

The applicant identified aquifers; groundwater use categories; sources of recharge; present and future withdrawals; flow rates; travel times and gradients and other properties that affect transport of radionuclides; groundwater levels in the site vicinity including seasonal and climatic variations; monitoring and protection plans; and manmade changes that have the potential to cause long-term changes in the localized flow system. This FSER section provides the staff's evaluation of the technical information presented in SSAR Section 2.4.12 (TVA 2017-TN5387).

2.4.12.3.1 Aquifer Descriptions, Onsite Use and Site Setting

The applicant provided a narrative of the hydrogeology of the region and the CRN Site located in the Valley and Ridge physiographic province of Roane County, Tennessee. Within the region, the aquifer system sequence (Figure 2.4.12-1) contains the following formations*:*

- Chickamauga Group
- Knox Group
- Conasauga Group
- Rome Formation.

The carbonate rock sequences of the Chickamauga and Knox Group are an important source of water for rural domestic water supplies. The CRN Site reactor technology PPE will not require groundwater as a source for cooling water, potable water, or other plant needs. Makeup water to a safety-related UHS (if necessary) and the non-safety-related circulating water system for a proposed plant will be drawn from the Clinch River. Dewatering may be required during construction but not when the proposed plant is operational.

2.4.12.3.1.1 *Information Submitted by the Applicant*

The applicant described a multi-step approach to developing a conceptual site model, which included desktop studies based on existing publications, a review of the CRBRP studies, review of the preliminary site layout, site-specific studies and observations conducted for the site, and an evaluation of these site-specific studies and observations in conjunction with regional and local information.

The applicant described the physiography and geomorphology of the CRN Site, which is located in the Valley and Ridge physiographic province. In the site area, folding, faulting, and erosion have created a series of northeast-southwest trending ridges and valleys (USGS 2004-TN6168). The dip of the northeast-southwest trending formations in the vicinity of the site is approximately 50 to 60 degrees to the southeast (Tucci 1992-TN5034) and varies to more shallow dips away from faults and higher dips in close proximity to faults.

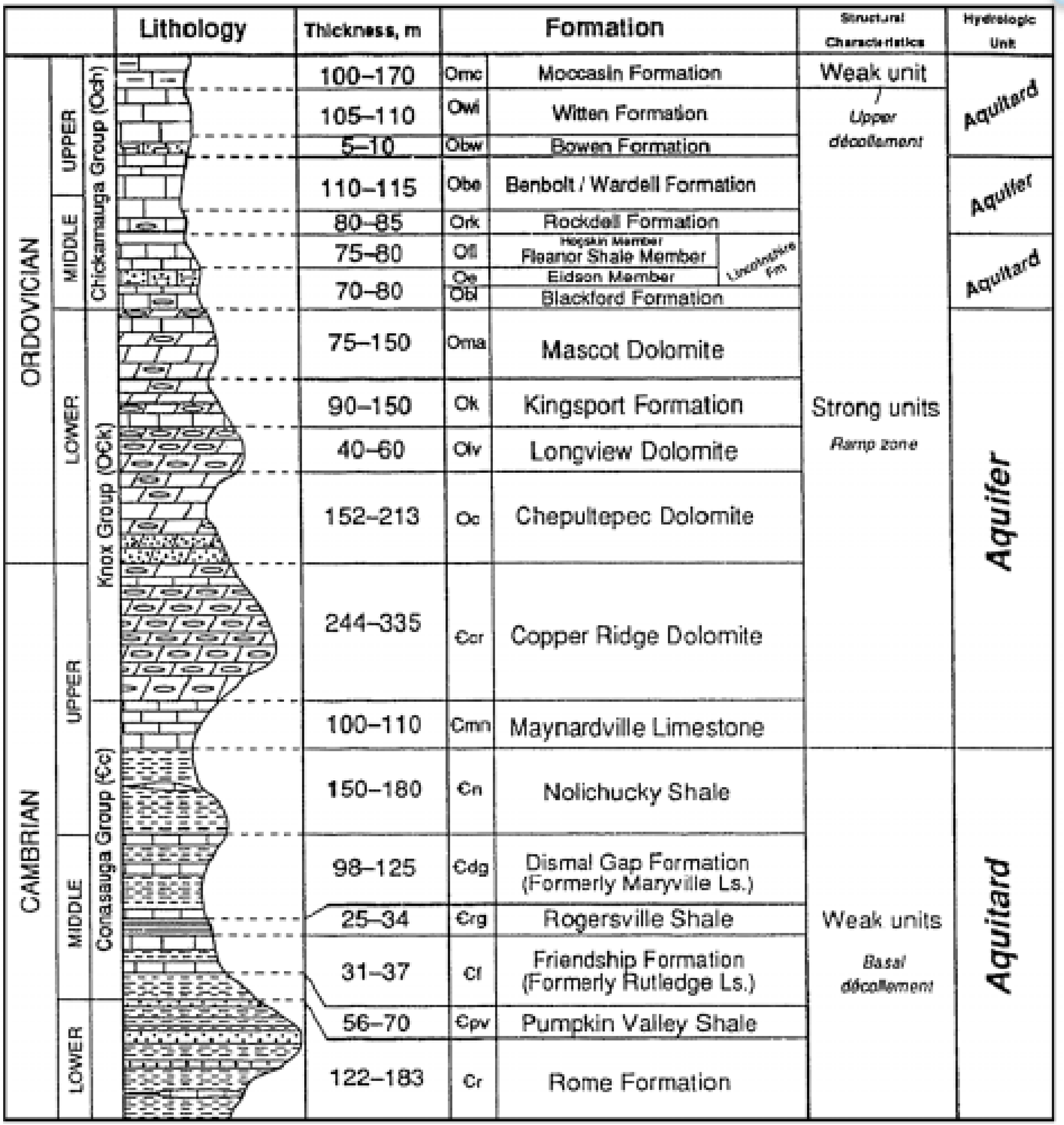


Figure 2.4.12-1 Hydrogeologic Stratigraphy of the Site and Surrounding Area (reproduced from SSAR, Revision 1 Figure 2.4.12-9 [TVA 2017-TN5387]).

Located in Roane County, Tennessee, the CRN Site would have a minimum site grade of 821.0 ft NAVD88 or approximately 81 ft above the normal summer pool elevation of 740 ft NAVD88 of the adjacent Clinch River tributary of the Watts Bar Reservoir. The site lies within an oxbow bend of the Clinch River between CRM 14.5 and 19.0 (Figure 2.4.12-2). Existing elevations range from approximately 740 ft NAVD88 at the Clinch River shoreline to over 1,100 ft NAVD88 along Chestnut Ridge at the northwest corner of the CRN Site boundary. The site has been altered by pre-construction activities associated with the CRBRP Limited Work Authorization (LWA) activities, which included excavation in the area of the proposed nuclear island. Upon termination of the CRBRP, the Atomic Safety Licensing Board (ASLB) issued a revocation of the

CRBRP LWA (NRC 1985-TN5949) under a condition that TVA perform site reparations in accordance with a final redress plan (DOE 1984-TN5282). The CRBRP Preliminary Safety Analysis Report (PSAR) describes the pre-construction topography, and documents the site preparation activities and the associated site characterization studies (BRC 1985-TN5245).

2.4.12.3.1.2 _Staff's Technical Evaluation_

The staff reviewed the applicant's multi-step approach to site characterization, and evaluated the applicant's hydrogeologic characterization of the region, including physiography and geomorphology. The staff confirmed that this characterization was acceptable based on publicly available information, including USGS topographic maps and physiographic characterization (USGS 2004-TN6168).

During the April 24–27, 2017 audit (NRC 2018-TN5915), the staff requested that the applicant provide the Historical Site Assessment (HSA) site redress plan (DOE 1984-TN5282) developed by the TVA and DOE for the staff's review. Subsequently, the staff reviewed the site redress plans as described in the HSA and the final plan selected. Based on the staff's review of the HSA plan, the ASLB's hearing on the plan (NRC 1985-TN5949), and information in the CRBRP PSAR (BRC 1985-TN5245), the staff found the applicant's description of the current site disposition acceptable as described in the SSAR (TVA 2017-TN5387).

2.4.12.3.2 Regional Hydrogeology and Groundwater Aquifers

2.4.12.3.2.1 _Information Submitted by the Applicant_

The applicant described the principal Valley and Ridge province aquifers as primarily carbonate rocks present in the valleys between ridges. Dissolution activity within these carbonate rocks can result in solution cavities within these aquifers. Fractures and solution openings in the carbonate rock aquifers may result in highly permeable zones with high localized well yields. The applicant stated that the majority of groundwater flow takes place within 200 to 300 ft of the land surface in valleys between the ridges and that springs, streams, and the Clinch River are primary discharge points. Groundwater discharges to springs are highly dependent on and correlated to rainfall. Groundwater in the aquifers moves primarily through fractures, bedding planes, and solution openings in the rocks. Preferential flow paths trend along the strike of the aquifer units. Dissolution from slightly acidic water circulating primarily within the upper 200 to 300 ft of the aquifers may enlarge solution openings and increase permeability in these zones (Brahana et al. 1986-TN6149).

The applicant noted important aquifers in the area, which are within the Knox Group. Portions of these aquifers may have a direct hydraulic connection to surface water (e.g., rivers and lakes). The applicant summarized regional groundwater use and stated that the lower Chickamauga and the Knox Group aquifers provide the largest well yields in the area. In the vicinity of the site, water quality gradually decreases with depth, transitioning from fresh "hard" water to sodium-bicarbonate at intermediate depths and to sodium-calcium-chloride (briny or saline water) at deep depths (greater than approximately 1,000 ft).

The applicant described the unconsolidated deposits on the site, which included residuum, colluvium, alluvium, and anthropogenic (backfill) material. Residuum consists of weathered bedrock; colluvium, a mixture of residuum and alluvial material; and anthropogenic material (i.e., the backfill and broken rock associated with past CRBRP site activities). The applicant characterized the subdivisions of the two (Chickamauga Group and Knox Group) primary

aquifers on and around the site (Figure 2.4.12-1). The nature of groundwater movement in these aquifers is consistent with groundwater fracture and solution opening flow and bedding planes orientation as described previously for the carbonate aquifers. The applicant described the Conasauga Group (below the Knox Group) as having an upper (Maynardville Limestone) member that is considered part of the Knox aquifer. The remainder of the lower members of the Conasauga are described as an aquitard (Figure 2.4.12-1). Beneath the Conasauga Group is the Rome Formation, which is generally considered to be an aquitard. The applicant noted that there are no sole-source aquifers within the area of the CRN Site and corresponding hydrogeologic boundaries.

2.4.12.3.2.2 *Staff's Technical Evaluation*

The staff reviewed the applicant's characterization of the regional aquifers and confirmed through reviews of independent studies and reports (e.g., Tucci 1992-TN5034; Brahana et al. 1986-TN6149) that dissolution and the resulting solution openings and fractures result in permeable zones, and that the majority of groundwater flow takes place within 200 to 300 ft of the land surface. Previous regional studies (Tucci 1992-TN5034; Brahana et al. 1986-TN6149; USGS 1995-TN6166) confirm the applicant's characterization that the majority of solution cavities and fractures are within 200 to 300 ft of the land surface and coincide with the most permeable groundwater flow zone.

The principal aquifers of East Tennessee consist of carbonate rocks, which compose the most productive aquifers. Typically, these rocks are hydraulically connected to sources of discharge or recharge, such as rivers or lakes through fractures and solution activity that may enlarge the original openings in the carbonate rocks (USGS 1995-TN6166). In the vicinity of the CRN Site, these carbonate aquifers include the limestones and dolomites of the lower Chickamauga and Knox Groups (Dorsch and Katsube 1999-TN6036), which are overlain by weathered rock, soil, and backfill from CRBRP site activities. The Conasauga Group, with the exception of the uppermost Maynardsville Limestone, is considered an aquitard (Dorsch and Katsube 1999-TN6036; DOE 2001-TN6165). The water quality of the aquifers varies from fresh hard water within the upper 300 ft of the aquifers, decreasing in quality beyond this depth, and grading into a briny characteristics at depths greater than 1,000 ft. The staff reviewed the applicant's description of the regional aquifers and the aforementioned publications and confirmed that the applicant acceptably described the regional hydrology and groundwater aquifer system.

2.4.12.3.3 Local Hydrogeology

In addition to reviewing site-specific studies conducted to characterize the local hydrogeology, the applicant reviewed several studies performed on the nearby Oak Ridge Reservation (ORR) which borders the northeastern portion of the CRN Site.

2.4.12.3.3.1 *Information Submitted by the Applicant*

The applicant described local hydrologic studies based on information derived from USGS studies (Tucci 1992-TN5034; Brahana et al. 1986-TN6149) and extensive studies conducted on the adjacent ORR (e.g., Moore 1991-TN6034; Parr and Hughes 2006-TN5058; Hatcher et al. 1992-TN4989). The northeast trending valleys and ridges and the broad extent of the carbonate rocks are the result of a combination of folding, thrust faulting, and erosion. These forces have resulted in repeated rock sequences in the province that have been fractured by compressive forces, which have displaced older rocks (primarily the Conasauga Group and the Rome Formation) over the top of younger rocks (the Chickamauga and the Knox Group) along

thrust fault planes for sequences of permeable and less permeable hydrogeologic units. The repeated sequences form a series of adjacent and shallow groundwater flow systems (Brahana et al. 1986-TN6149; Dorsch and Katsube 1999-TN6036).

The ORR studies included permeabilities and porosities for approximately 200 aquifer tests, which included bedrock and overburden aquifer material for the same or similar hydrogeologic units found at the CRN Site. The ORR is directly northeast of and adjacent to the CRN Site. From the data, the applicant noted a general trend of decreasing hydraulic conductivity with depth, with the exception of the Knox Group where fracturing and solutioning may contribute to the porosity throughout the unit.

2.4.12.3.3.2 _Staff's Technical Evaluation_

The hydrologic studies conducted at the ORR are particularly relevant to supplementing the CRN Site characterization because the ORR is adjacent to the CRN Site and the ORR studies incorporate sampling and testing information for many of the same hydrogeologic units found on the CRN Site. The staff reviewed the permeability and porosity studies conducted for the ORR adjacent to the CRN Site and determined that the applicant's characterization of the ORR studies and information as being applicable to the CRN Site was acceptable.

2.4.12.3.4 Site-Specific Hydrogeology

The CRN Site field investigations included drilling 82 borings, 3 test pits, 44 well installations, and associated testing of and observations related to the information derived from these activities.

2.4.12.3.4.1 _Information Submitted by the Applicant_

The applicant noted that the CRBRP investigation included 129 borings, installation of 37 observation wells, 11 piezometers, and 117 bedrock borehole permeability tests. The applicant identified no abandoned CRBRP wells while performing the CRN Site subsurface investigation activity. The applicant stated that the CRBRP wells were likely destroyed and/or removed during the excavation and subsequent CRBRP site redress. However, during a 2018 site walkdown, one CRBRP well was found. Further searches resulted in the discovery of two additional wells. The applicant is currently evaluating these wells for closure in accordance with TVA and TDEC requirements (TVA 2018-TN5760). Although no documentation of CRBRP well closures was identified, the applicant assumed that the DOE followed standard well-closure procedures during subsequent site redress activities.

The CRBRP site investigation identified predominate joint sets of N52^{o}E 37^{o}SE with a total of four bedrock joint set orientations at the site:

- N52^{o}E 37^{o}SE
- N52E^{o} 58^{o}NW
- N25^{o}W 80^{o}SW
- N65^{o}W 75^{o}NE.

From CRBRP hydraulic conductivity tests performed at the site, the applicant noted a similar trend in the ORR data of decreasing hydraulic conductivity at depths greater than 100 ft. The applicant noted that maximum groundwater levels were observed in January/February and minimum water levels were observed in October/November with approximately 20 ft of

fluctuation. Groundwater flow patterns generally follow the topography but are tempered relative to the extent of bedrock weathering. Ridges are generally considered groundwater divides, and groundwater use is primarily limited to agricultural and residential use. The CRN Site is bounded to the northwest by the Chestnut Ridge highlands, and the Clinch River oxbow surrounds the remaining site boundary.

CRN Site groundwater characterization activities included monitoring groundwater levels, and performing slug, packer, aquifer performance tests, and geochemical sampling. The applicant monitored intervals ranging from 15 ft to 297 ft below ground surface (bgs) in three monitoring zones: upper (15 to 105 ft bgs), intermediate (89 to 178 ft bgs), and deep (176 to 297 ft bgs). Upper, middle, and lower zone monitoring well identifications were designated with a "U", "L", or "D" suffix, respectively. The applicant supplemented the CRN Site characterization with information from the CRBRP studies, including packer hydraulic permeability testing in the Chickamauga and Knox Group aquifer materials, which exhibited a trend of decreasing hydraulic conductivity at depths beyond 100 ft.

The applicant noted that petroleum groundwater contamination has been observed in well OW-422L. The oversight authority for the contamination issue is the TDEC. TDEC (2014-TN5288) described the contamination as diesel petroleum hydrocarbons, and further TDEC analysis indicated the presence of low levels of radionuclides potentially originating from ORR sources northeast of the CRN Site. TDEC (2016-TN5350) indicated that the radionuclides are characteristic of past ORR waste streams and disposal operations. During the April 24–27, 2017 audit conducted by the NRC (NRC 2018-TN5915), the applicant described the petroleum contamination as diesel characteristic of a 1970s fuel blend based on past studies. The applicant indicated that the petroleum contamination is localized and is likely an artifact of leakage associated with heavy construction equipment fuel used during the CRBRP site construction activities in the late 1970s. Because no related petroleum contamination has been observed in any other monitoring wells during long-term monitoring or in monitoring wells during the CRN Site aquifer pumping test, the applicant concluded that the petroleum contamination is restricted to the immediate vicinity of OW-422L. The TDEC continues to monitor the disposition of OW-422 and characterize the associated contaminant-level measurements. The locations of TDEC monitoring wells, ORNL, the Hood Ridge area, and the applicant's aquifer pumping test wells are shown in Figure 2.4.12-2.

2.4.12.3.4.2 *Staff's Technical Evaluation*

The staff reviewed the studies conducted for the CRBRP and requested that the applicant clarify the disposition of the wells and borings installed during the CRBRP activities. During a site audit conducted April 24–27, 2017 (NRC 2018-TN5915), the applicant provided the CRBRP site redress plan (DOE 1984-TN5282) for the staff's review; the plan was developed by the TVA and the DOE. The staff reviewed the CRBRP site redress plan and the ASLB's 1985 order (NRC 1985-TN5949) related to the review of the plan, which described the orderly shutdown of site construction activities for the CRBRP. The staff found that the redress plan and the ASLB order described the last known status of the site, but not the disposition of borings and wells used to characterize the CRBRP.

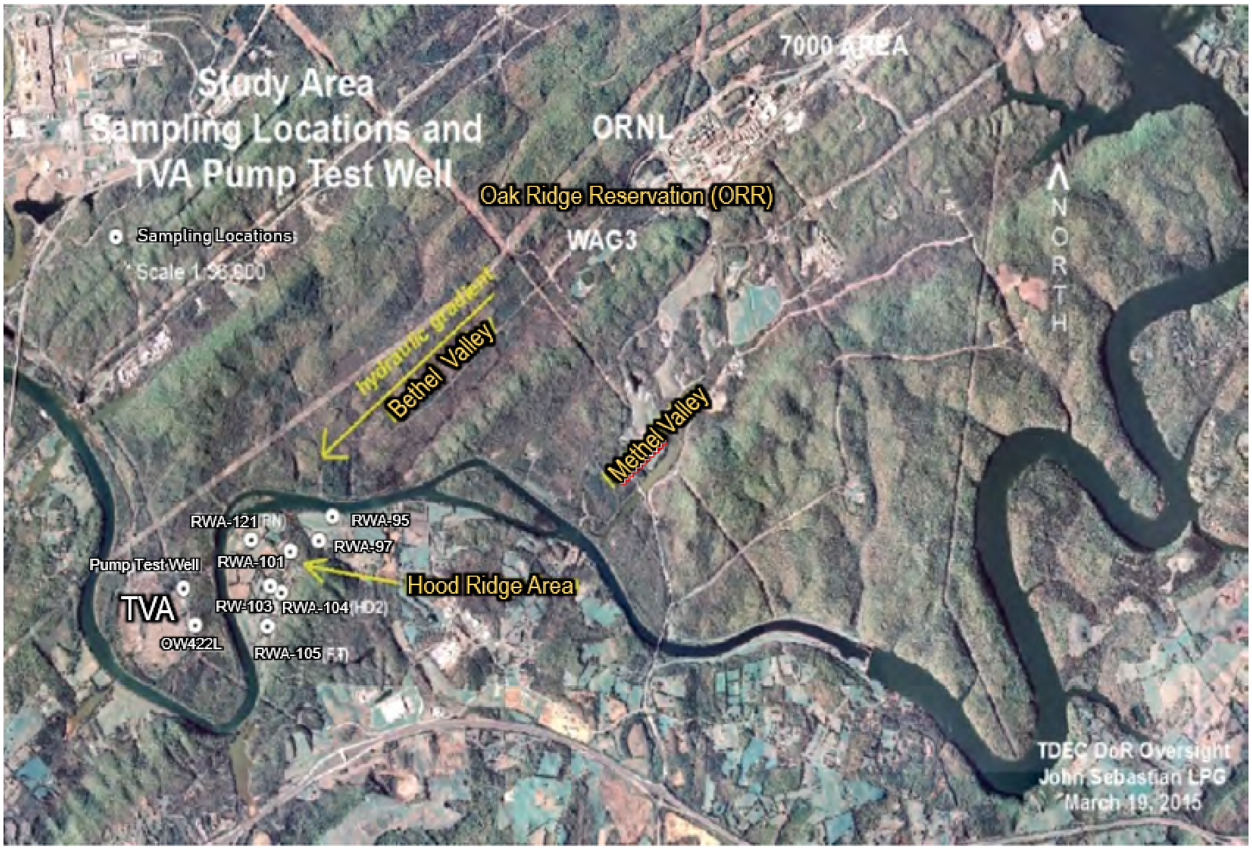


Figure 2.4.12-2 Study Area Sampling Locations and TVA Aquifer Pumping Test Well (after TDEC 2016-TN5350, Figure C.1).

The applicant noted that many of the CRBRP wells and borings would have been removed or destroyed during the site excavation. During the April 24–27, 2017 audit (NRC 2018-TN5915), the applicant indicated that the disposition of the CRBRP wells and borings installed is unknown. During 2018 site walkdown activities and subsequent searches, the applicant identified three of these wells. The applicant is currently investigating their disposition and evaluating them for closure in accordance with TVA and TDEC requirements (TVA 2018-TN5760). No evidence of CRBRP borings was found during the CRN Site characterization or field study activities prior to 2018. Improperly abandoned wells have the potential to channel shallow groundwater flow into lower levels of the aquifer system (i.e., "short-circuiting"). The applicant submitted supplemental information (TVA 2017-TN4987, TVA 2017-TN5950) to address the potential short-circuiting of liquid effluents and included this additional information in the SSAR (TVA 2017-TN5387).

The applicant stated that below the shallow groundwater system on the CRN Site there is no evidence of enhanced permeability or fractures in the deepest borings (TVA 2017-TN4987), including MP-101 near the center of the proposed power block, which is 540 ft bgs (260 ft NAVD88). The applicant noted a lack of dissolution cavities and healed (mineral sealed) fractures in other deep bore holes (MP-417 and MP-421 drilled to 320 ft NAVD88) on the CRN Site. The lack of permeability at depth is consistent with CRBRP studies (BRC 1985-TN5245), which describe permeabilities that are sharply reduced with depth as fracture discontinuities become tighter and less frequent, thereby strongly subduing hydraulic flow connections. The decreasing permeability is also consistent with the applicant's characterization of fracture

frequencies based on CRN Site borehole data (Figure 2.4.12-3). Within the supplemental information (TVA 2017-TN4987, TVA 2017-TN5950) provided, the applicant noted that minimal groundwater seepage was observed into and through the bottom of the CRBRP excavation, which measured approximately 480 ft long, 360 ft wide, and 100 feet deep (i.e., a bottom elevation of approximately 714 ft NAVD88), and the applicant included this information in the SSAR (TVA 2017-TN5387). The minimal seepage in the CRBRP excavation, which was 27 ft below the Clinch River median water level and below the water table, is consistent with decreasing fracture permeability with depth (Figure 2.4.12-3), as corroborated by CRN Site borehole investigations.

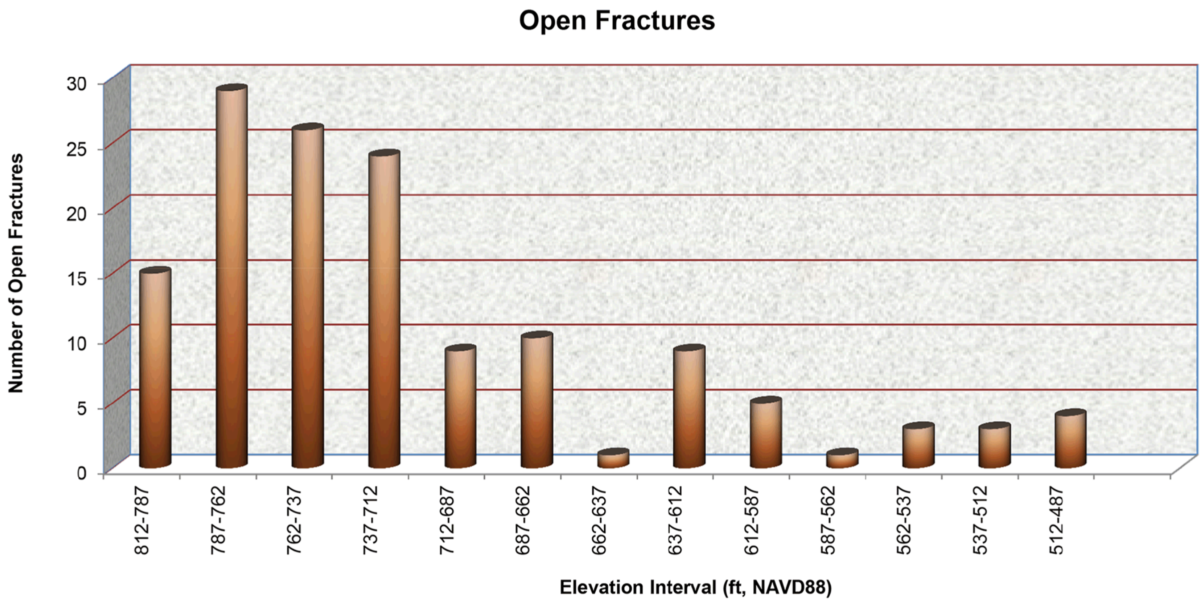


Figure 2.4.12-3 Frequency Distribution of Open Fractures with Elevation (reproduced from SSAR Figure 2.4.12-33 [TVA 2017-TN5387]).

The proposed CRN Site excavations will take place within the Chickamauga Group. In a response to a request for supplemental information (TVA 2017-TN4987), the applicant described two dominant flow systems within the Chickamauga Group—a shallow and a deep groundwater system as characterized for the adjacent Bethel Valley based on core fracture analysis (USGS 1995-TN6166)—and included this information in the SSAR (TVA 2017-TN5387). The shallow system was described as extending to a depth of approximately 150 ft and separated from the deep system by a subhorizontal interface that occurs where oxidized and reduced waters mix (Nativ et al. 1997-TN6010). In their supplemental response (TVA 2017-TN4987), the applicant noted that total dissolved solids (TDS) of typically less than 5,000 mg/L in the shallow groundwater zone are characteristic of TDS measurements for the CRN Site, which range from 290 to 1,100 mg/L over a depth range of 28 to 130 ft bgs. Consistent with CRN Site samples, the staff notes that TDS measurements of 497 mg/L were obtained from the deepest sample depth (160 ft bgs) during the CRBRP investigations (USGS 2004-TN6168). The TDS measurements characteristic of the CRBRP and CRN Site investigation borings indicate that the borings for these investigations remained within the shallow groundwater system on the CRN Site.

During the monitoring period (September 2013 to August 2015), groundwater gradients from OW-417 U/L were consistently upward at this well pair, which is adjacent to the Clinch River. The upward groundwater gradient (Figure 2.4.12-4) exhibited no observable correlation with the Clinch River stage over the monitoring period, indicating steady-state conditions. The consistent downward gradients in the upland areas of the site suggest precipitation recharge areas (e.g., at OW-202U/L/D well cluster) and upward hydraulic gradients near the Clinch River (e.g., at OW-417U/L); this indicates that the Clinch River acts as a discharge point for the shallow groundwater system flow from the CRN Site.

This trend is consistent with gradients near the Clinch River, as observed in studies conducted at the nearby ORR (Bechtel Jacobs Company 2011-TN6169; Dorsch and Katsube 1999-TN6036), indicating upward groundwater gradients toward the Clinch River at depth (Figure 2.4.12-5).

Given the low and decreasing fracture permeabilities of the deeper zones beyond 712 ft NAVD88, TDS measurements characteristic of the shallow groundwater system, and upward groundwater gradients indicating groundwater discharge to the Clinch River, the staff finds that the applicant's evaluation acceptably bounds potential short-circuiting pathways.

The staff reviewed the disposition of groundwater contamination observed in well OW-422L, and during an April 24–27, 2017 audit (NRC 2018-TN5915), the staff discussed the disposition of the well with the applicant. The applicant indicated that the groundwater contamination and associated monitoring and sampling of the well continues to be under the purview of TDEC in cooperation with the applicant. Past TDEC sampling results (TDEC 2016-TN5350) from the applicant's wells have indicated that radionuclides are present at or below detection limits and drinking water Maximum Contaminant Level-Derived Concentration (MCL-DC) levels in CRN Site wells PT-PW and OW-422L. TDEC (2016-TN5350) and DOE (DOE 2017-TN6170) studies have indicated that low levels of radionuclides prevalent in downgradient wells in the Hood Ridge area have likely migrated off the ORR toward the Hood Ridge area and OW-422L in the past. The staff confirmed that the radionuclides present are consistent with ORR operations and waste disposal practices that commenced in the 1940s. The extent of the resulting legacy contamination in the vicinity of the ORR is being characterized by ongoing DOE remediation and monitoring studies (DOE 2017-TN6170).

Based on a review of the CRN Site investigation information, the staff determined that the applicant's spatial extent of the vertical (borehole and well) data, associated aquifer test data, and description of the hydrogeology are acceptable for characterizing the CRN Site groundwater flow system.

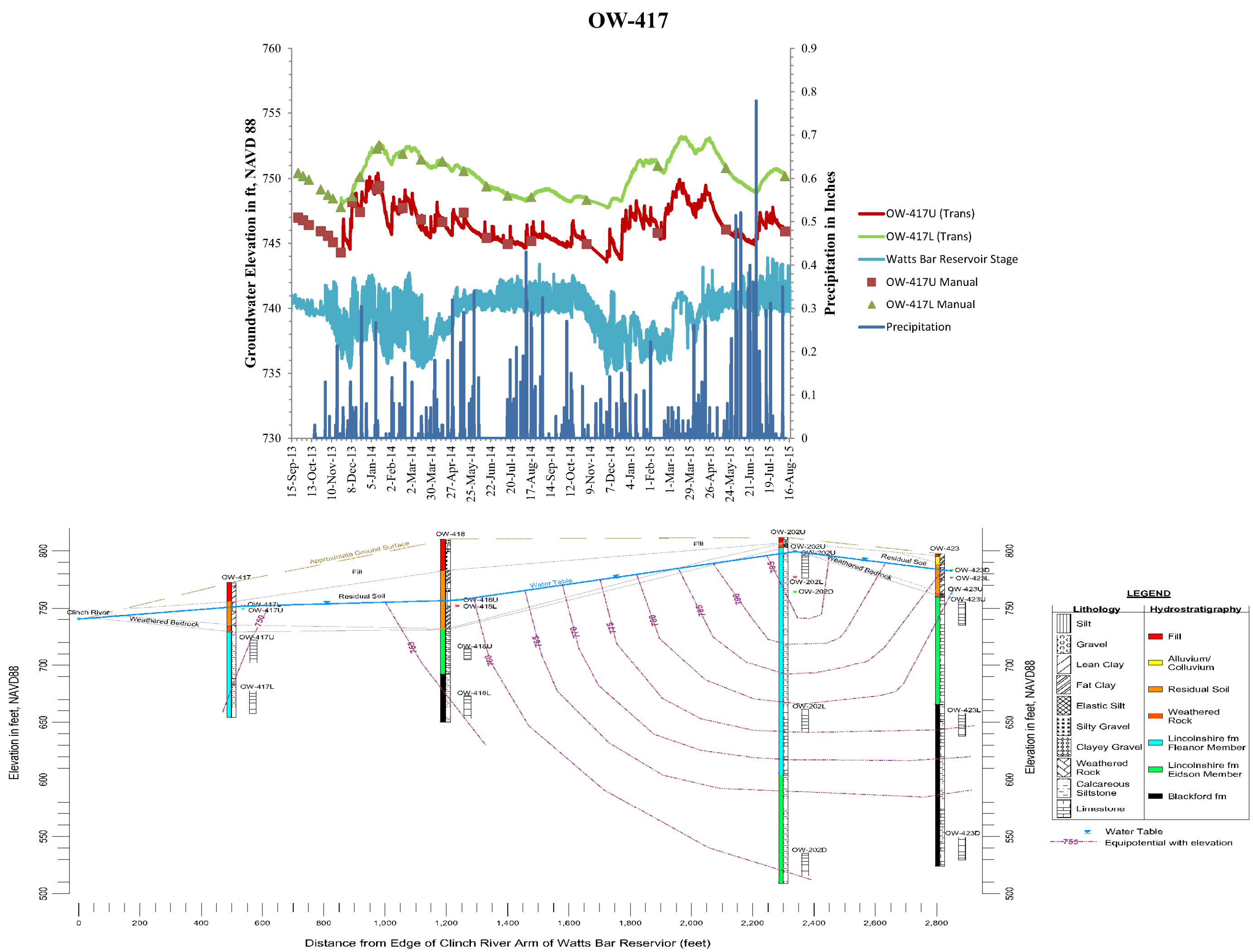
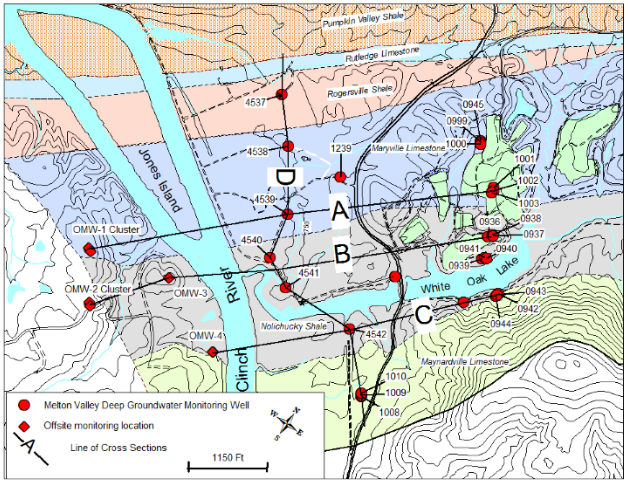
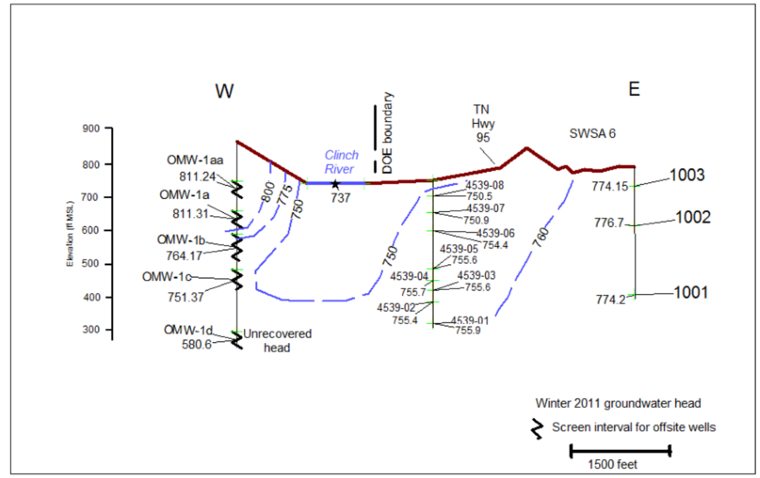


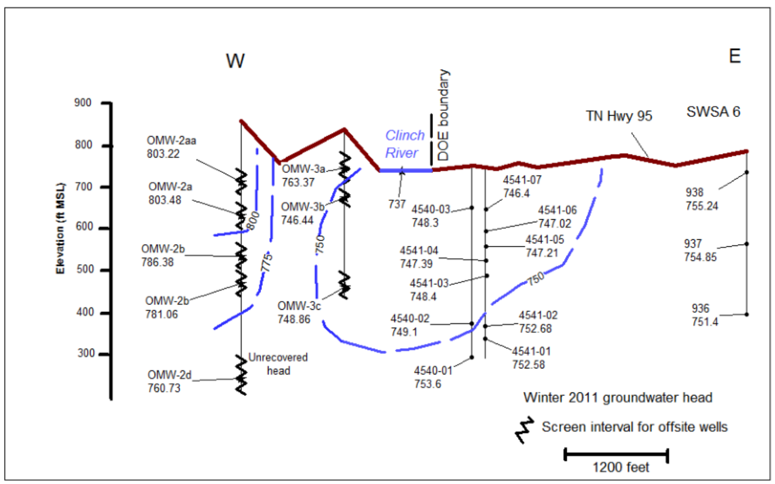
Figure 2.4.12-4 Hydrograph of OW-417 Well Pair (top) and, (bottom) Hydrologic Cross Section through the Clinch River, OW-417, OW-418, OW-202, and OW-423 from Left to Right (reproduced from Figures 2.4.12-29 and 2.4.12-32 [TVA 2017-TN5387]).



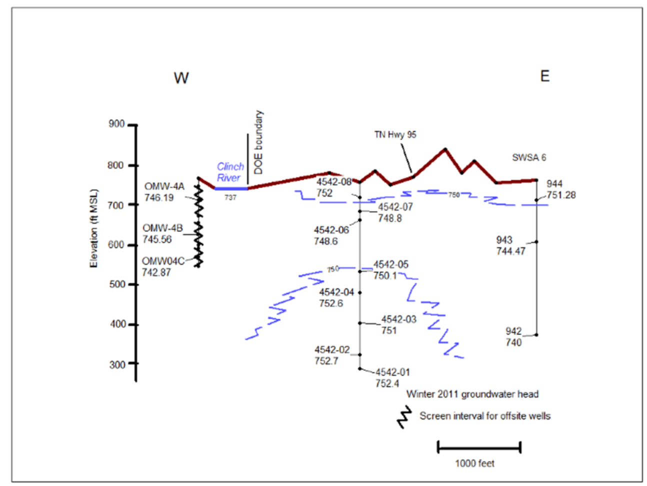
a) Groundwater well transects across the Clinch River



b) Hydrologic section along transect A



c) Hydrologic section along transect A



d) Hydrologic section along transect A

Figure 2.4.12-5 Location of Wells and Hydrologic Transects Along the Clinch River and, Cross Sections Along Transects A, B and C (after Bechtel Jacobs Company [2011-TN6169], Figures 7, 8, 9, and 10).

2.4.12.3.5 Groundwater Sources and Sinks

The applicant described the regional, local, and site-specific discharge, recharge areas, mechanisms, and characteristics of the groundwater flow system.

2.4.12.3.5.1 *Information Submitted by the Applicant*

The applicant described precipitation as the primary source of surficial recharge to the aquifer system with minor contributions from the Clinch River during high stages. As described above, the applicant cited a study by the DOE (Bechtel Jacobs Company 2011-TN6169) indicating discharge to the Clinch River from the surrounding shallow groundwater flow system in the vicinity of the ORR (Figure 2.4.12-5) consistent with patterns on the CRN Site.

During the April 24–27, 2017 site safety audit (NRC 2018-TN5915) and subsequent discussions with the applicant, the staff noted that a study by TDEC (2016-TN5350) indicated that the CRN Site pumping test performed on March 21–24, 2014, likely influenced the groundwater flow field in the Hood Ridge area approximately 3,000 ft east of the pumping well and across the Clinch River (Figure 2.4.12-2). The staff noted that the CRN pumping test's ability to influence wells across the Clinch River was contrary to the applicant's conceptual model of the Clinch River as a hydraulic boundary for the CRN Site. In response (TVA 2017-TN4987), the applicant evaluated the TDEC (2016-TN5350) study. The applicant stated that TDEC based its conclusion on contaminant sampling patterns obtained from three separate sample events (October 29, 2013, March 25, 2014, and July 22, 2014) at Hood Ridge wells over an approximately 9-month period. The applicant noted that the CRN Site pumping test occurred over a 72-hour period from noon on March 21, 2014, to noon on March 24, 2014. The applicant stated that while selected groundwater contaminant measurements may have exhibited trends over the 9-month interval of the three sampling periods, no consistent or discernable trend for groups of similar contaminants such as volatile organic compounds or radionuclides (technetium-99 [Tc-99] and strontium-90) could be correlated with the pumping test. The applicant stated that the lack of discernable trends in the measured contaminant levels from the three sampling events in the TDEC study (2016-TN5350) precludes the conclusion that the CRN Site pumping test influenced water quality in the Hood Ridge area. Based on CRN Site wells monitored during the pumping test, the applicant described the pumping test radius of influence as being limited to approximately 150 ft from the pumping with a vertical influence limited to a depth range of approximately 160 to 248 ft bgs. The applicant stated that the Hood Ridge area wells (RWA-121 and RWA-104), identified as having potential contaminant-level trends correlated with the CRN Site pumping test, are across the Clinch River and approximately 3,000 ft away from the pumping test well. The applicant further stated that these wells have depths of 400 to 610 ft, with casing depths of 105 to 126 ft, and are beyond the influence demonstrated by the CRN Site monitoring wells near the pumping well.

The applicant described current and projected groundwater use. The applicant characterized surface water as the primary source of water for all uses in the Tennessee River valley accounting for more than 98 percent of total withdrawals with groundwater providing the remainder. No sole-source aquifers were identified by the EPA in the study area. The applicant summarized groundwater withdrawals in the study area as being 3.5 Mgd, which is generally trending downward over time by category (i.e., industrial, public supply, and irrigation). The applicant included information in the SSAR about local groundwater use and well characteristics within a 1.5 mi radius of the CRN Site (TVA 2016-TN5018).

The applicant stated that the proposed plant design does not require groundwater for plant operations or potable use. The applicant stated that makeup water will be sourced from Clinch River surface water and there are no current or projected groundwater users on the CRN Site (SSAR Subsection 2.4.12.1 "Description of Onsite Use" [TVA 2016-TN5018]). Therefore, the applicant concluded that groundwater resources would not be affected by plant operations.

2.4.12.3.5.2 *Staff's Technical Evaluation*

As described in FSER Section 2.4.12.3.4, the staff determined that gradients observed in well pairs and the spatial groundwater gradient pattern over the CRN Site are consistent with the recharge in central upland areas of the site and discharge of the CRN Site shallow groundwater to the Clinch River.

The staff reviewed the TDEC monitoring report (TDEC 2016-TN5350) and associated contaminant-level trends with respect to the potential influence of the CRN Site pumping test. The staff determined that the applicant's evaluation of the contaminant-level measurement trends (TVA 2017-TN4987), coupled with the limited temporal and spatial influence of the CRN pumping test as described in the SSAR (TVA 2016-TN5018), provide an acceptable rationale for the applicant's conclusion that the pumping test influence is limited to an area within the CRN Site boundary.

Based on the staff's review of the PPE, the operation of the proposed units would not use groundwater for any safety-related purposes, and potable water would be obtained from public supplies. Because no pumping for groundwater use will take place on the CRN Site, the ambient groundwater flow field would not be significantly altered. As included in the SSAR Section 2.4.12 (TVA 2017-TN5387), the applicant provided a discussion of individual groundwater users and well characteristics within a 1.5 mi radius of the CRN Site (TVA 2017-TN5918). The staff finds the applicant's description of groundwater use on the CRN Site and in the site vicinity to be acceptable.

2.4.12.3.6 Groundwater Flow Directions

2.4.12.3.6.1 *Information Submitted by the Applicant*

As discussed in FSER Section 2.4.12.3.4, groundwater gradients and flow patterns indicate recharge in the central portion of the CRN Site and shallow groundwater discharge to the corresponding drainage features and the adjacent Clinch River. The applicant characterized pre-development groundwater flow directions from the CRBRP PSAR (BRC 1985-TN5245) as being generally toward the southeast or southwest from the center of the site based on CRBRP monitoring wells with long screen intervals, which provide an average water level over the monitoring interval. In general, the CRN Site investigation water levels and flow directions agreed with the CRBRP investigation, indicating flow toward the southeast and southwest from the CRBRP excavation area. The applicant calculated hydraulic gradients ranging from approximately 0.03 to 0.17 ft/ft over the December 2013 to August 2015 period of record for various transects and wells and developed maximum potentiometric contour maps based on maximum water levels for the period of record.

Regionally, the applicant cited trends in the nearest USGS wells. Water-level fluctuations were noted as being approximately 5 ft over a period of several years. The applicant noted that observed groundwater levels vary on the CRN Site from 10 to 25 ft and that maximum water levels occur in January/February. The applicant digitally recorded cluster well water levels at

five locations. Wells in these clusters show correlations with changes in the Clinch River stage, but the changes correlated primarily with precipitation events. Groundwater-level responses to precipitation events were noted in all of the CRN Site wells.

2.4.12.3.6.2 _Staff's Technical Evaluation_

The staff reviewed the information evaluated in the ESPA and found the applicant's characterization of groundwater gradients and flow patterns to be acceptable. The applicant provided acceptable hydrogeologic descriptions and references in the SSAR (TVA 2016-TN5018).

2.4.12.3.7 Aquifer Properties

The applicant performed onsite aquifer testing and laboratory testing of rock and soil samples collected during the CRN Site investigation. Effective porosities for the CRN Site were based on DOE studies characterizing the same hydrogeologic units found at the adjacent ORR (Dorsch and Katsube 1999-TN6036).

2.4.12.3.7.1 _Information Submitted by the Applicant_

Based on fracture frequency analysis of boreholes, the applicant stated that the fracture density decreases with depth over three general elevation zones: (1) pervasive fractures from 812 to 712 ft, (2) moderately fractured from 712 to 612 ft, and (3) slightly fractured from 612 to 487 ft (Figure 2.4.12-3). The applicant noted that fracture density in the upper zone is likely under-reported because casing on the upper end of boreholes masks the fractures in this zone. The applicant noted that the decreasing fracture density with depth is consistent with CRBRP investigations (BRC 1985-TN5245) and studies conducted on the ORR, which compare hydraulic conductivities with the depth of the testing interval (Tucci 1992-TN5034; Moore 1991-TN6034; Bittner and Dreier 1991-TN6146).

The applicant performed 41 packer tests in 12 boreholes; 19 tests yielded no analysis (5 tests exhibited flow by passing the packers and 14 had negligible formation flow rates). The packer tests resulted in a geometric mean for hydraulic conductivity of 0.44 and 0.54 ft/day for the Knox (9 tests) and Chickamauga (13 tests) intervals, respectively. In general, the decreasing hydraulic conductivities below a depth of 150 ft bgs are consistent with decreasing fracture frequency.

The applicant conducted slug (or sudden water displacement) tests in the most fractured (permeable) portion of selected observation well intervals. The applicant noted that the representative hydraulic conductivity of the low-permeability intervals on the ORR is 8.7×10^{-8} m/day (2.8×10^{-7} ft/day) indicating that negligible flow occurs through the rock matrix and fracture flow predominates. In general, the geometric mean of the Knox (0.14 ft/day for 6 tests) and Chickamauga (0.13 ft/day for 20 tests) results are in agreement with the values derived for the packer tests described above. Although the slug test values exhibit a wide range of values, the hydraulic conductivity exhibited a general trend of decreasing with depth. The applicant stated that the broad range may be due to the long length of the test intervals compared to the packer tests; longer lengths are representative of a greater variety of aquifer material.

The applicant performed a pumping test and included the data and analysis in the SSAR as Appendix 2.4.12B (TVA 2016-TN5018). The test included pumping test well PT-PW and nine observation wells. The pumping well was screened in the calcareous siltstone (Fleanor

Member) and limestone (Eidson Member) of the Lincolnshire Formation, and the Blackford Formation (siltstone, limestone, and dolomitic limestone) within the Chickamauga Group. The pumping test was performed over a period of 72 hours (from noon on March 21, 2014 to noon on March 24, 2014) at an average pumping rate of 14.5 gpm. The applicant stated that the highest transmissivity and hydraulic conductivity resulting from the test was for a well (OW-423L) located along the strike (N52°E) of the bedding planes, while analysis for wells perpendicular to the bedding plane (PT-OW-U2 and PW-OW-L2) yielded transmissivities and conductivity values that were an approximate order of magnitude lower that those along the strike. The higher permeabilities along the strike of the bedding planes are consistent with the principal groundwater flow direction along the strike. In general, the hydraulic conductivities derived for wells oriented perpendicular to the strike were an order of magnitude lower than those calculated (2.6 ft/day) for OW-423L. Based on the position and distance of the pumping test observation wells relative to the pumping well, the applicant noted that the pumping influence of PT-PW was limited to a radius of approximately 150 ft.

Based on petrophysical testing of rock samples on the ORR similar to the aquifer material on the CRN Site, the mean effective porosity was determined to be approximately 4 percent (0.04). The applicant summarized best estimate unit weights ranging from 120 to 175 lb/ft^3 and specific gravities ranging from 2.75 to 2.8 based on rock and soil samples, as described in SSAR Table 2.5.4-21 (TVA 2016-TN5018). The applicant noted that the properties of the backfill to be used for site construction will be established in the COLA, as described in SSAR Section 2.5.4.5.3, "Backfill Sources" (TVA 2016-TN5018).

The applicant stated that shallow groundwater is characteristic of mixed cation-bicarbonate water grading to sodium-bicarbonate at intermediate depths and sodium-chloride (saline) water at deep depths (i.e., below a depth of approximately 100 m [328 ft]). Information about an ORR well adjacent to the northwestern CRN Site boundary (Nativ et al. 1997-TN6010) indicated that the saline water is at an approximate depth of 126 m (413 ft). None of the CRN Site wells intercepted the saline layer characteristic of the deep groundwater system.

2.4.12.3.7.2 *Staff's Technical Evaluation*

Consistent with the applicant's evaluation of aquifer properties, ORR studies (Moore 1991-TN6034; Tucci et al. 1991-TN6011; Bittner and Dreier 1991-TN6146) confirm that most groundwater flow is transmitted through a layer of shallow fractures near the water table, this open fracture density decreases with depth, and only a small fraction (approximately 1 percent) reaches the lower portion of the aquifer system (greater than 250 ft depth) (Tucci 1992-TN5034).

During the April 24–27, 2017 NRC site audit (NRC 2018-TN5915), the applicant and staff discussed the results of the packer, slug, and aquifer tests. The staff noted that the slug test values are an estimate of the local hydraulic conductivity in the area surrounding the well, which may be affected by disturbance from drilling activity; therefore, significant variability in the slug test values derived from water-level observations are expected. The packer and aquifer test results are more representative of a larger volume of the aquifer and thus are more representative of average conditions. The staff reviewed the applicant's analysis of the aquifer test data and results and found the applicant's evaluation acceptable. Because the studies used to derive the CRN Site's effective porosity are from the ORR adjacent to the site and are within the same shallow groundwater system aquifer material as that of the CRN Site, the staff finds the applicant's characterization of the porosity acceptable.

The staff determined that the applicant's characterization of the hydrogeochemical characteristics of the aquifer system is acceptable and consistent with studies performed on the ORR (Nativ et al. 1997-TN6010) and those by the DOE (Bechtel Jacobs Company 2011-TN6169).

The staff notes that the construction backfill properties will be established in the COLA, as described in SSAR Section 2.5.4.5.3, "Backfill Sources" (TVA 2016-TN5018). As discussed in FSER Section 2.5.4.1.5, "Excavation and Backfill," the staff is tracking this issue as COL Action Item 2.5-8.

2.4.12.3.8 Subsurface Pathways and Monitoring or Safeguard Requirements

2.4.12.3.8.1 *Information Submitted by the Applicant*

The applicant noted that the topographic high of Chestnut Ridge creates a groundwater divide, while the Clinch River serves as the primary discharge point for the CRN Site shallow groundwater system. SSAR Section 2.4.12.3, "Subsurface Pathways," provides site-specific information supporting the premise that the Clinch River is a sink for shallow groundwater migrating from the CRN Site (TVA 2016-TN5018). The applicant's rationale included: a demonstrated lack of dissolution and fracture (i.e., permeability) features at depth, CRBRP excavations below the water table and the bottom of the Clinch River exhibiting negligible groundwater inflow, and CRN Site groundwater gradients consistent with those of DOE studies (Bechtel Jacobs Company 2011-TN6169) showing the Clinch River to be a hydrologic boundary.

The applicant used a groundwater travel time of 359 days based on advective transport parameters derived from aquifer tests in the shallow aquifer and hydraulic gradients derived from observed groundwater levels. The applicant stated that groundwater flow in the lower portion of the shallow groundwater system is controlled by discrete fractures and that over 90 percent of the groundwater flow occurred in the upper zone. The applicant assumed a postulated receptor location at the Clinch River site boundary located at the closest distance (1,400 ft) from the edge of the proposed power block. Based on a maximum hydraulic conductivity (2.6 ft/day), a mean hydraulic gradient (0.07 ft/ft), a mean effective porosity (0.05), and a 1,400 ft receptor distance, the applicant calculated a linear velocity of 3.90 ft/day and the resulting travel time of 359 days to the postulated receptor point at the Clinch River. The applicant's characterization of advective transport was based on site-specific data and parameters and porosities derived from ORR studies (Dorsch and Katsube 1999-TN6036) for the same aquifer material as that found at the CRN Site.

In the SSAR (TVA 2016-TN5018), the applicant committed to following NRC-endorsed NEI 07-07 groundwater protection initiative (TVA 2017-TN6171) for performing groundwater monitoring consistent with this initiative, which is an acceptable approach to help minimize contamination. The NEI 07-07 groundwater protection initiative identifies actions for improving a utility's management and response to instances where the inadvertent release of radionuclides may result in low but detectable levels of plant-related materials in subsurface soils and water, and describes an acceptable site groundwater monitoring program (TVA 2017-TN6171). The applicant described the groundwater level and geochemical monitoring that will take place during construction and plant operations. Consistent with NEI 07-07, the applicant will establish an onsite groundwater monitoring program in the COLA to ensure timely detection of inadvertent radiological releases to groundwater. The applicant states in the SSAR that the

operational accident monitoring includes quarterly sampling of groundwater from downgradient bedrock and backfill observation wells (TVA 2016-TN5018).

2.4.12.3.8.2 _Staff's Technical Evaluation_

As described in FSER Sections 2.4.12.3 and 2.4.12.3.5, the applicant provided further rationale (TVA 2017-TN4987, TVA 2017-TN5950) for describing the Clinch River as a hydrologic boundary for CRN Site shallow groundwater. The staff reviewed the applicant's information, including the significant decrease in cavities and contiguous fractures below an elevation of 720 ft NAVD88; CRBRP excavations below the water table and the bottom of the Clinch River, which exhibited negligible groundwater inflow; and potentiometric head relationships developed for nearby DOE studies (Bechtel Jacobs Company 2011-TN6169) that are consistent with CRN Site groundwater gradients. This information indicates that the Clinch River is a hydrologic boundary. Based on the staff's review of the site-specific information provided by the applicant and information contained in DOE studies, the staff found the applicant's rationale to be acceptable.

During the NRC April 24–27, 2017 site audit (NRC 2018-TN5915), the staff requested that the applicant clarify the SSAR reference to the NEI 07-07 groundwater initiative for evaluation of monitoring and safeguard requirements at the time of the proposed plant operation. The applicant included this information (TVA 2017-TN6171) in the SSAR (TVA 2017-TN5387). Before the start of operations, the applicant will select observation wells to be included in the monitoring program based on well condition, the well position relative to the proposed plant site and adjacent wells, and the well location relative to construction and plant operations. The applicant will also monitor field parameters (pH, temperature, specific conductance, oxidation-reduction potential, and dissolved oxygen), major cations and anions, TDS, silica, and additional water-quality parameters, as needed.

As discussed in FSER Section 2.4.12.3.4, radionuclides characteristic of past ORR activities have been identified as being present in TDEC sampling of CRN Site wells (TDEC 2016-TN5350). While NEI 07-07 identifies applicant actions necessary for implementation of a timely and effective groundwater protection program (TVA 2017-TN6171), the presence of pre-existing radionuclide concentrations on the CRN Site would make determination of a potential accidental release inconclusive or indeterminate without initial background concentrations to differentiate existing concentrations from accidentally released radionuclide concentrations.

Consistent with 10 CFR 20.1406. "Minimization of contamination" (TN283), the staff identified COL Action Item 2.4-3 to address future site characterization data and groundwater monitoring plans and to minimize the potential for release of contamination from accidental releases:

- COL Action Item 2.4-3: An applicant for a COL or CP that references this ESP should establish, as part of its plan to minimize contamination in accordance with 10 CFR 20.1406, a baseline for background radionuclide concentrations.

2.4.12.3.9 Subsurface Hydrostatic Loading and Dewatering

2.4.12.3.9.1 _Information Submitted by the Applicant_

The applicant developed two two-dimensional groundwater profile models along the geologic strike (principal flow direction) of the bedding planes to estimate maximum groundwater levels. Both models are representative of the stratigraphy within the Chickamauga Group; the northern site profile incorporated the Fleanor Shale and the southern site profile incorporated the Benbolt

Formation. The applicant based the model parameters primarily on CRN Site investigations, past CRBRP investigation information, and studies conducted by ORNL in Melton Valley (e.g., Rothschild et al. 1984-TN6172; Moore and Young 1992-TN6033; SAIC 1995-TN6028). The surface elevations along the model profile were extracted from Tennessee Light Detection and Ranging data sets (TNGIS 2018-TN6173). From upper top layers to bottom layers, the groundwater profile models consist of six layers, including a top fill layer, a soil layer, a highly fractured bedrock layer, and three lower layers of progressively decreasing fracture density. A uniform hydraulic conductivity was used for each of the six layers. A constant head boundary was assigned to the Clinch River with an elevation set at approximately 741.0 ft NAVD88, which is an approximate average of the regulated tailwater values of the Melton Hill Dam. Below an elevation of 658 ft NAVD88, the model assumed no flow, which was based on the trend of decreased fractures and hydraulic conductivity with depth. The applicant calibrated the profiles by varying hydraulic conductivity and recharge within the ranges of the site studies to simulate the observed heads, which were measured during subsurface investigations. Groundwater levels used for the model calibration included 34 observation wells, which included 6 locations consisting of two-well clusters and 8 locations consisting of three-well clusters. From the calibrated model, the sensitivity of the model parameters was evaluated by adjusting hydraulic conductivity within the range of aquifer test values and precipitation recharge within the ranges of site studies (Bailey and Lee 1991-TN6032) to evaluate the maximum groundwater level.

For the post-construction profile models, modifications were made to the pre-construction model, including the addition of an extra layer representing granular backfill extending to the base of the reactor technology PPE excavation to determine maximum head at the proposed foundation base. Surface elevations were based on the PPE minimum site grade elevation of 821.0 ft NAVD88. Building foundations were simulated as no-flow groundwater model cells and included a radwaste building with foundation embedment at 818 ft NAVD88, a reactor building foundation embedment elevation selected at approximately 681 ft NAVD88 for the deepest reactor technology PPE excavation and at approximately 770 ft NAVD88 for the shallowest reactor technology PPE excavation, and an auxiliary building at approximately 748 ft NAVD88 for the deepest reactor technology excavation in the PPE and about 770 ft NAVD88 for the shallowest reactor technology excavation in the PPE. Independent of the PPE, the embedment depth of the turbine building was assumed to be at an elevation of 814 ft NAVD88.

Based on the calibrated and post-construction models, the applicant determined a post-construction recharge rate of 8.76 in./yr resulting in a range of maximum heads from 807.3 to 816.1 ft, which is consistent with the PPE maximum groundwater elevation of 816.1 ft for hydrostatic loading.

2.4.12.3.9.2 *Staff's Technical Evaluation*

The staff reviewed the applicant's conceptual model, post-construction groundwater model parameters, and model surface elevations and determined that the models acceptably represent the CRN Site topography and hydrogeology. The staff determined that the simulated post-construction conditions for a shallow and deep embedment depth bound the proposed PPE for the CRN Site and acceptably represent maximum groundwater levels based on the resulting model calibration and parameter sensitivity simulations.

Within the area of the power block, the maximum measured water level during CRN Site monitoring (September 2013 through March 2014) was 800.3 ft at OW-201U. The staff notes that the monitoring period includes the relatively wet year of 2013 when the total annual rainfall was approximately 37 percent higher than the area's average annual rainfall (UTIA 2014-

TN6183). The staff notes that maximum observed ground levels during the September 2013 to August 2015 monitoring period would be relatively high and near an overall maximum for the CRN Site because of the relatively high precipitation during the monitoring period. Based on the applicant's groundwater modeling results, which are consistent with water-level observations over the monitoring period, the staff finds that the applicant's determination of the maximum groundwater level is acceptable.

2.4.12.3.10 Construction Dewatering

2.4.12.3.10.1 *Information Submitted by the Applicant*

The applicant described dewatering plans based on the CRBRP excavation studies (BRC 1985-TN5245), which included potential horizontal gravity drains in excavated rock faces and sump pumping around the base of the excavation. The excavation of the CRBRP power block to an elevation of 714 ft NGVD29 (713.6 ft NAVD88), or below the water table and 6 ft below the invert of the Clinch River, showed no evidence of continuous groundwater flow into the excavation (BRC 1985-TN5245). The applicant noted that localized grouting may be necessary if high groundwater flows are encountered. The applicant stated that these methods localized to the power block area, coupled with the Clinch River forming a shallow groundwater system boundary on the east, south, and west side of the site, would limit the impact of dewatering to the immediate vicinity of the power block excavations.

In a response (TVA 2017-TN4987) to the staff's request for supplemental information related to dewatering (NRC 2018-TN5915), the applicant provided further bases for their conclusion that there would be no anticipated impacts on offsite groundwater users and included this information in the SSAR (TVA 2017-TN5387). As discussed in Section 2.4.12.3.5, TDEC studies (TDEC 2016-TN5350) suggested potential hydraulic communication across the Clinch River based on the response of Hood Ridge area wells to the CRN Site pumping test (Figure 2.4.12-2). The applicant stated that the Hood Ridge area wells are approximately 3,000 ft away from the CRN Site pump test well, while the Clinch River is approximately 1,200 ft from the pump test well—far beyond the radius of pumping well influence of approximately 150 ft. The applicant stated that CRN Site observation wells near the Clinch River show an upward gradient (Figure 2.4.12-4), while wells in upland areas show downward gradients. This indicates that the Clinch River is a hydrologic sink for the shallow groundwater system of the site, which is consistent with the findings of past DOE studies (Bechtel Jacobs Company 2011-TN6169) (Figure 2.4.12-5). The applicant noted groundwater occurs primarily within 65 ft of the surface, and groundwater flow is negligible below 714 ft NAVD88 due to sharp reductions in fracture and cavity porosity (permeability) with depth. This is consistent with CRBRP investigations (Drakulich 1984-TN5940).

2.4.12.3.10.2 *Staff's Technical Evaluation*

The applicant evaluated potential dewatering using an estimated configuration of the nuclear island and support structures. The staff evaluated the CRN Site data including the pumping test data, TDEC reports (TDEC 2016-TN5350), and relevant DOE studies (Bechtel Jacobs Company 2011-TN6169), and determined that the applicant's evaluation of dewatering effects is acceptable.

The staff noted that the applicant would coordinate proposed dewatering actions associated with CRN Site construction activities with TDEC. The applicant described anticipated dewatering rates consistent with the negligible rates observed during the CRBRP excavation

activities (Drakulich 1984-TN5940). However, the applicant acknowledged that localized grouting may be necessary if groundwater flow into the excavation is higher than anticipated. The staff determined that the applicant's estimates of dewatering effects are consistent with CRN Site and CRBRP site characterizations and are therefore acceptable.

2.4.12.4 *Conclusion*

The staff reviewed the ESPA and confirmed that the applicant has demonstrated that the groundwater characteristics have no safety-related impact on the CRN Site, and no outstanding information is required to be addressed in the SSAR related to this section. As set forth above, the applicant has provided sufficient information pertaining to groundwater at the CRN Site. Further, the applicant has considered the most severe natural 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, in establishing site characteristics pertaining to groundwater that are acceptable for design purposes. Therefore, the staff concludes that the applicant has met the requirements related to groundwater in 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.20(c) (TN282), and 10 CFR 100.23(d) (TN282). The COL applicant will address COL Action Items 2.4-3 and 2.5-8.

2.4.13 Accidental Releases of Radionuclides in Ground and Surface Waters

SSAR Section 2.4.13, "Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters," considers the potential effects of relatively large accidental releases from systems that handle liquid effluents generated during normal plant operations (TVA 2016-TN5018). Such releases would contain relatively low levels of radionuclides but could be large in volume (e.g., several thousands of gallons). Normal and accidental releases are considered in the applicant's environmental report. The accidental release of radionuclides into groundwater and surface waters is evaluated based on the hydrogeological characteristics of the site that govern existing uses of groundwater and surface waters and their known and likely future uses consistent with SRP Section 2.4.13, "Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters" (NRC 2007/2018-TN5898).

The source term from a postulated accidental release of liquid waste is reviewed under SRP Section 11.2, "Liquid Waste Management" (NRC 2007/2018-TN5898), following the guidance in Branch Technical Position (BTP) 11-6, "Postulated Radioactive Releases Due to Liquid-containing Tank Failures" (NRC 2016-TN6196) and DC/COL-ISG-013, "Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks for Combined License Applications" (NRC 2013-TN5953),as incorporated into BTP 11.6, Revision 4. The source term is determined based on a postulated release from a single tank outside of the containment. The results of a consequence analysis are evaluated against SRP Section 11.2 (NRC 2007/2018-TN5898) and BTP 11-6 guidance (NRC 2016-TN6196) and the effluent concentration limits (ECLs) of Table 2, Column 2, in 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" (TN283). Under SRP guidance (NRC 2007/2018-TN5898), the ECLs of 10 CFR Part 20, Appendix B (TN283), are applied as acceptance criteria only for the purpose of assessing the acceptability of the results of the consequence analysis, and are not intended to be used for demonstrating compliance with the public dose limit in 10 CFR 20.1301 (TN283) and 10 CFR 20.1302 (TN283).

This section presents an evaluation of the following specific areas:

- alternate conceptual models of the hydrology that reasonably bound hydrogeological conditions at the site inasmuch as these conditions affect the transport of liquid radionuclide effluent in the groundwater and surface-water environment;
- a bounding set of plausible surface and subsurface pathways from potential points of an accidental release to determine the critical pathways that may result in the most severe impact on existing uses and known and likely future uses of groundwater and surface-water resources in the vicinity of the site;
- the ability of the groundwater and surface-water environments to delay, disperse, dilute, or concentrate accidentally released liquid radionuclide effluent during its transport; and
- any additional information required by the regulations discussed below in the Regulatory Basis section.

2.4.13.1 *Summary of Application*

In SSAR Section 2.4.13, the applicant provided the analysis of an accidental liquid release of effluents or radioactive wastes into groundwater at the CRN Site. The applicant's postulated accident scenario was combined with the conceptual site model to evaluate potential impacts on receptors if a catastrophic tank rupture were to occur during plant operations and instantaneously release radionuclides to the groundwater environment. The applicant's resulting calculated concentrations that would reach the potential surface-water receptors were then compared to the ECLs in 10 CFR Part 20, Appendix B (TN283). The applicant's calculated results were then assessed using the unity rule where the sum of the ratios of the calculated concentrations to the corresponding ECLs for all radionuclides in the effluent release may not exceed 1. Further, the dose to a member of the public in the nearest unrestricted area must meet 10 CFR 20.1301 (TN283) and 10 CFR 20.1302 (TN283) requirements.

2.4.13.2 *Regulatory Basis*

The relevant requirements of the NRC regulations for the pathways of liquid effluents in groundwater and surface waters, and the associated acceptance criteria, are described in SRP Section 2.4.13 (NRC 2007/2018-TN5898).

The applicable regulatory requirements for liquid effluent pathways for groundwater and surface water are as follows:

- 10 CFR 20.1301 (TN283), 10 CFR 20.1302 (TN283), and Table 2, Column 2, and Note 4 of Appendix B to 10 CFR Part 20 (TN283), as they relate to radioactivity in liquid effluents released to unrestricted areas and doses to offsite receptors located in unrestricted areas.
- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).

The staff also used the following acceptance criteria and sources identified in SRP Section 2.4.13:

- Alternate Conceptual Models: Alternate conceptual models of hydrology in the vicinity of the site are reviewed.
- Pathways: The bounding set of plausible surface and subsurface pathways from the points of release are reviewed.
- Characteristics that Affect Transport: Radionuclide transport characteristics of the groundwater environment with respect to existing and known and likely future users should be described.
- Consideration of Other Site-Related Evaluation Criteria: The applicant's assessment of the potential effects of site proximity hazards, seismic, and non-seismic events on the radioactive concentration from the postulated tank failure related to accidental release of radioactive liquid effluents to groundwater and surface waters for the proposed plant site is needed.
- DC/COL-ISG-013, "Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks for Combined License Applications" (NRC 2013-TN5953): Clarifies guidance defining the mechanism of the assumed tank failure, development of the radioactive source term, assumptions and level of conservatism used in the analysis, and the approach applied in assessing the radiological impacts. DC/COL-ISG-013 was incorporated into BTP 11-6, Revision 4 (NRC 2016-TN6196).
- BTP 11-6, Revision 4 (NRC 2016-TN6196): Provides guidance for assessing a potential release of radioactive liquids resulting from the postulated failure of a tank and its components, located outside of containment, and the effects of the release of radioactive materials at the nearest potable water supply, located in an unrestricted area, for direct human consumption or indirectly through animals, crops, and food processing.
- DC/COL-ISG-014, "Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks in Ground and Surface Waters for Combined License Applications" (NRC 2013-TN5952): Is a revision to SRP Section 2.4.13 (NRC 2007/2018-TN5898), which clarifies the radionuclide transport analyses methods in groundwater and surface water through the use of a structured hierarchical approach emphasizing the hydrogeologic conditions that control radionuclide transport.

The staff used current best practices to analyze groundwater transport of radioactive liquid effluents. In addition, the staff compared the hydrologic characteristics described in the ESPA to relevant sections of RG 1.113, "Estimating Aquatic Dispersions of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I" (NRC 1977-TN4788).

2.4.13.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.4.13 submitted by the applicant related to the accidental release of radioactive liquid effluents in groundwater and surface waters (TVA 2016-TN5018).

2.4.13.4 *Accident PPE Liquid Effluent Release Source Term*

The staff evaluated the applicant's methodology and basis for developing the accident PPE liquid effluent release source term used for the postulated accidental release of radionuclides to the aquifer system (groundwater) at the CRN Site.

2.4.13.4.1 Information Submitted by Applicant

The applicant provided radionuclides and their associated activities to create a composite or surrogate source term at the CRN Site for developing the accident PPE liquid effluent release source term in SSAR Table 2.0-5 (TVA 2016-TN5018). In the postulated accidental release of radionuclides to the groundwater, the applicant assumed that a 10,000 gal liquid radwaste tank would rupture and release 80 percent (8,000 gal) instantly into the groundwater system at a point outside of containment. No credit was taken for the travel time and the associated decay of radionuclides in traveling from the liquid waste management system to the saturated groundwater flow system, nor was credit taken for any mitigating design features. During an April 24–27, 2017 site audit (NRC 2018-TN5915), the applicant further explained their methodology and basis for evaluating source term information submitted by vendors from the four light-water-cooled SMR technologies considered for the postulated accidental release of radionuclides to the groundwater. The staff noted that the failed fuel fraction used by the applicant for the accident PPE liquid effluent source term was 1 percent, while the radionuclide concentrations and total inventory of radioactive materials based on BTP 11-6 guidance (NRC 2016-TN6196) suggests a 0.12 percent failed fuel fraction of the fuel producing power in a pressurized-water reactor. The applicant provided supplemental information about the basis for developing the accident PPE liquid effluent release source term (TVA 2017-TN5884).

2.4.13.4.2 Staff's Technical Evaluation

The staff reviewed the applicant's methodology and basis for developing the accident PPE liquid effluent release source term. The staff reviewed source term information from two vendors with preliminary designs that the applicant stated did not include features to mitigate a postulated accidental liquid release of radionuclides. Therefore, a site-specific analysis would be performed for these two vendor designs as part of the COLA. The staff also reviewed the applicant's comparison of source term information from these vendors and the justification for selection of radionuclides and activities in the surrogate plant to develop the accident PPE liquid effluent release source term. Further, the staff reviewed the applicant's comparison of the accident PPE liquid effluent source term at the CRN Site to that approved by the NRC in the Public Service Enterprise Group ESP, which considered four large light-water (pressurized- and boiling-water) reactor designs. Based on the above, the staff found that the applicant developed an accident PPE liquid effluent release source term that was reasonable for evaluating a postulated accidental release of radionuclides to the groundwater at the CRN Site. The calculated exposure pathway dose resulting from the postulated accidental liquid effluent release of radionuclides to the groundwater at the CRN Site is evaluated by the staff in FSER Section 2.4.13.4.7.

2.4.13.4.3 Receptors, Primary Conceptual Model, and Alternative Conceptual Model

The applicant considered a receptor at a point beyond the site boundary where the applicant has no administrative control. For the release, the applicant developed a primary conceptual model to evaluate the postulated radionuclide release and considered an alternative conceptual model for the release.

2.4.13.4.3.1 *Information Submitted by Applicant*

The nearest boundary where the applicant has no administrative control is the right bank (looking downstream) of the Clinch River. There are no surface-water users at this location. The applicant noted that the nearest surface-water intake is the City of Oak Ridge West End

Water Treatment Plant (WEWTP), which was idled in September 2014. The WEWTP is located near the northwestern CRN Site boundary. During an April 24–27, 2017 site audit (NRC 2018-TN5915), the applicant provided further information about the WEWTP, stating that the City of Oak Ridge has no plans to make use of the plant but retains the surface-water permit from the State of Tennessee (TVA 2017-TN6157).

For the primary conceptual model, the applicant assumed that the radionuclides released from the radwaste tank travel through the surface and into the backfill and pervasively fractured bedrock before reaching the Clinch River. The applicant assumed the shortest travel distance (1,400 ft) from the release point to the Clinch River. As an alternative conceptual model, the applicant considered groundwater discharge directly to surface drainages and runoff into the surface waters of the Clinch River; however, the applicant considered this conceptualization less conservative than the primary conceptual model because of added dilution from surface runoff before exiting the applicant's administrative control area. The applicant stated that the added dilution would result in radionuclide concentrations lower than those of the primary conceptual model.

The applicant stated that shallow groundwater flow underneath the Clinch River and resulting exposure to water users across the river is very unlikely based on (1) the absence of cavities and contiguous fractures below an elevation of 720 ft NAVD88; (2) the head relationships observed at the Melton Valley Exit Pathway monitoring wells (Bechtel Jacobs Company 2011-TN6169); and (3) the observed vertical hydraulic gradients that demonstrate that the Clinch River acts as a hydrologic sink. As further corroboration, staff determined the following, based on information provided by the applicant:

- There is no evidence of contiguous cavities or fractures originating from the power block area and extending below the Clinch River tributary of the Watts Bar Reservoir based on geologic core analysis from CRN Site subsurface investigations.
- The CRBRP excavation, completed to an elevation of 714 ft NGVD29 (713.6 ft NAVD88) and 6 ft below the invert elevation of the Clinch River tributary of the Watts Bar Reservoir, showed no evidence of any continuous groundwater flow; this is likely due to an absence of cavities and continuous fractures below an elevation of 720 ft NAVD88.
- Only 5 percent of the observed cavities fall below the elevation of 718.4 ft NAVD88, and the average elevation of observed cavities is 782.6 ft NAVD88.
- An analysis of site-specific geologic core analysis, fracture frequency analysis, and groundwater vertical gradient data provides no evidence supporting a pathway for radionuclide transport occurring underneath the Clinch River tributary of the Watts Bar Reservoir within the shallow groundwater system.

2.4.13.4.3.2 *Staff's Technical Evaluation*

The staff reviewed the primary conceptual model assuming that the radionuclide concentrations travel through the most permeable material of the backfill and pervasively fractured rock. The flow through these upper units is consistent with groundwater flow directions based on CRN Site monitoring data and studies, which show that more than 99 percent of the groundwater flow occurs in the upper 250 to 300 ft of the aquifer material within the study area (Tucci 1992-TN5034; Brahana et al. 1986-TN6149).

The staff reviewed the applicant's alternative conceptual model assuming direct discharge to surface water, seeps, and springs, and found the applicant's conclusion that there would be

lower radionuclide concentrations (less conservative) due to additional dilution from runoff to be acceptable. Because the seeps and springs flow primarily during wet periods, the applicant's assumption that additional dilution would take place due to precipitation runoff is acceptable.

As described above and discussed in FSER Sections 2.4.12.3 and 2.4.12.4, the applicant expanded upon the bases for the Clinch River as a CRN Site hydrologic boundary by providing site-specific supporting information (TVA 2017-TN4987, TVA 2017-TN5950). The staff reviewed and evaluated information related to the CRN Site, including pumping test results; groundwater gradients; previous TVA (Drakulich 1984-TN5940), DOE (Bechtel Jacobs Company 2011-TN6169), and TDEC (2016-TN5350) studies; and previous site boring logs. The staff confirmed that the SSAR's site-specific description of the hydraulics, hydrogeology, and boring information described as the basis for the Clinch River as a CRN Site boundary (TVA 2017-TN5387) is acceptable.

2.4.13.4.4 Radionuclide Transport Analysis and Estimation of Initial Concentrations

The applicant conducted a radionuclide transport analysis to estimate the concentrations and resulting radiometric dose from the postulated release scenario.

2.4.13.4.4.1 *Information Submitted by Applicant*

The applicant based the radionuclide transport analysis on methodology described in NUREG/CR-3332, "Radiological Assessment, A Textbook on Environmental Dose Analysis" (Till and Meyer 1983-TN6023). Using this methodology, the applicant derived the dilution factor as a function of time to find the minimum dilution factor to yield the maximum concentration for the instantaneous radwaste tank release to the Clinch River. The dilution factor, $D_{L,}$ is calculated as:

$$\mathrm{DL} = 1/\left[\frac{V_T}{\mathrm{Q}} \cdot \frac{\left(\mathrm{x}+\frac{\mathrm{U \cdot t}}{\mathrm{Rd}}\right)}{4 \cdot \sqrt{\frac{\pi \cdot \mathrm{Dx \cdot t3}}{\mathrm{Rd}}}} \cdot \exp\left(-\frac{\left(\mathrm{x}+\frac{\mathrm{U \cdot t}}{\mathrm{Rd}}\right)^2}{\frac{4 \cdot \mathrm{Dx \cdot t}}{\mathrm{Rd}}} - \lambda \cdot \mathrm{t}\right)\right]$$

where

D_L	=	dilution factor [C_0/C]
V_T	=	tank volume [L^3]
Q	=	flow rate of river [L^3/T]
x	=	distance [L]
U	=	groundwater pore velocity [L/T]
t	=	time [T]
R_d	=	retardation coefficient
D_x	=	α_L*U [L^2/T]
λ	=	radionuclide decay constant ($\lambda = \ln(2)/T_{1/2}$) [1/T]
$T_{1/2}$	=	radionuclide half-life [T]
α_L	=	longitudinal dispersivity [L].

The equation accounts for advection, dispersion, sorption (retardation), and radionuclide decay, in addition to dilution due to the groundwater mixing with the Clinch River at the point of release. The applicant introduced conservatism by decaying terms to 50 years to allow the peak activities of the daughter products to be used in the dose calculations. Further, time-to-peak

concentrations were evaluated by the applicant based on a transport travel time to the postulated receptor of less than 1 year for all peak concentrations, regardless of when the time-to-peak concentrations were calculated. This approach overestimates the total activity that would be released, because the parent radionuclide activities are not decreased while daughter products are increased. As described previously, all radionuclides except niobium (Nb)-93m and uranium (U)-235 reach peak activity within 50 years. Nb-93m has a relatively short (14-year) half-life and will not accumulate, thereby contributing negligible concentrations to the final estimated concentrations. U-235, which occurs from the decay chain of NP-239—plutonium (Pu)-239 to U-235m to U-235—would not occur for thousands of years and would be on the order of a million times lower than the ECL. As such, the U-235 would also have negligible effects on the final estimated concentrations.

2.4.13.4.4.2 *Staff's Technical Evaluation*

The staff reviewed the applicant's approach to estimating radionuclide transport in groundwater. The applicant used analytical methods in NUREG/CR-3332 (Till and Meyer 1983-TN6023) developed to simulate groundwater flow and radionuclide transport. The analytical equations consider the processes of advection, dispersion, sorption, and decay during the groundwater transport and dilution due to surface-water bodies intercepting the groundwater. The staff reviewed available publications that outline the methodology (Taylor and Guha 2017-TN6018) used in NUREG/CR-3332 (Till and Meyer 1983-TN6023) and confirmed that the radionuclide transport equations presented in SSAR Section 2.4.13 (TVA 2016-TN5018), as used by the applicant, were applied correctly to the radionuclide analysis. The staff notes that the applicant applied a tank volume fraction ($\boldsymbol{f}$) of (0.80) to the resulting radionuclide concentrations per BTP 11-6 (NRC 2016-TN6196), while the initial concentrations assumed a 10,000 gal tank. The applicant's methodology of assuming these initial concentrations results in a conservative estimate of the concentrations such that the dilution factor, D_L, is as follows:

$$\mathrm{DL} = \frac{1}{\left[\frac{f \cdot \mathrm{V}_T}{\mathrm{Q}} \cdot \frac{\left(\mathrm{x}+\frac{\mathrm{U \cdot t}}{\mathrm{Rd}}\right)}{4 \cdot \sqrt{\frac{\pi \cdot \mathrm{Dx \cdot t3}}{\mathrm{Rd}}}} \cdot \exp\left(-\frac{\left\{\mathrm{x}+\frac{\mathrm{U \cdot t}}{\mathrm{Rd}}\right\}^2}{\frac{4 \cdot \mathrm{Dx \cdot t}}{\mathrm{Rd}}} - \lambda \cdot \mathrm{t}\right)\right]}$$

where the terms are the same as those defined for the previous equation and $\boldsymbol{f}$ is defined as the tank volume fraction (0.80) released to the aquifer.

As discussed in the NRC CRN Site Audit Summary Report (NRC 2018-TN5915), the applicant provided a spreadsheet in native format incorporating radionuclide transport analysis calculations consistent with guidance in NUREG/CR-3332 (Till and Meyer 1983-TN6023). The staff performed confirmatory analyses of the applicant's approach to estimating radionuclide transport concentrations in groundwater for comparison with SSAR Table 2.4.13-5 (TVA 2016-TN5018). In the staff's confirmatory analysis, six radionuclides were selected for sampling: tritium, carbon-14, cobalt-60, Tc-99, iodine-129, and cesium-137. Dilution factors, D_L, were calculated with sorption ($R_d > 0$) and without sorption ($R_d = 1$) for each of the six radionuclides and compared with the equations, parameters, and assumptions used in the applicant's calculations. The minimum D_L (most conservative value) is determined by iteratively varying the time (t) in Equation 2.4.13-2 to find the smallest (most conservative) value of D_L that produces the largest radionuclide concentrations at the postulated receptor location, where the ECL ratios and exposure pathway doses to a member of the public are calculated. Based on the staff's review of NUREG/CR-3332 (Till and Meyer 1983-TN6023), the applicant's implementation of

guidance methods, and the applicant's site conceptualization, the staff determined the applicant's methodology and approach to be acceptable.

Based on the PPE developed with input from the four vendor technologies being considered in the SSAR, the applicant developed initial concentration estimates based on a failed fuel fraction of 1 percent (NRC 2018-TN5915). This is conservative because BTP 11-6 guidance states that a failed fuel fraction of 0.12 percent is sufficient for derivation of a source term (NRC 2016-TN6196). The applicant also conservatively assumed that parent and daughter products were at peak concentrations during the initial release, which maximized the concentrations of the source term for the postulated release. The applicant provided acceptable clarification of the basis for the accidental liquid effluent release source term and included this information (TVA 2016-TN5019; TVA 2017-TN5888) in the SSAR (TVA 2017-TN5387). Based on the applicant's conservative assumptions of limited dilution of radionuclides, conservative source term release, and initial concentration estimates, the staff determined the applicant's evaluation of radionuclide transport to be acceptable.

2.4.13.4.5 Input Parameters

The applicant used the transport parameters, as described below, to determine the dilution factor, D_L, as defined in Equation 2.4.13-1, for the postulated accidental release scenario.

2.4.13.4.5.1 *Information Submitted by Applicant*

The applicant used a tank release volume, V, of 8,000 gal based on a release of 80 percent of a 10,000 gal radwaste tank. For the groundwater pore velocity, U, a value (3.9 ft/day) was calculated as follows:

$$U = -\frac{K}{n_e} \cdot \frac{dH}{dx}$$

where the hydraulic conductivity, K, of 2.6 ft/day was based on the CRN Site aquifer pumping test, the effective porosity, n_e, of 0.0467 was derived from ORR studies (Dorsch and Katsube 1996-TN6035; Dorsch 1997-TN6019) and the hydraulic gradient, $\frac{dH}{dx}$, of 0.07 was calculated as the mean from CRN Site data.

The retardation coefficient (Rd) was calculated using the equation:

$$Rd = 1 + \frac{\rho_b \cdot K_d}{n_e}$$

The aquifer bulk density, ρ_b, was selected as the lowest value (1.4 g/cm^3) derived from laboratory analysis of site samples for faster, and therefore more conservative, transport travel times. The applicant noted that these lower ρ_b values neglect the higher values (approximately 2.7 g/cm^3) based on measurements within the primary transport material of the weathered/fractured bedrock for added conservatism. Site-specific distribution coefficients, K_d, were used where available, others were based on the available literature, and many were values taken from the ORNL studies (e.g., Bechtel Jacobs Company 1998-TN6021) performed on land adjacent to the CRN Site. For yttrium (Y), no site-specific value was available; however, Y is a lanthanide and is often associated with the lanthanide cerium (Ce) (NUREG/CR-5512, "Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating

Contamination Levels to Annual Total Effective Dose [Kennedy and Strenge 1992-TN5701]). Therefore, the site-specific geometric K_d mean for Ce (54 mL/g) was used. If no K_d value was available for a specific radionuclide, the applicant substituted a conservative value of zero (no retardation). The effective porosity, n_e, used was based on ORR studies, as described above (0.0467). The values of K_d based on laboratory testing of CRN Site samples are listed in SSAR Table 2.4.13-4 (TVA 2016-TN5018).

Depending on the field scale (Gelhar et al. 1992-TN6016), longitudinal dispersivity was estimated by the applicant using a relationship scaled between dispersivity (α_L) (in meters) and transport distance (in meters) based on Xu and Eckstein (1995-TN6017):

$$\alpha_L = 0.83 \cdot (log_{10}x)^{2.414}$$

where x is 426.7 m (1,400 ft) or the distance from the edge of the power block to the edge of the Clinch River. The dispersivity, α_L, was estimated as 8.57 m (28.1 ft). The equation above weighs field study measurements according to reliability (Xu and Eckstein 1995-TN6017). The data with the highest reliability are weighted more than those of lower reliability as ranked by Gelhar et al. (1992-TN6016).

The applicant selected half-lives for the radionuclides based on available studies (Xu and Eckstein 1995-TN6017; Dorsch and Katsube 1996-TN6035) to determine the decay constant for each radionuclide.

The applicant used a value of 400 cfs for the value of flow, Q, in the Clinch River to estimate radionuclide dilution. The applicant stated that the value of 400 cfs is a minimum flow based on the installation of an upstream bypass at the Melton Hill Dam to maintain hydrothermal requirements for operation of the proposed units.

2.4.13.4.5.2 *Staff's Technical Evaluation*

The staff reviewed the input parameters used for the transport analysis. The tank release volume, V, represented by a release of 80 percent of the tank volume was based on the PPE and is consistent with the guidance of BTP 11-6 Revision 4 (NRC 2016-TN6196). For calculating the groundwater pore velocity, U, the applicant used values of hydraulic conductivity derived from the aquifer test data for wells along the geologic strike. Using the hydraulic conductivities derived along the geologic strike is consistent with conservative assumptions of the highest hydraulic conductivities (i.e., a fast travel time with less decay), and the preferred groundwater flow path. The relatively low effective porosity (0.0467) selected from ORR studies conducted nearby (Dorsch and Katsube 1996-TN6035; Dorsch 1997-TN6019) is also conservative and contributes to a relatively fast groundwater velocity, because the groundwater pore velocity is inversely proportional to the porosity. For the hydraulic gradient, $\frac{dH}{dx}$, the applicant used a mean of 0.07 ft/ft for the CRN Site, as derived from site-specific water-level measurements. Based on these values, the applicant estimated travel time from the proposed power block area to the Clinch River to be approximately 359 days. The staff reviewed the applicant's selection of parameter values and determined that the groundwater matrix pore velocity estimated by the applicant was based on plausible and conservative parameters, and is therefore acceptable.

The staff reviewed the input parameters used in the calculation of retardation coefficients. Where available, the applicant used site-specific values for the parametric components of the

retardation equation. The bulk density, ρ_b, values were derived from shallow site samples, which were the lowest values, while higher values were derived from bedrock, which is the primary aquifer transport material at the CRN Site. Distribution coefficients, K_d, were derived from laboratory tests on site-specific CRN Site samples with the exception of Y. The K_d for Ce, comparable to a lanthanide like Y, was used for Y because no site-specific value was measured for Y. The effective porosity used was based on testing performed on the same or similar aquifer materials at the ORR as are found at the CRN Site (Dorsch and Katsube 1996-TN6035; Dorsch and Katsube 1999-TN6036). Based on the staff's review of the parameters and methods used to determine the retardation coefficients, the staff found that the applicant's calculation methods are based on plausible and conservative parameters, and are therefore acceptable.

Dispersivity is particular to a specific site (field) scale for predicting the subsurface movement and spreading of the radionuclides. Field scale is defined as the distance traveled from the source under ambient conditions, or the distance between the injection well and the observation well for the case of an induced flow configuration (Gelhar et al. 1992-TN6016). For the CRN Site, the "injection point" is represented as the release point and the "observation well" is the postulated receptor location. The applicant applied methods that account for the CRN Site scale given the 1,400 ft distance from the power block to the Clinch River resulting in a dispersivity of 28.1 ft. The staff reviewed the dispersivity equation and determined that the weighted field scale measurements (Xu and Eckstein 1995-TN6017) relative to the measurement reliability (Gelhar et al. 1992) are reasonable. Based on the staff's evaluation of the studies (Gelhar et al. 1992-TN6016; Xu and Eckstein 1995-TN6017) used by the applicant, and the scale applied to the dispersivity equation, the staff finds the applicant's dispersivity value of 28.1 ft acceptable for the CRN Site.

The staff reviewed the studies and reports used for the applicant's characterization of radioactive decay and subsequent calculation of radionuclide half-life and resulting decay constants, and finds that the applicant's resulting decay constants is consistent with published literature (Dorsch and Katsube 1996-TN6035; Till and Meyer 1983-TN6023; ICRP 2008-TN6025), and is therefore acceptable.

A summary of radionuclide transport equation parameters used in Equation 2.4.13-2 is included in Table 2.4.13-1.

Table 2.4.13-1 Summary of Equation 2.4.13-2 Radionuclide Transport Parameters.

Parameter	Calculation	Value	Units
Source term tank volume (V_T)	-	10,000	gal
Tank release volume (V)	$V = f \cdot V_T$	8,000	gal
Tank volume fraction (f)	-	0.8	-
Hydraulic conductivity (K)	-	2.6	ft/day
Effective porosity (η_e)	-	0.0467	-
Hydraulic gradient (dh/dx)	-	0.07	ft/ft
Groundwater velocity (U)	$U = \frac{K}{\eta_e} \cdot \frac{dh}{dx}$	3.90	ft/day
Distance (L)	-	1,400	ft
Longitudinal dispersivity (α_L)	$\alpha_L = 0.83 \cdot (log_{10} L)^{2.414}$	28.1	ft
Longitudinal dispersion coefficient (D_x)	$D_x = \alpha_L \cdot U$	109.6	ft^2/day

Parameter	Calculation	Value	Units
Flow rate of Clinch River (Q)	-	400	cfs
Bulk density (ρ_b)	-	1.4	g/cm^3
Retardation factor (R_d)	$R_d = 1 + \frac{\rho_b \cdot Kd}{\eta_e}$	Calculated per K_d [(a)]	-
Decay constant (λ)	$\lambda = \frac{\ln(2)}{T_{\frac{1}{2}}}$	Calculated per $T_{\frac{1}{2}}$ [(b)]	per day

(a) From SSAR Table 2.4.13-4 (TVA 2016-TN5018).
(b) From SSAR Table 2.4.13-5 (TVA 2016-TN5018).

Where applicable, an appropriately consistent metric equivalent of the parameters above were used in Equation 2.4.13-2 calculations to derive the resulting radionuclide concentrations (SSAR Table 2.4.13-4 [TVA 2016-TN5018). The staff determined that the parameters used by the applicant for the calculation of radionuclides at the postulated receptor location are acceptable.

2.4.13.4.6 Radionuclide Concentrations at the Clinch River

Based on the postulated release, the applicant calculated dilution factors and concentrations with sorption ($K_d \neq 0$) and without sorption ($K_d = 0$) to estimate the radionuclide concentrations at the CRN Site boundary at the Clinch River.

2.4.13.4.6.1 *Information Submitted by Applicant*

The applicant’s calculated minimum dilution factors and associated maximum concentrations in the Clinch River assume no sorption exceeded the ECLs in Appendix B of 10 CFR Part 20 (TN283) for several radionuclides. Accounting for sorption and retardation, the applicant’s calculations resulted in estimated concentrations at the CRN Site boundary below the ECLs for all radionuclide isotopes.

For the radionuclide release, the applicant assumed that the release to groundwater was instantaneous with no credit for mitigating design features and that all radionuclide and associated daughter product concentrations were at their peaks. The flow in the Clinch River was assumed to be 400 cfs, which represents the minimum flow based on the installation of an upstream bypass at the Melton Hill Dam reservoir operating policy (TVA 2017-TN6171). The applicant noted that the value of 400 cfs is 4.4 times lower than the minimum daily-average flow rate over 1 year and 12.2 times lower than the daily-average flow rate (4,876 cfs). The rate of 400 cfs assumes no tributary or groundwater inflows between the Melton Hill Dam and the CRN Site (a distance of approximately 5 river miles), which would increase the downstream flow rate and dilution capability of the Clinch River between the dam and the CRN Site. The applicant stated that the lower assumed flow rate would result in relatively higher radionuclide concentrations/ doses at the receptor location. The applicant stated that the distribution coefficients with no site-specific distribution coefficients were assumed to be zero, resulting in shorter travel times (i.e., less decay) toward the receptor location.

2.4.13.4.6.2 _Staff's Technical Evaluation_

The staff reviewed the applicant's radionuclide concentration calculations for the Clinch River and requested clarification of the applicant's methodology described in the SSAR (TVA 2016-TN5018). During the April 24–27, 2017 NRC site audit (NRC 2018-TN5915), the applicant clarified the methodology used for the calculated concentrations based on NUREG/CR-3332 (Till and Meyer 1983-TN6023). The applicant referred to a technical publication (Taylor and Guha 2017-TN6018) to describe the applicability of the NUREG/CR-3332 equations as used by the applicant. The staff reviewed the applicant's methodology using NUREG/CR-3332 (Till and Meyer 1983-TN6023) and Taylor and Guha (2017-TN6018) and performed independent confirmatory analyses of the applicant's methods and calculations. Based on the staff's review and confirmatory analysis, the staff determined that the applicant's methodology and resulting radionuclide concentration calculations are consistent with the staff's results, and are therefore acceptable.

The applicant states in the SSAR that 400 cfs is the minimum daily average reservoir-release requirement for the Melton Hill Dam (TVA 2016-TN5018). The staff determined that in addition to groundwater inflow to the Clinch River, tributaries along the 5 river miles between Melton Hill Dam and the CRN Site contribute additional flow to the Clinch River before reaching the site, thereby increasing the minimum flow. Correspondingly, this increased flow would increase the radionuclide dilution and lower the resulting concentrations at the postulated receptor location. Therefore, the applicant's assumption of 400 cfs for the Clinch River minimum flow rate near the CRN Site is acceptable for the characterization of the resulting radionuclide dilution at the postulated receptor location because it is conservative.

2.4.13.4.7 Dose Evaluation

The applicant is required to meet the 10 CFR 20.1301 (TN283) dose limit for a member of the public in addition to meeting the ECLs listed in 10 CFR Part 20, Appendix B, Table 2 (TN283).

2.4.13.4.7.1 _Information Submitted by Applicant_

The applicant used the LADTAP II computer code to calculate exposure pathway dose associated with the accidental release using the radionuclide concentrations at the Clinch River site boundary. To calculate the total effective dose equivalent (TEDE) required to satisfy 10 CFR 20.1301 (TN283), the applicant modified the dose conversion factors within the LADTAP II code using the dose conversion factors for ingestion from Federal Guidance Report (FGR) 11 (Eckerman et al. 1988-TN68), and the dose conversion factors for ground deposition and immersion from FGR 12 (Eckerman and Ryman 1993-TN3955), because the LADTAP II code calculates total body and organ doses, not TEDE. The applicant evaluated the following exposure pathways for the resulting dose estimate:

- consumption of the water, fish, and invertebrates from the Clinch River;
- consumption of vegetables, milk, and meat affected by irrigation water from the Clinch River; and
- boating, swimming, and shoreline activities on the Clinch River.

The applicant's primary inputs and assumptions are as follows:

- No dilution is credited beyond the calculated radionuclide concentrations at the postulated receptor location (SSAR Table 2.4.13-5 [TVA 2016-TN5018]).

- The transit time to dose receptors is assumed to be zero.
- The irrigation rate is assumed to be 1 in./week, which bounds the actual rate near the proposed site of 0.24 in./week (Bohac and Bowen 2012-TN5026).
- The consumption and usage rates are the default values for the MEI from RG 1.109, Table E-5, while assuming that the time spent boating and swimming are the same as that for shoreline activities.
- The exposure duration is assumed to be 1 year.
- The TEDE dose conversion factors for ingestion were obtained from the FGR 11 (Eckerman et al. 1988-TN68).
- The TEDE dose conversion factors for ground deposition and immersion were obtained from FGR 12 (Eckerman and Ryman 1993-TN3955).

The resulting total annual dose from all exposure pathways was 93 mrem TEDE to an adult receiving the maximum dose, which is below the 100 mrem TEDE dose limit in 10 CFR 20.1301 (TN283).

2.4.13.4.7.2 *Staff's Technical Evaluation*

The staff reviewed the applicant's dose evaluation based on the estimated radionuclide calculations for the postulated accidental release. The staff reviewed the applicant's modification of the dose conversion factors within the LADTAP II computer code and found the modifications to be reasonable and acceptable for calculation of the TEDE. The staff reviewed the exposure pathways and found them to be consistent and acceptable for calculating the dose for a postulated accidental liquid effluent release of radionuclides to the groundwater at the CRN Site based on the applicant's inputs and assumptions described in SSAR Section 2.4.13.4 (TVA 2016-TN5018). During the NRC April 24–27, 2017 site audit (NRC 2018-TN5915), the staff discussed the maximum dose estimate with the applicant noting that the calculated annual dose of 93 mrem TEDE is close to the dose limit of 100 mrem TEDE in 10 CFR 20.1301 (TN283). In response, the applicant noted several conservatisms in the radionuclide calculations that resulted in the maximum dose estimate, including the following:

- a source term based on a 1 percent failed fuel fraction where 0.12 percent is suggested within NRC guidance (BTP 11-6 [NRC 2016-TN6196]);
- a catastrophic tank release assuming no credit for mitigating design features;
- an instantaneous and direct release of the tank contents to the groundwater flow system;
- an assumed minimal Clinch River flow (400 cfs) for dilution, a flow which has not occurred for extended periods during the period of current protocols for reservoir operations (TVA 2016-TN5018);
- a minimal radionuclide travel distance from the release point to the Clinch River;
- incorporation of transport parameters that minimize radionuclide travel time (and radionuclide decay) to maximize radionuclide concentrations at the postulated receptor; and
- an assumption that all radionuclides (including daughter products) are at peak concentrations upon release.

The staff agrees that the above inputs and assumptions result in conservative radionuclide calculations for deriving the estimated dose for the postulated accidental release. As described in the NRC CRN Site Audit Summary Report (NRC 2018-TN5915), the staff noted that Tc-99 is identified as a radionuclide in the normal PPE liquid effluent release source term, but is excluded in the accidental PPE liquid effluent release source term in SSAR Table 2.0-5 (TVA 2016-TN5018). Although Tc-99 is excluded in SSAR Table 2.0-5, the applicant considered Tc-99 in SSAR Tables 2.4.13-1, 2.4.13-2, and 2.4.13-5 (TVA 2016-TN5018) in the radionuclide transport analysis and estimation of initial liquid effluent release concentrations evaluated by the staff below.

The guidance in DC/COL-ISG-013 (as incorporated into BTP 11-6 Revision 4 [NRC 2016-TN6196]) states that long-lived, hard-to-detect radionuclides such as Tc-99 that are highly mobile in the environment should be included in any assessment of an accidental release of radioactive material from liquid radwaste tanks. Therefore, the staff requested that the applicant include Tc-99 in the accidental PPE liquid effluent release source term and exposure pathway dose analysis or justify its exclusion. Subsequently, the applicant calculated the impact of Tc-99 in the accidental PPE liquid effluent release source term.

The staff reviewed the applicant's calculation to evaluate an accidental release from a failed tank and groundwater transport that included a Tc-99 radioactivity concentration of 4.67E-11 $\mu Ci/cm^3$ in the accidental PPE liquid effluent release source term resulting in a Tc-99 release rate of 4.17E-05 Ci/yr. In the applicant's calculation, the conservative assumptions used included a zero transit time; default parameters in Table E-5 of RG 1.109 (NRC 1977-TN90) for boating, swimming, and shoreline recreational activities; an assumed exposure time of 1 year; an irrigation rate of 110 L/m^2/month; the FGR 11 (Eckerman et al. 1988-TN68) ingestion dose conversion factors; and the FGR 12 (Eckerman and Ryman 1993-TN3955) external dose conversion factors. The applicant performed additional calculations using niobium-95 to confirm that the FGR 11 (Eckerman et al. 1988-TN68) and FGR 12 (Eckerman and Ryman 1993-TN3955) dose conversion factors were properly modified for each exposure pathway change (ingestion, shoreline activities, and swimming and boating). The resulting calculated dose of 93 mrem/yr TEDE at the CRN Site boundary that includes Tc-99 meets the public dose limit of 100 mrem/yr TEDE in 10 CFR 20.1301 (TN283).

Based on the staff's review of the applicant's method, model, and assumptions used in the dose calculation, the staff determined that the applicant's dose calculation meets the requirements of 10 CFR 20.1301 (TN283), and is acceptable.

As described above, the staff confirmed the adequacy of the applicant's dose calculation from a postulated accidental liquid effluent release of radionuclides to the groundwater using an accident PPE liquid effluent release source term. The staff determined that because the source term information for the reactor technology is not known at the ESP stage, a COL applicant or a CP applicant that references this ESP will need to verify that the calculated dose to members of the public from a postulated accidental liquid radionuclide effluent release to the groundwater from a chosen reactor technology at the CRN Site is bounded by the dose evaluated by the staff in this FSER. A COL or CP applicant referencing this ESP should address and justify any discrepancies. This would include justifying any changes made to address differences in the reactor design used to calculate the dose (e.g., basis of the accident PPE liquid effluent release source term, radionuclide transport analysis and initial concentrations, and exposure pathway dose modeling). The staff identified these items collectively as COL Action Item 2.4-4:

- COL Action Item 2.4-4: An applicant for a COL or CP referencing this ESP should verify that the calculated dose to members of the public from a postulated accidental liquid radionuclide effluent release to the groundwater from a chosen reactor design at the CRN Site is bounded by the dose evaluated in the CRN Site ESP application (ESPA) as reviewed by the NRC staff. The applicant should evaluate discrepancies and justify any changes made to address differences in the source term for the reactor design used to calculate the dose for a COL or CP application.

2.4.13.5 *Conclusion*

The staff has reviewed the ESPA and confirmed that the applicant has demonstrated that accidental release of radionuclides has no safety-related impact, and no outstanding information is required to be addressed in the SSAR related to this section. As set forth above, the applicant presented and substantiated information to establish the potential effects of accidental releases from the liquid waste management system. Therefore, the staff concludes that the applicant has met the requirements of 10 CFR 52.17(a)(1)(vi) (TN251) and 10 CFR 100.20(c) (TN282) with respect to determining the acceptability of the site, and with respect to 10 CFR Part 20 (TN283) as it relates to ECLs and compliance with the dose limit to a member of the public.

2.4.14 Technical Specifications and Emergency Operation Requirements

In SSAR Section 2.4.14, the applicant addresses the technical specifications and emergency operation requirements and includes descriptions of bounding site characteristics and design parameters. Because a specific reactor technology will be selected for the COLA, there are no requirements for technical specifications or emergency operation protective measures designed to minimize the impact of hydrology-related events on safety-related or risk-significant facilities at the ESPA stage. Therefore, the ESPA does not include technical specifications or emergency operating procedures.

2.4.14.1 *Summary of Application*

The information in the SSAR was provided for the staff to assess the suitability of the CRN Site given the PPE provided. For the COLA, the applicant would choose a specific reactor technology and evaluate technical specifications and emergency operating procedures.

2.4.14.2 *Regulatory Basis*

The relevant requirements of the NRC regulations for consideration of emergency protective measures, and the associated acceptance criteria, are described in SRP Section 2.4.14 (NRC 2007/2018-TN5898).

The applicable regulatory requirements are as follows:

- 10 CFR Part 100 (TN282), as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c) (TN282).
- 10 CFR 100.23(d) (TN282), as it sets forth the criteria for determining the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

2.4.14.3 *Technical Evaluation*

2.4.14.3.1.1 *Information Submitted by Applicant*

(SRI/CEII) In SSAR Section 2.4.14 (TVA 2016-TN5018), the applicant presented a summary of the hydrologic engineering evaluations presented in the preceding SSAR sections. Where applicable, the applicant retained elevation datum consistent with the historical record for comparison of corresponding values in the SSAR analyses. The applicant restated site characteristics and bounding design parameters, including the plant design grade of the CRN Site of 821.0 ft NAVD88 (821.4 ft NGVD29) and the Clinch River DBF of **[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88). The applicant stated that the maximum groundwater elevation is 816.1 ft NAVD88 (816.5 ft NGVD29). The applicant stated that there are no requirements for emergency protective measures to minimize the impact of hydrology-related events and none are necessary for incorporation into the technical specifications or emergency operating procedures.

2.4.14.3.1.2 *Staff's Technical Evaluation*

The staff reviewed SSAR Section 2.4.14 (TVA 2016-TN5018) and found the applicant's summary of hydrologic engineering evaluations, site characteristics, and bounding parameters to be acceptable. For the ESPA, the staff determined that there are no applicable technical specifications or emergency operating procedure necessary and finds the applicant's evaluation acceptable.

As described in the preceding FSER sections, the staff determined that the site characteristics and bounding design parameters as given in Table 2.4.14-1 and Table 2.4.14-2 below, should be included in an ESP that may be granted for the CRN Site. Figure 2.4.14-1 (reproduced based on SSAR Figure 2.1-1) depicts the proposed CRN Site boundary areas.

(SRI/CEII) **Table 2.4.14-1 Proposed Site Characteristics Related to Hydrology.**

Site Characteristic	CRN Site Value[(a)]	Definition
Proposed Facility Boundaries	Figure 2.4.14-1 depicts the proposed facility area boundaries.	CRN Site boundary areas within which all safety-related SSCs will be located.
Maximum Groundwater	816.1 ft NAVD88 (816.5 ft NGVD29)	The maximum elevation of groundwater at the CRN Site.
Maximum Stillwater Flood Elevation (MSWFE)	**[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88)	The stillwater surface, without accounting for wind-induced waves, reaches the elevation equal to the computed PMF elevation (**[[**[redacted]**]]** ft) plus a **[[**[redacted]**]]** ft of margin.
Wave Runup (2-year wind)	**[[**[redacted]**]]** ft	The height of water reached by wind-induced waves running up on the site.

Site Characteristic	CRN Site Value[(a)]	Definition
(SRI/CEII) Combined Effects Maximum Flood Elevation (Design Basis Flood)	**[[**[redacted]**]]** ft NGVD29 (**[[**[redacted]**]]** ft NAVD88)	The water-surface elevation at the point in time where the combination of the stillwater level and wave runup is at its design basis maximum.
Local Intense Precipitation	17.4 in./hr	The depth of PMP for duration of 1 hour on a 1 mi^2 drainage area, including moisture adjustment. The surface-water drainage system should be designed for a flood produced by the local intense precipitation (see COL Action Item 2.4-1).
Frazil, Surface or Anchor Ice	The CRN Site does not have the potential for frazil and surface ice.	Potential for accumulated ice formation in a turbulent flow condition.
Minimum River Water-Surface Elevation	733.7 ft NGVD29 (733.3 ft NAVD88)	The surface-water elevation for which low water level conditions recorded at the headwater of Watts Bar Dam extend to the CRN Site.
Maximum Ice Thickness	11 in.	Maximum calculated potential ice thickness on the Clinch River at the CRN Site.
Hydraulic Conductivity	SSAR Table 2.4.12-12[(b)]	Groundwater flow rate per unit hydraulic gradient.
Hydraulic Gradient	SSAR Table 2.4.12-8[(b)]	Slope of the groundwater surface under unconfined conditions or the slope of the hydraulic pressure head under confined conditions.

(a) First datum listed is the native datum as recorded in the historical record and/or associated analyses.
(b) TVA 2016-TN5018.

Table 2.4.14-2 Bounding Design Parameters

Bounding Design Parameter	Value[(a)]	Definition
Site Grade	821.0 ft NAVD88 (821.4 ft NGVD29)	Finished site grade elevation for the power block area on the CRN Site.

(a) The first datum listed is the native datum of the associated analyses.

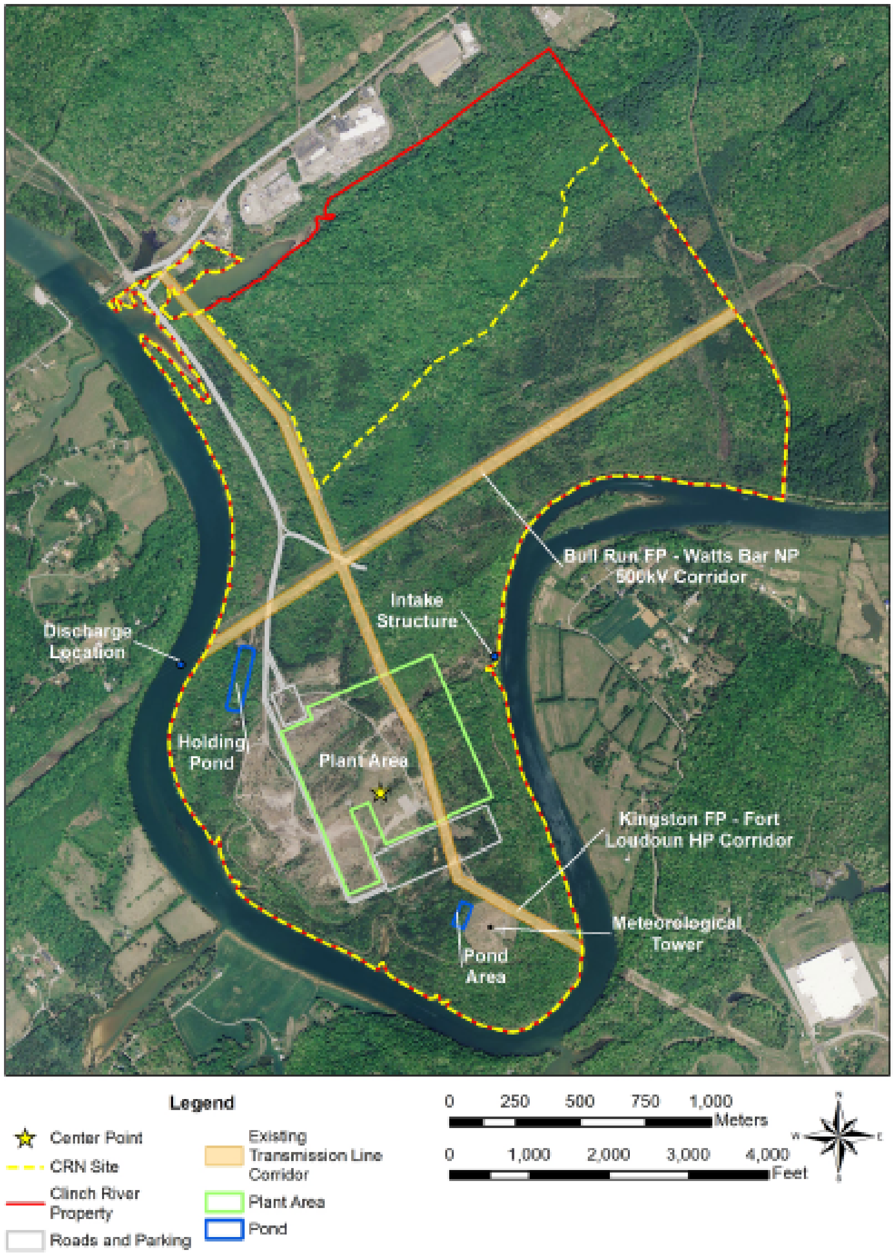


Figure 2.4.14-1 Proposed CRN Site Layout (reproduced from Revision 1, Figure 2.1-1 [TVA 2017-TN5387]).

2.4.14.4 *Conclusions*

The staff concludes that no technical specifications or emergency operation procedures are required in the ESPA for the CRN Site. Therefore, the staff finds it acceptable that the ESPA does not include the identification and consideration of technical specifications and emergency operation procedures. As summarized above and as supported by the staff's evaluations in FSER Sections 2.4.1 through 2.4.13, the staff finds that the bounding site characteristics and design parameters of site grade meet the requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.20(c) (TN282), and 10 CFR 100.23(d) (TN282).

2.5 Geology, Seismology, and Geotechnical Engineering

Section 2.5 of the site SSAR, Revision 1 (TVA 2017-TN5387), prepared by the TVA for the CRN Site ESPA, contains information about geologic, seismic, and geotechnical engineering characteristics of the proposed CRN Site. The applicant followed guidance in RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)" (NRC 2007-TN3035), to develop the information presented in SSAR Section 2.5 (TVA 2017-TN5387). The applicant also followed guidance in RG 1.208, "A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion" (NRC 2007-TN5858; the SRP), to define the following four zones around the site in which site characterization investigations conducted by the applicant proceeded in progressively greater detail passing from the larger site region to the smaller site location:

- site region – area within a 320 km (200 mi) radius of the site location
- site vicinity – area within a 40 km (25 mi) radius of the site location
- site area – area within an 8 km (5 mi) radius of the site location
- site location – area within a 1 km (0.6 mi) radius of the proposed plant.

To prepare the SSAR (TVA 2017-TN5387), the applicant incorporated regional and site-specific geologic, geophysical, seismic, and geotechnical engineering information derived from reviews of previous reports prepared for the proposed CRBRP, ORNL reports related to the ORR, and published literature. The applicant also used data obtained from surface and subsurface field investigations specifically conducted to characterize the CRN Site for the ESPA.

Section 2.5 of this FSER comprises five main parts, Sections 2.5.1 through 2.5.5, which parallel the five SSAR sections (TVA 2017-TN5387) prepared by the applicant for the CRN Site ESPA. The five FSER sections are as follows:

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

These FSER sections address the geologic, seismic, and geotechnical engineering characteristics of the proposed CRN Site. Each of the five main sections consists of two parts: (1) the staff's summary of materials presented by the applicant in the SSAR, including associated analyses, explanations, and conclusions made by the applicant as documented in the SSAR; and (2) the staff's detailed technical evaluation of information presented by the applicant in the SSAR (TVA 2017-TN5387). The technical evaluation section presents the results of the staff's detailed safety review, including information obtained through NRC site visits and audits, applicant responses to requests for additional information (RAIs), evaluation of those RAI responses, and findings and conclusions made by staff based on their detailed safety review.

2.5.1 Geologic Characterization Information

In Section 2.5.1 of the CRN Site SSAR (TVA 2017-TN5387), the applicant describes geologic characterization information, including regional and site-specific geologic, geophysical, and seismic data derived from reviews of previous reports for the proposed CRBRP, ORNL reports related to the ORR, and published literature, as well as data obtained from surface and

subsurface field investigations specifically conducted to characterize the CRN Site. The applicant conducted the field investigations at progressively greater levels of detail nearer to the site within each of the four circumscribed areas corresponding to site region, site vicinity, site area, and site location as defined above in Section 2.5. These investigations made it possible for the applicant to assess the geologic and seismic suitability of the site, determine whether new geologic or seismic data existed that could significantly impact seismic design based on results of probabilistic seismic hazard analysis, and provide geologic and seismic data appropriate for plant design. The applicant indicated that, by following guidance in RG 1.206 (NRC 2007-TN3035) and RG 1.208 (NRC 2007-TN5858) for developing the geologic site characterization information, the content of SSAR Section 2.5.1 (TVA 2017-TN5387) demonstrates compliance with the regulatory requirements in 10 CFR 100.23(c) (TN282), "Geological, seismological, and engineering characteristics." The requirements in 10 CFR 100.23(c) (TN282) specifically state that geologic, seismic, and engineering characteristics of a site and its environs must be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site, provide sufficient information for estimating the safe shutdown earthquake (SSE) ground motion, and permit adequate engineering solutions for actual or potential geologic and seismic effects at the proposed site. The applicant also considered guidance in NUREG–0800, "Standard Review Plan for Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)," (NRC 2007/2018-TN5898; hereafter the SRP) when developing SSAR Section 2.5.1.

2.5.1.1 *Summary of Application*

SSAR Section 2.5.1 has two main sections (TVA 2017-TN5387). SSAR Section 2.5.1.1, "Regional Geology," includes information about the area within a 320 km (200 mi) radius of the CRN Site location (i.e., the site region). SSAR Section 2.5.1.2, "Local Geology," contains information about the areas within 40 km (25 mi) and 8 km (5 mi) radii of the CRN Site location (i.e., the site vicinity and site area, respectively) and the 1 km (0.6 mi) radius of the proposed plant (i.e., the site location) (TVA 2017-TN5387). Sections 2.5.1.1.1 and 2.5.1.1.2 below summarize the geologic and seismic information presented by the applicant in SSAR Section 2.5.1 (TVA 2017-TN5387).

2.5.1.1.1 Regional Geology

SSAR Section 2.5.1.1 provides information about physiography, topography, and geomorphic processes; fluvial processes; karst processes and occurrence; geologic history and tectonic evolution; stratigraphy; tectonic setting; geophysical data; distribution of stress and seismicity; and non-seismic geologic hazards for the CRN Site region (TVA 2017-TN5387). The following sections summarize the information provided by the applicant in SSAR Section 2.5.1.1 (TVA 2017-TN5387).

2.5.1.1.1.1 *Regional Physiography, Topography, and Geomorphic Processes*

SSAR Section 2.5.1.1.1 describes the six physiographic provinces that lie within a 320 km (200 mi) radius of the CRN Site location (i.e., within the site region), regional geomorphic processes, and regional topography (TVA 2017-TN5387). From west to east, the physiographic provinces are the Central Lowlands, the Interior Low Plateaus, and the Appalachian Plateaus, which include the Cumberland Plateau at the latitude of the site region, the Valley and Ridge, the Blue Ridge, and the Piedmont. Figure 2.5.1-1 (reproduced from SSAR Figure 2.5.1-1 [TVA 2017-TN5387]) shows these physiographic provinces relative to the location of the CRN Site, which lies in the Valley and Ridge province.

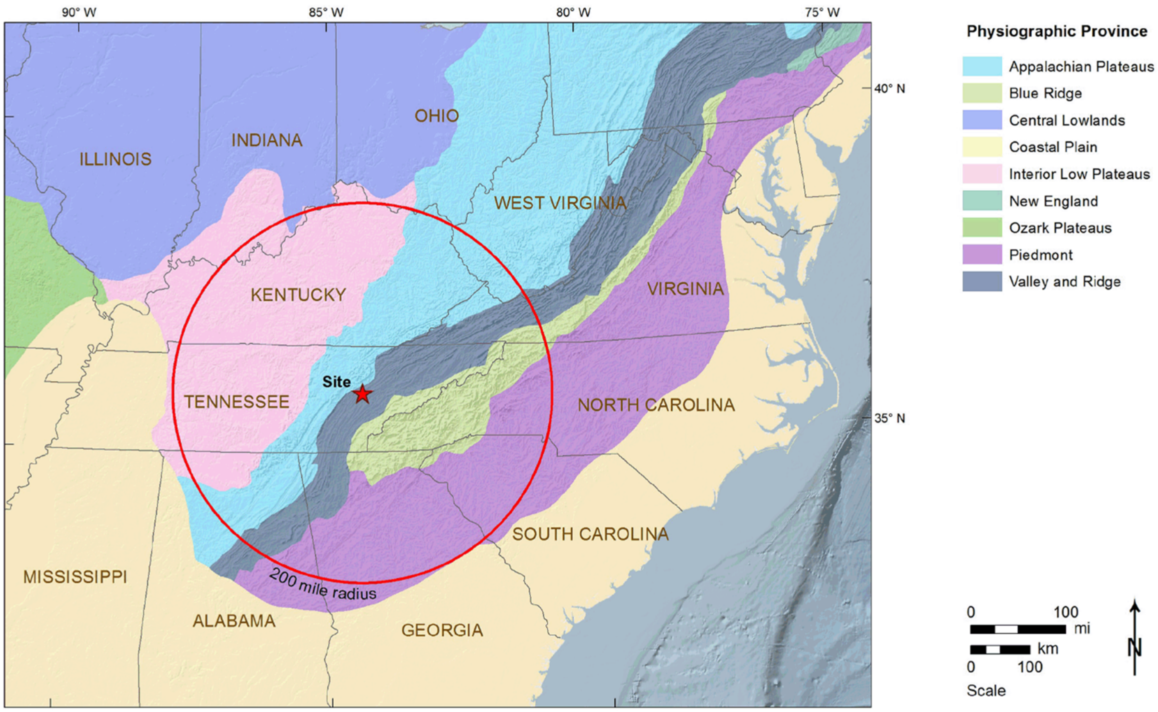


Figure 2.5.1-1 Map Showing Physiographic Provinces in the CRN Site Region (reproduced from SSAR Figure 2.5.1-1 [TVA 2017-TN5387])

SSAR Section 2.5.1.1.1 discusses the Valley and Ridge physiographic province in which the site lies (TVA 2017-TN5387). The applicant stated that this province extends about 1,931 km (1,200 mi) southwest from the Saint Lawrence Lowlands and eastern New York to central Alabama and ranges in width from 22.5 to 129 km (14 to 80 mi). The applicant reported that parallel ridges and valleys trending northeast-southwest characterize the province, and that the geomorphology is related directly to the differential weathering and erosion of the folded and faulted Paleozoic sedimentary strata found in the province. The Paleozoic era covered the time frame between 541 and 252 million years (Ma) ago. The applicant explained that approximately 16 major thrust faults cut stratigraphic units at the latitude of the CRN Site. The applicant noted that most of the site vicinity lies within the Tennessee River drainage basin, and the Clinch River meanders westerly in an entrenched channel that cuts across regional topography in the site area.

SSAR Section 2.5.1.1.1.2 briefly describes fluvial processes in the site region (TVA 2017-TN5387). The applicant referenced SSAR Section 2.5.1.2.1, which contains a discussion of fluvial processes in relation to the CRN Site, including those operative during Pleistocene time (between 2.58 Ma to 11,700 years ago) associated with the formation of the entrenched meanders and fluvial terraces of the Tennessee and Clinch Rivers (TVA 2017-TN5387).

SSAR Section 2.5.1.1.1.3 describes karst processes and the occurrence of soluble carbonate strata (i.e., limestone and dolomite) in the site region (TVA 2017-TN5387). The applicant discussed geologic hazards that can potentially occur in karst landscapes, including ground subsidence or collapse, rapid underground drainage, irregular soil-bedrock contacts, and deep weathering along bedding planes, joints, fractures, and faults. The applicant explained that development of a karst landscape and associated potential geologic hazards is the result of the karstification process, which involves chemical dissolution of soluble rock due to circulation of

weakly acidic groundwater through the rock units. The applicant noted that in humid temperate to subtropical regions such as Tennessee, abundant vegetation, high rainfall, and high atmospheric carbon dioxide also favor dissolution of soluble rock units. The applicant reported that distinct karst terrains in the Valley and Ridge and Interior Low Plateaus physiographic provinces dominate the site region. Karst terrains in both provinces form in similar Paleozoic carbonate rock units under similar climatic conditions.

SSAR Section 2.5.1.1.1.3.1 describes karst features in the folded and faulted Paleozoic carbonate rocks of the Valley and Ridge province in which the CRN Site lies (TVA 2017-TN5387). These features include sinkholes, caves, springs, seeps, and sinking streams. The applicant stated that cover-collapse sinkholes, which are formed by the collapse of unconsolidated deposits or residual soils into cavities produced by dissolution of soluble bedrock, are the most common type of sinkholes in the province. The applicant reported that caves in the Valley and Ridge province tend to be less than a few kilometers in length because folded carbonate units and interbedded clastic strata strongly control cave development. The applicant indicated that most cave passages parallel the strike of bedding, with the passages oriented along joints or joint-bedding plane intersections. The applicant stated that 9,839 known caves exist in Tennessee, about 15 percent of which are located in the Valley and Ridge province.

2.5.1.1.1.2 <u>*Regional Geologic History and Tectonic Evolution*</u>

SSAR Section 2.5.1.1.2 describes geologic history and tectonic evolution of the site region (TVA 2017-TN5387). The applicant stated that the CRN Site lies immediately west of the main northeast-southwest-trending axis of the Appalachian orogenic belt. The applicant explained that at least three regional Paleozoic contractional events affecting the eastern margin of ancestral North America (i.e., Laurentia), and associated with the opening and closing of several proto-Atlantic Ocean basins, formed the Appalachian orogenic belt. The applicant noted that these three orogenies, which directly influenced the geology and structural features of the CRN Site region, included the Middle Ordovician (about 470–458 Ma) Taconic orogeny, the Early Devonian to Mississippian (about 419–358 Ma) Acadian/Neoacadian orogeny, and the Pennsylvanian to Permian (about 320–280 Ma) Alleghanian orogeny. The applicant stated that the latest stages of the Alleghanian orogeny resulted in the folding and faulting of stratigraphic units in the Valley and Ridge province and accommodated more than 400 km (250 mi) of crustal shortening.

2.5.1.1.1.3 <u>*Regional Stratigraphy*</u>

SSAR Section 2.5.1.1.3 describes stratigraphy of the site region (TVA 2017-TN5387). Because the CRN Site lies in the Valley and Ridge physiographic province, the applicant focused on stratigraphic units found in that province. The applicant stated that the CRN Site, which lies in the southwestern portion of the Valley and Ridge province, consists predominantly of a sequence of Paleozoic sedimentary rocks ranging in age from Lower Cambrian to Pennsylvanian (i.e., about 541 to 323 Ma). The applicant noted that the following four major subdivisions deposited atop ancient continental crust (greater than 980 Ma in age) make up this sedimentary sequence: (1) the Lower Cambrian Rome Formation, a basal, mainly clastic transgressive unit with a western source; (2) a thick, extensive Cambrian to Ordovician carbonate shelf sequence that includes formations of the Middle Cambrian Conasauga, Upper Cambrian to Lower Ordovician Knox, and Middle Ordovician Chickamauga Groups; (3) a thin, laterally variable shelf sequence of Upper Ordovician to Lower Mississippian carbonate rocks and thin clastic units; and (4) a Middle Mississippian to Pennsylvanian synorogenic (i.e., synchronous with the orogenic event) clastic wedge.

2.5.1.1.1.4 *Regional Tectonic Setting*

SSAR Section 2.5.1.1.4 describes the tectonic setting of the CRN Site region, including subdivision of tectonic terranes and physiographic provinces, regional geophysical data, and the distribution of seismicity and stress in the Eastern United States (TVA 2017-TN5387). SSAR Section 2.5.1.1.4.1 discusses the Valley and Ridge province in which the CRN Site lies in relation to structural style and deformation history (TVA 2017-TN5387). The applicant stated that the Valley and Ridge province exhibits a unique structural style compared to adjacent terranes and physiographic provinces, noting that the linear northeast-southwest-trending ridges and valleys characteristic of the province are the direct result of differential erosion of Paleozoic strata deformed into an imbricate stack of southeast-dipping thrust sheets. The applicant indicated that $^{40}Ar/^{39}Ar$ age dates on clay fault gouge from several major faults in the Valley and Ridge province indicate emplacement of the thrust sheets occurred at 276–280 Ma.

SSAR Section 2.5.1.1.4.2 describes geophysical data sets, including information derived from seismic reflection and aeromagnetic and gravity surveys used to delineate the distribution of tectonic elements in the southern Appalachians (TVA 2017-TN5387). The applicant noted seismic reflection data collected by the Consortium for Continental Reflection Profiling showed that major Valley and Ridge faults propagate from a basal detachment near the basement-cover interface, but major structures in the Valley and Ridge province are generally not visible on gravity and aeromagnetic maps.

SSAR Section 2.5.1.1.4.3 (TVA 2017-TN5387) presents information related to the current orientation of maximum horizontal compressive stress in the CRN Site region (i.e., generally northeast-southwest) based on Hurd and Zoback (2012-TN6122) and briefly addresses vertical stresses derived from upper mantle buoyancy forces based on Biryol et al. (2016-TN6119). The applicant stated that the combination of local upper mantle buoyancy forces proposed by Biryol et al. (2016-TN6119) and far-field ridge-push forces from the Mid-Atlantic Ridge proposed by Zoback and Zoback (1989-TN6120) provide a viable explanation for the combined mechanisms that generate the current regional stress field in the Southeastern United States, including the site region and, consequently, the current state of stress at the CRN Site.

SSAR Section 2.5.1.1.4.3 (TVA 2017-TN5387) also describes the broad zone of elevated seismic activity from low-magnitude earthquakes (i.e., a maximum magnitude of **M**4.6 from historical records) that occurred in the Eastern Tennessee Seismic Zone (ETSZ). The applicant noted that this zone is approximately 300 km (186 mi) long and 50 km (31 mi) wide and trends northeasterly beneath eastern Tennessee and parts of North Carolina, Georgia, and Alabama. The applicant pointed out that the CRN Site lies within this seismic zone. The applicant stated that instrumentally located epicenters in the ETSZ indicate most of the earthquakes have a source beneath the 5 km (3 mi) thick Appalachian foreland fold-thrust belt in ca. 1 Ga (billion-year-old) Precambrian basement rocks at a mean focal depth of approximately 15 km (9 mi).

2.5.1.1.1.5 *Regional Non-Seismic Geologic Hazards*

SSAR Section 2.5.1.1.5.1 states that carbonate rock dissolution and karst formation are the dominant non-seismic geologic hazard in the CRN Site region (TVA 2017-TN5387). The applicant explained that the folded and faulted Paleozoic limestones and dolomites in the Valley and Ridge province contain fractures, which provide conduits for fluid flow and enhanced carbonate dissolution, and that cave development and geometry show structural control of karst features.

In SSAR Section 2.5.1.1.5.2, the applicant stated that the site lies in an area of moderate susceptibility for and low incidence of landslides, whereas surrounding areas in the site region range from high to moderate susceptibility (TVA 2017-TN5387). The applicant stated that erosion has produced steep slopes, and persistent rainfall followed by more intense precipitation have resulted in damaging debris slides and avalanches. The applicant indicated that common forms of mass wasting in the site region consist of rock slides originating from detached rock slabs and translational landslides involving soils containing elevated groundwater under a hydrostatic head.

2.5.1.1.2 Local Geology

SSAR Section 2.5.1.2 provides information about local physiography and geomorphologic processes; geologic history; stratigraphy and lithology; structural geology, including folds, faults, and shear-fracture zones; geologic hazards, including a detailed discussion of karst; and site engineering geology (TVA 2017-TN5387). The applicant indicated that the geologic investigations conducted to characterize the CRN Site covered the site vicinity, site area, and site location and specifically included field reconnaissance, karst mapping, river terrace mapping, and geomorphic analyses complemented by high-resolution light-detection and ranging (LiDAR) digital elevation data acquired for the site area. The following sections summarize the information provided by the applicant in SSAR Section 2.5.1.2 (TVA 2017-TN5387).

2.5.1.1.2.1 Local Physiography and Geomorphic Processes

SSAR Section 2.5.1.2.1 describes local physiography and geomorphic processes (TVA 2017-TN5387). In SSAR Section 2.5.1.2.1.1, the applicant stated that the CRN Site lies in the northwestern Valley and Ridge physiographic province, which is the topographic expression of structures in the southern Appalachian foreland fold-thrust belt that formed during the Alleghanian orogeny (TVA 2017-TN5387). The applicant noted that the CRN Site vicinity contains parallel ridges and intervening valleys, oriented northeast-southwest, which are typical of the regional physiographic setting of the Valley and Ridge province. The applicant stated that the southeastern third of the CRN Site area contains low hills and exhibits a dendritic drainage pattern, and that Knox Group carbonate rock units containing karst features underlie this area.

SSAR Section 2.5.1.2.1.2 describes surficial Quaternary (2.6 Ma to the present in age) deposits at the site (TVA 2017-TN5387). The applicant stated that these surficial deposits include both colluvium (as weathered residuum deposited at the toe of hillslopes and in hollows on hillsides) and alluvium (as weathered residuum deposited in hillside gullies and principal tributary valleys across the site area). The applicant also noted the occurrence of fluvial terraces along the Clinch River.

SSAR Section 2.5.1.2.1.3 describes geomorphic features in the site vicinity (TVA 2017-TN5387). The applicant discussed Late Tertiary (about 5.3 to 2.6 Ma) and Early Pleistocene (about 2.6 to 1.8 Ma) geomorphic processes; Pleistocene geomorphic processes; and the modern Holocene (11,700 years to present) geomorphic period. In SSAR Section 2.5.1.2.1.3.1 (TVA 2017-TN5387), the applicant noted that, although the Late Paleozoic Alleghanian orogeny was the last orogenic event to affect the Valley and Ridge province, a growing body of evidence indicates that the southern Appalachians might have experienced uplift in the Late Tertiary, specifically during Miocene time (23–5.3 Ma). The applicant remarked that this uplift might have affected development of karst in the site area. The applicant also stated that glacial periods during the Pleistocene (2.6 Ma to 11,700 years ago) had a strong influence on the geomorphic

development of the CRN Site vicinity because each glacial period produced changes in base level that resulted in isolation and erosion of stream terraces. The applicant reported that recent studies identified Pleistocene terraces in the site vicinity, which the applicant used to evaluate the presence or absence of surface deformation using terraces along the Clinch River.

2.5.1.1.2.2 *Local Geologic History*

SSAR Section 2.5.1.2.2 describes the geologic history of the CRN Site vicinity in relation to the three primary Paleozoic orogenic events that affected the Appalachian orogenic belt (i.e., the Middle Ordovician Taconic orogeny, the Early Devonian to Mississippian Acadian/Neoacadian orogeny, and the Pennsylvanian to Permian Alleghanian orogeny) (TVA 2017-TN5387). The applicant explained that the Alleghanian orogeny, which drove deformation in the Valley and Ridge province, was mainly responsible for the physiographic and geomorphic expression of the foreland fold-and-thrust belt, as observed in the CRN Site vicinity. The applicant stated that the west-directed thrust sheets propagated from the Rome Formation at the basement-cover interface, which is about 3 km (1.9 mi) deep at the CRN Site. The applicant reported that geochronologic analyses of fault gouge from several Valley and Ridge thrust faults indicate emplacement of the thrust sheets around 276–280 Ma.

The applicant identified the Lower Cambrian Rome Formation as the basal stratigraphic unit in the CRN Site vicinity that nonconformably overlies ca. 1 billion-year-old Grenvillian basement rocks. A nonconformity is an unconformity between sedimentary rocks and older plutonic or metamorphic rocks that were eroded prior to deposition of the overlying sedimentary units. The applicant stated that sedimentary rocks of the Middle to Late Cambrian Conasauga Group conformably overlie the Rome Formation and consist of fine-grained siliciclastic rocks that become progressively more dolomitic up-section, grading into carbonate rocks of the Late Cambrian to Early Ordovician Knox Group. The applicant indicated that deposition of the dolomite and limestone units, the main components of which compose the Knox Group, coincided with a eustatic (i.e., global) sea level high that was possibly 180 m (590 ft) above present-day mean sea level. The applicant noted that a sea level drop and subsequent erosion produced the Middle Ordovician Knox unconformity, after which a sea level rise resulted in continued carbonate deposition of the Middle Ordovician Chickamauga Group atop the Knox Group. The applicant pointed out that the Chickamauga Group, composed predominantly of limestone in the northwest but becoming increasingly clastic to the southeast in the CRN Site vicinity, dominates the stratigraphic sequence in the CRN Site area.

2.5.1.1.2.3 *Local Stratigraphy and Lithology*

SSAR Section 2.5.1.2.3 discusses the stratigraphy and lithology of the CRN Site (TVA 2017-TN5387). After discussing the basis for stratigraphic nomenclature in SSAR Section 2.5.1.2.3.1, in SSAR Section 2.5.1.2.3.2, the applicant stated that the stratigraphy at the CRN Site comprises rock units of the Lower Cambrian Rome Formation, the Middle Cambrian to Lower Ordovician Knox Group, and the Middle Ordovician Chickamauga Group (TVA 2017-TN5387). The applicant reported that the Rome Formation does not crop out at the CRN Site. The applicant indicated that 76 boreholes drilled at the CRN Site encountered the following stratigraphic units, ranging in age from oldest to youngest: the Rome Formation; the Newala Formation of the Knox Group; and the Blackford Formation, Eidson and Fleanor Members of the Lincolnshire Formation, Rockdell Formation, Benbolt Formation, Bowen Formation, and Moccasin Formation of the Chickamauga Group. FSER Figure 2.5.1-2, reproduced from SSAR Figure 2.5.1-30 (TVA 2017-TN5387), presents a northwest-southeast geologic cross section showing the specific stratigraphic units that underlie the CRN Site.

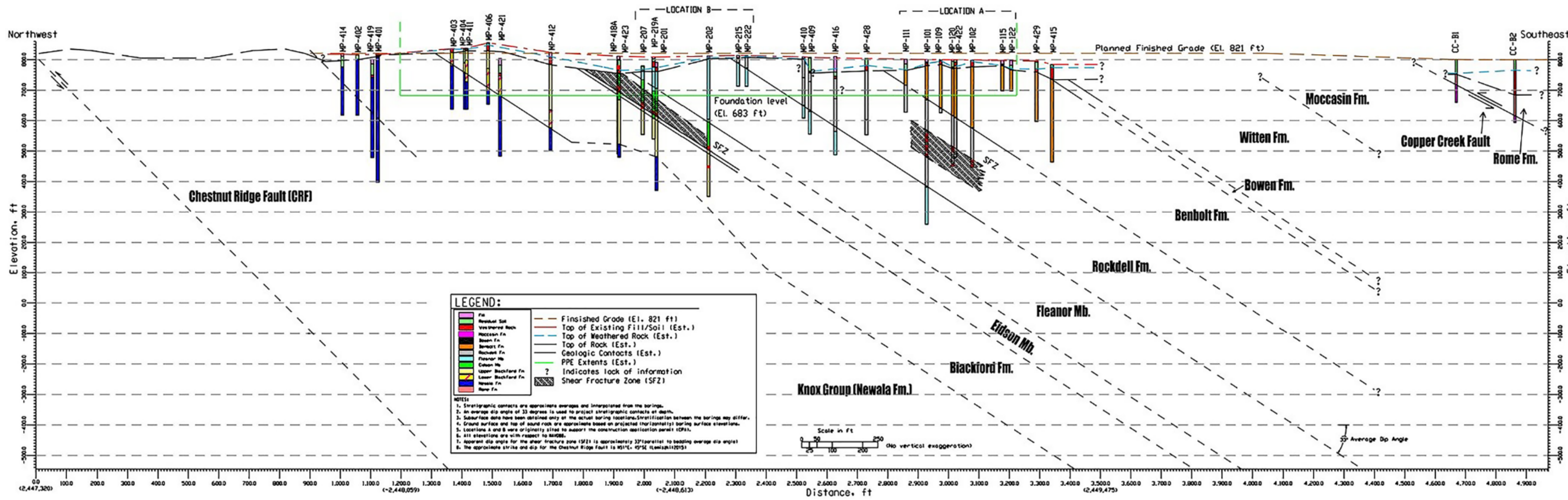


Figure 2.5.1-2 Northwest-Southeast Geologic Cross Section Across the CRN Site Showing Stratigraphic Units Underlying the Site at Locations A and B; Shear-Fracture Zones Penetrated in the Eidson Member of the Lincolnshire Formation Under Location B and in the Rockdell Formation Under Location A; Location of the Chestnut Ridge Fault in the Subsurface Northwest of Location B; Location of the Copper Creek Fault and Boreholes CC-B1 and CC-B2 that Penetrate the Fault to the Southeast of Location A. (Figure reproduced from SSAR Figure 2.5.1-30 [TVA 2017-TN5387])

In SSAR Section 2.5.1.2.3.3, the applicant described rock units encountered at the CRN Site in the Rome Formation and the Knox and Chickamauga Groups based on borings and geologic mapping conducted for the CRN Site ESPA and previous investigations (TVA 2017-TN5387). The applicant supplemented lithologic descriptions with laboratory, downhole geophysical, and petrographic data collected during subsurface investigations at the CRN Site.

The applicant stated that the Rome Formation comprises mainly shale and siltstone with lesser amounts of sandstone, dolostone, limestone, and evaporite deposits. The applicant indicated that two boreholes placed to locate and characterize the Copper Creek thrust fault on the southern end of the CRN Site penetrated the Rome Formation, which does not crop out at the CRN Site. The applicant reported that approximately 1.3 to 2.3 m (4.3 to 7.4 ft) of fault gouge related to the Copper Creek thrust occurs between the base of the Rome Formation and the top of the stratigraphically younger Chickamauga Group Moccasin Formation, which underlies the Rome Formation due to thrusting of the Rome Formation over the Moccasin Formation. The applicant stated that the Newala Formation stratigraphically overlies the Rome Formation and represents the Knox Group at the CRN Site. The applicant described the Newala Formation as a fine- to medium-grained, variegated (i.e., gray, pink, and green in color) dolomite that commonly contains nodular, bedded jasperoidal chert. The applicant indicated that the formation also contains several 1.5 to 4.6 m (5 to 15 ft) thick limestone and dolomitic limestone interbeds. The applicant reported that stratigraphic units of the Chickamauga Group are lithologically variable and consist mainly of interbedded limestone and siltstone (TVA 2017-TN5387).

2.5.1.1.2.3.1 Karst Evaluation

In SSAR Section 2.5.1.2.3.4, the applicant reviewed existing dissolution cavity data and discussed the shape of conduits (TVA 2017-TN5387). The applicant stated that, based on compiled borehole data, the largest and highest frequency of dissolution cavities at the CRN Site occur in the Rockdell Formation and the Eidson Member of the Lincolnshire Formation of the Chickamauga Group. The applicant reported that these two stratigraphic units also contain the greatest thicknesses of pure limestone compared to other Chickamauga Group strata at the site. The applicant also stated that environment of formation, hydrologic setting, and rock characteristics control the shape of dissolution cavities. The applicant indicated that variation in rock solubility, bed thickness, structural discontinuities, geometry of fracture pathways, and the degree to which initial fractures have been enlarged governs the shape of conduits.

2.5.1.1.2.4 *Local Structural Geology*

SSAR Section 2.5.1.2.4 describes the structural geology of the site vicinity and site area (TVA 2017-TN5387). The applicant stated that the structural geology at the CRN Site is directly related to its position in the foreland fold-and-thrust belt (i.e., the Valley and Ridge province) of the Appalachian orogenic system. The applicant explained that thrust faults in a foreland fold-and-thrust belt propagate through mechanically weak layers at lower angles rather than through mechanically stronger units, which results in the characteristic ramp-flat geometry of the faults observed in the Valley and Ridge province.

2.5.1.1.2.4.1 Macroscopic Structures in the Site Vicinity

In SSAR Section 2.5.1.2.4.1, the applicant discussed macroscopic structures (i.e., folds and faults) that occur in the site vicinity (TVA 2017-TN5387). The applicant stated that macroscopic-scale folds in the CRN Site vicinity are open, upright to overturned synclines and anticlines with

axes trending parallel to the major faults and strike of lithologic units. The applicant reported that these macroscopic-scale folds extend for distances of 0.8 km (0.5 mi) to more than 11.3 km (7 mi) throughout the site vicinity, with fold axes normal to the inferred regional shortening direction, which supports their development as coincident with Alleghanian emplacement of Valley and Ridge thrust sheets.

The applicant explained that most faults in the CRN Site vicinity are bedding-parallel, northeast-striking, southeast-dipping thrust faults, which formed during the late stages of the Alleghanian orogeny and represent a cumulative shortening greater than 120 km (75 mi). The applicant reported that radiometric age dates on features associated with deformation in the Valley and Ridge province agree with this timing and range from 265 to 290 Ma. The applicant noted that recent $^{39}Ar/^{40}Ar$ analyses of fault gouge from several Valley and Ridge faults suggest emplacement occurred 276 to 280 Ma. The applicant discussed individual faults that occur in the site vicinity with regard to fault geometry and amount and timing of displacement. These faults, illustrated in FSER Figure 2.5.1-3 (reproduced from SSAR Figure 2.5.1-27 [TVA 2017-TN5387]), are as follows, with genetically related subordinate faults grouped together.

- Emory River and Bitter Creek Faults (Faults 7 and 2 in FSER Figure 2.5.1-3)
- Rockwood, Harriman, and Chattanooga Faults (Faults 11, 8, and 3 in FSER Figure 2.5.1-3)
- Kingston Fault (Fault 9 in FSER Figure 2.5.1-3)
- Beaver Valley Fault (Fault 1 in FSER Figure 2.5.1-3)
- Saltville Fault (Fault 12 in FSER Figure 2.5.1-3)
- Knoxville Fault (Fault 10 in FSER Figure 2.5.1-3)
- Dumplin Valley, Chestuee, and Wildwood Faults (Faults 6, 4, and 14 in FSER Figure 2.5.1-3).

2.5.1.1.2.4.2 Macroscopic Structures in the Site Area

In SSAR Section 2.5.1.2.4.2, the applicant discussed three faults that lie within the CRN Site area: Whiteoak Mountain fault, Copper Creek fault, and Chestnut Ridge fault (TVA 2017-TN5387). The applicant discussed the use of both seismic reflection and refraction data for subsurface investigations.

In SSAR Section 2.5.1.2.4.2.1, the applicant stated that the primary objectives of the seismic reflection surveys conducted for the CRN Site were to interpret the contact between the Knox and Chickamauga Group rocks, interpret the dip of bedding between borehole locations, and identify possible subsurface structures beneath survey lines (TVA 2017-TN5387). The applicant also stated that the primary objective of the seismic refraction surveys was to map the depth to bedrock, and that the objectives for both types of surveys were accomplished.

In SSAR Section 2.5.1.2.4.2.2, the applicant stated that the Whiteoak Mountain fault, located 3.2 km (2 mi) northwest of the CRN Site as shown in FSER Figure 2.5.1-3 (i.e., Fault 13), is a major regional thrust that places Cambrian Rome Formation above Cambrian to Mississippian footwall strata with a minimum displacement of 10 to 12 km (6.2 to 7.5 mi) (TVA 2017-TN5387). The applicant stated that the Whiteoak Mountain fault is a Late Paleozoic thrust related to development of the foreland fold-and-thrust belt.

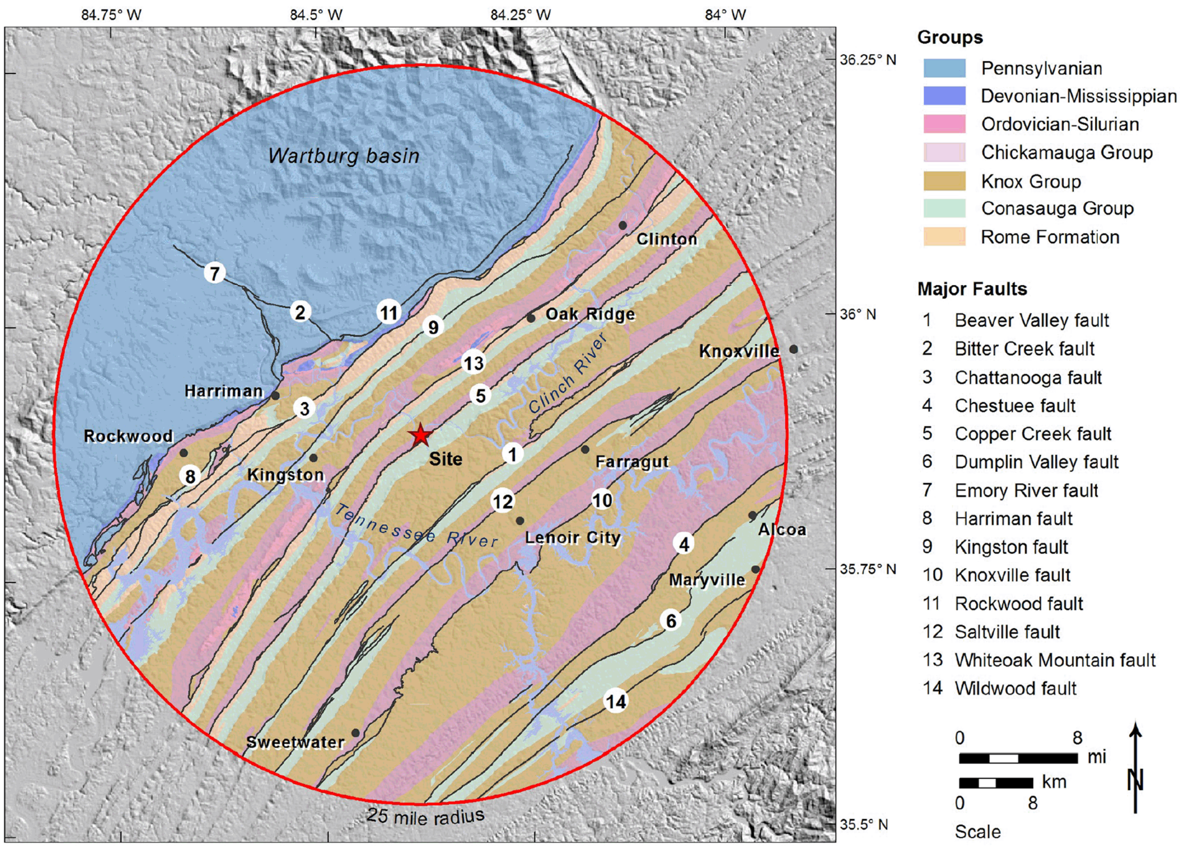


Figure 2.5.1-3 Simplified Site Vicinity Geologic Map (reproduced from SSAR Figure 2.5.1-27 [TVA 2017-TN5387])

In SSAR Section 2.5.1.2.4.2.3, the applicant described the Copper Creek fault, located 1 km (0.6 mi) southeast of the CRN Site as shown in FSER Figure 2.5.1-3 (Fault 5), as a major thrust in the Valley and Ridge fold-and-thrust belt (TVA 2017-TN5387). (FSER Figure 2.5.1-2 also shows the location of the Copper Creek fault in a northwest-southeast geologic cross section, as well as boreholes CC-B1 and CC-B2 that penetrated the fault.) The applicant noted that this fault places Cambrian Rome Formation rocks above the Ordovician Moccasin Formation with an estimated displacement of 12 to 50 km (7.4 to 31 mi). The applicant stated that materials indicative of fault displacement (i.e., fault gouge, breccia, and cataclasite) occur in association with this fault at the CRN Site and in the site area, and that $^{40}Ar/^{39}Ar$ age dates on gouge samples collected from the fault in northeastern Tennessee gave an age of 279.5 +/-11.3 Ma.

In SSAR Section 2.5.1.2.4.2.4 (TVA 2017-TN5387), the applicant stated that the Chestnut Ridge fault is a subordinate thrust no greater than 4.5 km (2.8 mi) in length, located about 1 km (0.6 mi) northwest of the CRN Site, as shown in the cross section of FSER Figure 2.5.1-2. The applicant noted that the fault is similar in strike orientation to major thrust faults of the Valley and Ridge province, although displacement along the fault is likely to be relatively small because it does not juxtapose rock units with significant stratigraphic or temporal differences, which would be indicative of a larger displacement. The applicant explained that the interpreted relatively steep dip of the Chestnut Ridge fault, which is not exposed at the surface, could have resulted from rotation of the fault in the hanging wall block of the Whiteoak Mountain fault as the hanging wall of the Whiteoak Mountain fault climbed over a footwall ramp during Alleghanian deformation of the Valley and Ridge province. The applicant stated that this rotation suggests

displacement along the Chestnut Ridge fault pre-dated at least some of the movement along the Whiteoak Mountain fault.

2.5.1.1.2.4.3 Mesoscopic Structures in the Site Vicinity

SSAR Section 2.5.1.2.4.3 describes folds, bedding, fractures, and shear-fracture zones at the CRN Site and in the site vicinity (TVA 2017-TN5387). The applicant stated that the data include information derived for the CRN Site from geologic field investigations, boreholes, and seismic reflection and refraction surveys.

In SSAR Section 2.5.1.2.4.3.1, the applicant explained that mesoscopic-scale folds in the site vicinity are primarily buckle folds with wavelengths of 0.3 m (1 ft) or less, which formed during compression and shortening that drove deformation in the Valley and Ridge fold-and-thrust belt (TVA 2017-TN5387). The applicant noted that several tight, asymmetric, overturned meter-scale folds with wavelengths of about 1 m (3.3 ft) also occurred in the CRBRP excavation.

In SSAR Section 2.5.1.2.4.3.2, the applicant stated that geologic mapping, acoustic televiewer borehole log data, and geometric solutions derived from three elevation points measured on key stratigraphic horizons in boreholes (i.e., standard three-point problem solutions) indicate that bedding at the site primarily strikes 050 to 070 (N50°E to N70°E) and dips between 20 to 50 degrees southeast (TVA 2017-TN5387). The applicant noted that seismic reflection data support consistent dips of stratigraphic units between boreholes at the CRN Site.

In SSAR Section 2.5.1.2.4.3.3 (TVA 2017-TN5387), the applicant discussed information from Hatcher et al. (1992-TN4989) suggesting that fracture sets developed before Alleghanian Valley and Ridge thrust faulting. The applicant noted that the orientation of fracture sets consistently rotates with the orientation of the bedding, which provides evidence of the development of the fracture sets prior to deformation related to thrust faulting. The applicant stated that two orthogonal fracture sets occur throughout the CRN Site area—one set parallel to the strike of bedding but perpendicular to the bedding dip, and the other set perpendicular to both the strike and dip of the bedding (TVA 2017-TN5387).

In SSAR Section 2.5.1.2.4.3.4, the applicant discussed shear-fracture zones identified within the site vicinity and described four attributes used to classify a feature as a "shear-fracture zone" based on borehole data (TVA 2017-TN5387). The geologic cross section of FSER Figure 2.5.1-2 shows the subsurface positions of two separate shear-fracture zones penetrated in boreholes beneath potential CRN Site Locations A and B. The applicant interpreted bedding-parallel stylolites that truncate the shear-fracture zones and calcite veins in the zones to demonstrate a pre- to syn-diagenetic, nontectonic origin for the zones due to pressure solution caused by lithostatic loading during burial. In addition, the applicant interpreted the truncation of calcite veins in the shear-fracture zones by steeply dipping stylolites, folding and deformation of calcite veins, and slickensides on veins and bedding surfaces to demonstrate a post-diagenetic, tectonic overprint on the zones related to Alleghanian emplacement of Valley and Ridge thrust faults, including the Whiteoak Mountain and Copper Ridge faults known to occur in the site area. Therefore, the applicant determined that both diagenetic and tectonic stylolites occur in the shear-fracture zones. The applicant considered a "shear zone" previously described in the excavation for the CRBRP site (Drakulich 1984-TN5940), no longer visible for a direct comparative examination, and the shear-fracture zones penetrated by boreholes at the CRN Site to most likely have a similar origin. The applicant made this interpretation because the description of the "shear zone" provided by Drakulich (1984-TN5940) is similar to the shear-

fracture zones observed in rock core samples from the CRN Site based on the four attributes used by the applicant to classify those zones.

In SSAR Section 2.5.1.2.4.4, the applicant stated that attributes of the Valley and Ridge thrust faults within the site area are a function of lithology and mechanical and chemical responses to stress during deformation (TVA 2017-TN5387). The applicant reported that two borings at the CRN Site penetrated the Copper Creek fault (i.e., CC-B1 and CC-B2, located on the geologic cross section of FSER Figure 2.5.1-2). The applicant noted that materials collected from the fault zone over a 1.2 to 2.1 m (4 to 7 ft) interval in the borings comprised angular carbonate and siliciclastic fragments in a clayey gouge matrix, which represent mechanical grain-size reduction due to cataclasis (i.e., fracturing, milling, crushing, and grinding) resulting from displacement along the fault.

2.5.1.1.2.5 *Local Geologic Hazards*

In SSAR Section 2.5.1.2.5, the applicant assessed potential geologic hazards in the site vicinity, site area, and at the site location (TVA 2017-TN5387). The applicant explained that karst features and active karst processes are common throughout the site vicinity and include sinkholes, caves, springs, underground drainage, and irregular soil-bedrock contacts. The applicant stated that karst dissolution of carbonate bedrock, which underlies all plant facilities, is the primary potential geologic hazard at the CRN Site.

2.5.1.1.2.5.1 Karst Hazards

In SSAR Section 2.5.1.2.5.1, the applicant discussed karst processes and features in the site vicinity, site area, and at the site location (TVA 2017-TN5387). The applicant reviewed conceptual karst models to provide a context for discussion of hazards at the CRN Site due to karst. The applicant presented discussions of previous karst studies in the site area, a detailed inventory of karst features in the site area, and a summary of local karst development. The applicant also discussed karst processes and features at the CRN Site, including karst susceptibility of stratigraphic units at the site, and karst-related surface and subsurface features at the site.

The applicant classified conceptual karst models based on whether karst evolved by epigenic or hypogenic dissolution, or both, of carbonate bedrock by water. The applicant explained that epigenic dissolution occurs by water moving downward from the ground surface into soluble rock formations, then through those formations along the hydraulic gradient. The applicant noted that the permeability of the rock formations controls the depth to which the water can penetrate for development of epigenic karst. The applicant explained further that hypogene dissolution occurs when groundwater moves upward from below, with movement of water being independent of recharge from the ground surface. The applicant indicated that hypogenic karst systems require a setting in which waters descend to great depths and then move upward through overlying soluble rocks. The applicant noted that the rising water can aggressively dissolve soluble rock units because of water chemistry or increased water temperature.

The applicant reported that studies of karst aquifers by Wolfe et al. (Wolfe et al. 1997-TN6189) resulted in development of a karst model for the Valley and Ridge province of Tennessee showing epigenic karst dissolution throughout the vadose (i.e., above the water table) and shallow and deep phreatic (i.e., below the water table) zones. Based on this model, the applicant stated that dissolution is most intense near the surface, but also proceeds downward along bedding planes and joints. The applicant noted that dissolution can extend to depths greater than 180 m (600 ft).

Karst in the Site Vicinity and Site Area

Because karst development in the site vicinity is similar to that in the site area due to the consistency of stratigraphy and geologic structure, the applicant focused the detailed discussions of karst in SSAR Section 2.5.1.2.5.1.1 on the site area (TVA 2017-TN5387). The applicant explained that, although all carbonate units contain some dissolution features, karst development varies strongly in relation to stratigraphic unit such that the thickest and purest carbonate rocks generally have the largest and most abundant karst features. The applicant stated that dissolution rates are variable and depend on multiple factors, including bedrock geochemistry, location of rock units relative to the water table, fracture density, and localized anthropogenic effects such as acid mine drainage. The applicant reported that the dissolution rate of carbonate bedrock in the Appalachians is in the range of 30 mm (1.2 in.) per thousand years.

In SSAR Section 2.5.1.2.5.1.1, the applicant stated that previous studies to characterize karst development at the ORR, which composes most of the northern half of the CRN Site area, significantly advanced the understanding of karst in the CRN Site area (TVA 2017-TN5387). To extend the information derived about karst at the ORR to the CRN Site area, the applicant conducted detailed mapping and prepared an inventory of karst features in the site area based on interpretation of high-resolution LiDAR data obtained in 2013 for characterization of the CRN Site.

SSAR Section 2.5.1.2.5.1.1 provides an explanation of the karst features inventory of the site area, completed for the CRN Site ESPA, to assist with understanding the nature and extent of karst development as a function of bedrock lithology, structure, and topography (TVA 2017-TN5387). The information presented included a discussion of the mapping of karst features, distribution of karst depressions, and cave development.

Regarding distribution of karst depressions, the applicant identified a total of 2,797 karst depressions in the karst inventory, 1,210 of which were sinkholes at least 0.6 m (2 ft) deep and 9.2 m^2 (100 ft^2) in area. The applicant calculated depression density for the CRN Site area within an 8 km (5 mi) radius of the site. The applicant reported that the analysis showed stratigraphic units characterized by thick and relatively pure carbonate have the highest depression density (i.e., number of depressions per unit area examined). The applicant noted that these stratigraphic units included the Knox Group dolomites and the purer limestones of the Chickamauga and the Conasauga Groups. The applicant stated that the Witten and Rockdell Formations, stratigraphic units of the Chickamauga Group underlying the CRN Site footprint, averaged 8 to 9 depressions per square kilometer (0.39 mi^2), while other units of the Chickamauga Group contained less than three depressions per square kilometer (0.39 mi^2), based on mapping by the applicant within a 9 km (5 mi) radius of the site. The applicant noted that stratigraphic units containing interbedded carbonate and clastic lithologies (e.g., the Benbolt formation of the Chickamauga Group) have depressions ranging from a moderate number to a few, and units dominated by clastic material (i.e., sandstone, siltstone, shale) have few to no depressions.

Regarding cave development, the applicant described two categories of cave passages based on groundwater setting. The applicant explained that vadose zone cave passages are formed above the water table by water moving down from the surface toward the water table, and the passages tend to follow the steepest available openings such as vertical joints and dipping bedding planes. The applicant further explained that phreatic cave passages are formed at or just beneath the water table where groundwater flows laterally in the direction of the hydraulic gradient. The applicant stated that the ideal phreatic passage is a tube-shaped conduit

reflecting dissolution on all sides of the water-filled passage, although the shape of the conduit can be modified by joints and bedding planes and the presence of less soluble strata. The applicant explained that, during the Late Tertiary and Quaternary, stream incision and landscape lowering resulted in abandonment of former phreatic passages, which consequently became dry. The applicant also explained that, after abandonment, passages can divide into segments because of surface erosion and be partially filled with sediments, cave formations, and collapsed rock from the dry conduit ceiling.

The applicant identified 24 caves within the 8 km (5 mi) site radius, all of which formed in the Copper Ridge Dolomite, Chapultepec Dolomite, or Maynardville Limestone. The applicant reported that the largest cave in the CRN Site area, the Copper Ridge Cave, has a stream-carved entrance passage that carries water from the hillside that then flows underground in a down-dip direction for about 213 m (700 ft). The applicant noted that a 122 m (400 ft) long segment of the entrance passage follows a prominent northwest-oriented joint set, and the passage eventually intersects a 12.2 m (40 ft) diameter tube-shaped passage. The applicant interpreted the passage, now more than 30.5 m (100 ft) above the present-day level of the Clinch River, as a relict phreatic feature formed when base level was higher. The applicant reported that most of the caves represent relict abandoned phreatic passages.

Summary of Local Karst Development

In the summary regarding local karst development, the applicant reiterated that field inspections and descriptions of local caves in the CRN Site area support the concept of geologic structure, stratigraphy, and lithology strongly controlling cave development. The applicant stated that the extent to which deep phreatic conditions existed, including hypogenic conditions, is currently unknown, and cave passage geometry is consistent with either phreatic or vadose dissolution. However, the applicant indicated that the presence of deep cavities in water wells suggests that deep phreatic dissolution is occurring, although no clear evidence of hypogene dissolution (e.g., secondary minerals characteristic of hypogene processes, such as travertine springs, or exotic minerals deposited in caves) has been documented in the site area. The applicant noted that most springs on the ORR have water chemistry typical of meteoric water.

Karst Processes and Features at the CRN Site

In SSAR Section 2.5.1.2.5.1.2, the applicant discussed the karst susceptibility of site-specific stratigraphic units, karst-related surface and subsurface features at the site, and the site-specific karst model (TVA 2017-TN5387). The applicant explained that karst features at the CRN Site consist primarily of karst depressions (i.e., sinkholes) observed at the ground surface and cavities encountered in boreholes. The applicant stated that information derived from geologic mapping, field reconnaissance, and geotechnical investigations conducted for the CRBRP and the CRN Site provided the basis for the discussion.

The applicant stated that the susceptibility of a stratigraphic unit to karst development depends strongly on the composition, bedding, and jointing characteristics of the unit. Regarding rock composition, the applicant indicated that the stratigraphic units of the Chickamauga Group, which underlie the CRN Site, comprise varying proportions of calcite, sand, silt, clay, and chert. The applicant noted that the Eidson Member of the Blackford Formation and the Rockdell and Benbolt Formations have the highest carbonate content, while the Fleanor Shale, the rest of the Blackford Formation, and the Bowen Formation have relatively lower carbonate contents. The applicant also noted that variability in carbonate content within any given stratigraphic unit reflected the presence of alternating interbeds of carbonate and clastic strata, as observed in

core of the Chickamauga Group. Regarding bedding and jointing, the applicant stated that bedding planes, joints, and fracture zones constituted the initial pathways for water to penetrate the stratigraphic units and start the dissolution process.

The applicant stated that the primary documentation of subsurface dissolution features at the CRN Site comes from boreholes. However, the applicant also stated that borings show only a fraction of the dissolution features present in the subsurface. In addition, the borings do not clearly define the extent and geometry of the features due to the spacing between borings and the small diameter of the borings. The applicant indicated that two seismic reflection lines completed during the CRN Site investigations showed planar beds of uniformly dipping strata, which provides evidence against the presence of large-scale subsurface karst collapse features along the survey lines.

The applicant reported that rock core borings drilled in the CRN Site area revealed both open and clay-filled cavities. The applicant observed that, of the 180 borings completed at the CRBRP (104) and the CRN Site (76), 75 borings encountered one or more cavities and frequency and size of cavities, which were greater in stratigraphic units that had a higher carbonate content, generally decreased with depth. The applicant stated that borings in the Rockdell Formation of the Chickamauga Group encountered the greatest number of and largest cavities (i.e., more than 100 cavities up to 5 m [16.5 ft] in the vertical dimension), while borings in the Fleanor Shale, which had the lowest carbonate content of the Chickamauga Group, encountered 19 cavities up to 0.4 m (1.4 ft) in the vertical dimension. The applicant pointed out that the shear-fracture zones, penetrated in 15 boreholes during subsurface investigations, did not appear to be the loci for accelerated dissolution.

In SSAR Section 2.5.1.2.5.1.2, the applicant presented the features of a conceptual model for karst development at the CRN Site based on concepts, observations, and data derived from regional, local, and site-specific investigations (TVA 2017-TN5387). The applicant also stated that a geologic mapping and subsurface exploration program would be implemented during site excavation to delineate karst features below the floor of the excavation.

Potential Karst Hazard at the CRN Site

In SSAR Section 2.5.1.2.5.1.3, the applicant stated that overburden and cavities formed by dissolution near the top of rock would be removed during the excavation process and there would be little hazard due to cover-collapse sinkholes at plant facilities sited on these excavations (TVA 2017-TN5387). The applicant acknowledged that this type of sinkhole is the most common type in the CRN Site area. The applicant stated that dissolution cavities have been observed in boreholes down to an elevation of 201 m (660 ft), and data collected for the CRN Site provide a comprehensive understanding of karst within approximately 91 m (300 ft) of the ground surface.

The applicant discussed three types of potential karst hazards posed by dissolution cavities at the CRN Site. The first potential hazard is related to the presence of cavities below the water table in the walls of the excavation, which might result in discharge of groundwater from the cavities that could make it difficult to maintain a dry excavation. The applicant stated that information from the CRBRP excavation into the Fleanor Shale showed the excavation to have been relatively dry. The second potential hazard involves the presence of dissolution cavities below the base of the foundation that might require mitigation to ensure foundation stability. The applicant stated that small cavities can be mitigated by grouting, geophysical tests or boreholes in the finished excavation can be used to detect deeper cavities, and the information derived can be used to determine the appropriate mitigation strategy for the cavities. The

applicant indicated that final conclusions regarding karst hazard would be based on detailed geologic mapping of the excavations and geophysical surveys that penetrate below the foundation level. The third potential hazard relates to the presence of cavities that might enable rapid movement of an accidental release (TVA 2017-TN5387).

2.5.1.1.2.5.2 Other Local Geologic Hazards

In SSAR Section 2.5.1.2.5.2, the applicant addressed local geologic hazards related to slope failure, unrelieved residual stresses, and effects of human activities (TVA 2017-TN5387). For a discussion of slope failure, the applicant cross-referenced SSAR Section 2.5.3 (TVA 2017-TN5387). Regarding unrelieved residual stresses, the applicant characterized the local stress regime as an unloading condition within the consistent stress field of the Eastern United States. The applicant commented that stress release due to weathering and erosion might be expressed in closely spaced joints that occur near the ground surface, but there are no conditions conducive to high residual stresses in the rock units. The applicant noted that underground mining and hydrocarbon extraction have not taken place at the site, and the site has not experienced significant groundwater withdrawal. Therefore, the applicant stated that subsidence due to mining, hydrocarbon or mineral extraction, or groundwater withdrawal are not potential hazards at the CRN Site (TVA 2017-TN5387).

In a summary evaluation of local geologic hazards in SSAR Section 2.5.1.2.5.3, the applicant indicated that the primary geologic hazard at the CRN Site is the potential for karst dissolution features, which could compromise the safety or stability of the excavation or enable rapid movement of groundwater (TVA 2017-TN5387). The applicant stated that such hazards related to karst, if present, can be mitigated during construction. The applicant reiterated that the planned geologic mapping of the walls and floor of excavations for safety-related structures would be conducted to fully describe karst features and enable planning of an appropriate mitigation approach.

2.5.1.1.2.6 *Site Engineering Geology*

In SSAR Section 2.5.1.2.6, the applicant summarized conditions related to engineering geology beneath the power block area at the CRN Site based on information derived from review of existing site-specific reports and geologic literature, as well as geologic and geotechnical investigations (TVA 2017-TN5387). The applicant stated that bedrock belonging to the Knox and Chickamauga Groups underlies the CRN Site, and that the discussions in SSAR Section 2.5.1.2.6 (TVA 2017-TN5387) focus on geologic features and characteristics that might affect the bedrock units.

In SSAR Section 2.5.1.2.6.1 (TVA 2017-TN5387), the applicant reported that the subsurface investigation program for the CRN Site involved drilling and sampling a total of 82 geotechnical borings, including 6 soil borings (see borehole location map, FSER Figure 2.5.4-2). The applicant noted that ground surface elevations within the potential power block area range from about 260.6 m (855 ft) to 237.7 m (780 ft) NAVD88 (i.e., North American Vertical Datum of 1988). The applicant stated that the stratigraphic units underlying the power block area include the Newala Formation of the Knox Group overlain up-section by the Blackford, Lincolnshire (Eidson and Fleanor Members), Rockdell, and Benbolt Formations of the Chickamauga Group. The applicant stated that the estimated final grade elevation at the CRN Site is 250 m (821 ft) NAVD88 (TVA 2017-TN5387).

In SSAR Section 2.5.1.2.6.2, the applicant briefly discussed ranges of the Geologic Strength Index (GSI) for each of the stratigraphic units that underlie the CRN Site (TVA 2017-TN5387).

In SSAR Section 2.5.1.2.6.3, the applicant reported that borings drilled at the CRN Site indicate the occurrence of fracture zones or zones of weathering within the stratigraphic units, which likely represent early dissolution of limestone (TVA 2017-TN5387). The applicant stated that most of the fracture zones occurred between elevations of approximately 243.8 to 22.6 m (800 to 750 ft NAVD88). The applicant noted that rock mass discontinuities became tighter and less frequent with depth, although fracture zones occur between depths ranging between about 1.8 to 122 m (6 to 400 ft) below the ground surface, and few fractures below the power block foundation level exhibit weathering.

In SSAR Section 2.5.1.2.6.4, the applicant indicated that the average GSI rating for each of the stratigraphic units in which the zones occur incorporates the shear-fracture zones, so the determination of the bearing capacity based on GSI considered these zones (TVA 2017-TN5387). The applicant stated that further evaluation of the shear-fracture zones might be required for a future COLA. The applicant also stated that detailed geologic mapping of the excavations for safety-related engineered structures would provide additional characterization of the shear-fracture zones if they occur in the excavations.

In SSAR Section 2.5.1.2.6.8, the applicant stated that no permitted natural gas wells, coal mines, or quarries occur within 8 km (5 mi) of the CRN Site (TVA 2017-TN5387). SSAR Section 2.5.1.2.6.9 states that groundwater levels at the site are likely to require temporary dewatering of foundation excavations and notes that solution cavities, bedding planes, and open fractures might require grouting to reduce groundwater flow into the excavation and to reduce the amount of dewatering (TVA 2017-TN5387). In SSAR Section 2.5.1.2.6.10, the applicant stated that future excavations for safety-related engineered structures would be geologically mapped in detail and any unforeseen geologic features that are encountered would be evaluated (TVA 2017-TN5387). The applicant indicated that the detailed geologic mapping would document dissolution features, determine whether dissolution cavities decrease in size and abundance with depth, provide the opportunity to collect in situ data to refine rock mass characterization, confirm or refine interpretations of subsurface geology derived from borehole data, and verify the absence of active tectonic faults.

2.5.1.1.2.7 <u>Relational Analysis</u>

In SSAR Section 2.5.1.2.9 (TVA 2017-TN5387), the applicant discussed the relationships between stratigraphic units, structural geology, and karst features at the proposed CRN Site and the previous CRBRP site. The applicant considered this analysis important because the two sites are co-located on the peninsular landform defined by the incised Clinch River arm of the Watts Bar Reservoir and the results of the investigations for each can be compared.

Regarding karst features, the applicant indicated that borehole data revealed 216 subsurface dissolution cavities at the CRBRP site and 23 at the CRN Site; the fewer number of cavities encountered in the CRN Site borings, which overlapped those for the CRBRP site, was consistent with removal of the cavity-rich near-surface strata during excavation at the CRBRP site. The applicant also indicated that the distribution of cavity size with elevation at the CRN Site is consistent with data collected at the CRBRP site. Based on the quality and compatibility of both boring programs, the applicant determined that the two data sets could be combined and used for analysis of subsurface cavities at the CRN Site. The applicant stated that results of the CRBRP site investigations (i.e., geologic mapping and subsurface investigations) can be used to enhance understanding of the geology and engineering suitability of foundation rock units at the CRN Site.

2.5.1.2 *Regulatory Basis*

The applicable regulatory requirements for basic geologic and seismic information that must be considered in an ESPA are as follows:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to identifying the geologic and seismic characteristics of a proposed site with appropriate consideration of the most severe natural phenomena that have been historically reported for the site and surrounding area, and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR 100.23 (TN282), as it relates to evaluating the suitability of a proposed site based on consideration of geologic, geotechnical engineering, geophysical, and seismic characteristics of the proposed site. Geologic and seismic siting information must be sufficient to support estimates of the SSE for the site and identify the potential for surface tectonic and nontectonic deformation.

The related acceptance criteria from SRP Section 2.5.1 (NRC 2018-TN5898) are as follows:

- Regional Geology (SSAR Section 2.5.1.1): Requirements of 10 CFR 52.17 (TN251) and 10 CFR 100.23(c) (TN282) are met and guidance in RGs 1.206 (NRC 2007-TN3035), 1.208 (NRC 2007-TN5858), and 4.7 (NRC 2014-TN3550) is followed for this area of review if a complete and documented discussion is presented for geologic setting, tectonic framework, and conditions caused by human activities that have the potential to affect safe siting and design of the proposed facility. This SSAR section should contain a review of regional stratigraphy, lithology, structural geology, geologic and tectonic history, tectonic features (with an emphasis on the Quaternary period), seismology, geomorphology, paleoseismology, and physiography within the 320 km (200 mi) site region, or beyond as necessary, to provide a framework within which significance to safety can be evaluated in regard to geology, seismology, and conditions caused by human activities. Geologic maps and cross sections constructed at scales adequate to illustrate relevant regional features should be included in the application.
- Site Geology (SSAR Section 2.5.1.2): Requirements of 10 CFR 52.17 (TN251) and 10 CFR 100.23(c) (TN282) are met and guidance in RGs 1.206 (NRC 2007-TN3035), 1.208 (NRC 2007-TN5858), and 4.7 (NRC 2014-TN3550) is followed for this area of review if the SSAR contains a description and an evaluation of geologic features, tectonic features, and conditions caused by human activities at appropriate levels of detail for determining any potential natural hazards that might affect the design and operation of the proposed facility. This section should contain the following information within the 40 km (25 mi) site vicinity, the 8 km (5 mi) site area, and the 1 km (0.6 mi) site location:
  - structural geology, including identification and characterization of faults, joints, and other tectonic deformation features and discussion of the relationships between these features and regional tectonic structures;
  - geologic maps and cross sections constructed at scales adequate to clearly illustrate pertinent features;
  - stratigraphy and lithology of rock units and discussion of their relationships to the regional lithostratigraphic framework;
  - geomorphologic features as tectonic strain markers or indicators of other potentially hazardous natural phenomena (e.g., landslides, karst development and dissolution collapse, growth faults);

- geologic and tectonic history, particularly for the Quaternary period, and discussion of the relationship to regional geologic and tectonic history;
- tectonic framework description, including identification of historical and instrumentally recorded earthquakes; identification and characterization of any local tectonic features that might be related to seismicity; discussion of the relationships between local and regional tectonic structures and any relationships to seismicity;
- evidence of paleoseismic features, including a description of investigations performed by the applicant to verify the presence or absence of the features; and
- geologic features that have significance for geotechnical engineering, including (1) zones of mineralization, alteration, irregular or deep weathering, or structural weakness in surface or subsurface materials; and (2) surface and subsurface dissolution features in soluble rocks such as limestone, gypsum, or salt.

2.5.1.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.5.1 of the CRN Site ESPA (Revision 1 [TVA 2017-TN5387]) to ensure that the materials provided by the applicant present the information required for geologic characterization of the CRN Site. The information presented in SSAR Section 2.5.1 includes geologic, geophysical, and seismic data for the site region, site vicinity, site area, and site location derived from the applicant's reviews of previous CRBRP reports, ORNL reports, and published literature, as well as from surface and subsurface field investigations specifically conducted by the applicant to characterize the geology of the CRN Site for the ESPA (TVA 2017-TN5387).

SSAR Section 2.5.1 contains information related to assessment of the potential for tectonic and nontectonic surface deformation at the CRN Site, including faulting and limestone dissolution, which the applicant addressed in detail in SSAR Section 2.5.3, as well as geologic and seismic data to support the analysis of vibratory ground motion and development of the site-specific ground motion response spectrum (GMRS) in SSAR Section 2.5.2 (TVA 2017-TN5387). In addition, SSAR Section 2.5.1 includes site-specific geotechnical information related to the suitability of subsurface materials and foundations, which the applicant discussed in detail in SSAR Section 2.5.4 (TVA 2017-TN5387).

The staff's review of SSAR Section 2.5.1 (TVA 2017-TN5387) confirmed that materials included in the ESPA addressed the types of information required for geologic characterization of the CRN Site. By performing the review, the staff determined that the applicant had collected sufficient information for geologic characterization of the site to comply with applicable regulatory requirements in 10 CFR 52.17(a)(1)(vi) (TN251) and 10 CFR 100.23(c) (TN282), and conducted the site characterization investigations at the appropriate levels of detail in accordance with guidance in RG 1.208 (NRC 2007-TN5858). RG 1.208 recommends that an applicant evaluate any significant new geologic, seismic, and geophysical data to determine whether revisions to existing seismic source models and ground motion attenuation relationships are necessary (NRC 2007-TN5858). RG 1.208 also recommends that an applicant evaluate faults encountered at a site to determine whether they are seismogenic or might cause tectonic surface deformation (NRC 2007-TN5858).

To further confirm that the applicant provided the information necessary for adequate geologic characterization of the CRN Site, the staff participated in two site audits and a site visit. The staff conducted the first audit for the CRN Site on July 17–18, 2013, to observe field activities being undertaken by the applicant to collect subsurface geotechnical and geologic data prior to

submitting the ESPA for the site. The Audit Report of this first audit (NRC 2013-TN5925) documents the information discussed during this first site audit.

The second site audit, conducted on May 8–9, 2017 (NRC 2017-TN5908), and the site visit, held on January 30–31, 2018 (NRC 2018-TN5941), occurred after the applicant had submitted the ESPA for the CRN Site. During the May 2017 audit, the staff interacted with the applicant to discuss the geologic, seismic, geophysical, and geotechnical investigations conducted by the applicant to characterize the proposed site. The staff held these discussions while examining select core samples to observe subsurface characteristics of the Copper Creek fault, a shear-fracture zone, karst-related cavities, and the Knox unconformity; rock outcrops; and geomorphic features. The staff visited field locations where three subsurface geologic features (i.e., the Copper Creek fault, a shear-fracture zone, and the Chestnut Ridge fault) would likely intersect the ground surface based on the interpreted subsurface orientations of these features. The interpreted subsurface orientations were derived from rock core samples, previous geologic mapping, and the analysis of subsurface stratigraphy. The staff's visit confirmed there is no evidence that these three features are presently visible at the ground surface. The applicant marked the location of the surface projection of the Copper Creek fault on a Quaternary river terrace to enable staff to confirm that the terrace surface did not exhibit any evidence of Quaternary offset. The staff also visited and examined sinkholes, the Melton Hill and Copper Ridge Caves, and exposures of pinnacle and cutter type karst in the site area to increase understanding of the overall characteristics of karst at and around the CRN Site. A thorough understanding of the karst activity at and near the CRN Site is necessary because limestone dissolution, which creates karst, can produce subsurface cavities that might affect site suitability. The May 2017 Audit Summary Report (NRC 2017-TN5908) summarizes the features observed and the information discussed during the May 2017 site audit.

The January 2018 site visit (NRC 2018-TN5941) allowed staff to re-examine and analyze some of the geologic features observed during the May 2017 site audit (NRC 2017-TN5908) and get further clarification from the applicant related to the applicant's descriptions and interpretations of those features. The primary focus of the site visit was on the field characteristics of the shear-fracture zones and karst features. During the January 2018 site visit (NRC 2018-TN5941), the staff confirmed the applicant's descriptions and interpretations of karst features provided in SSAR Section 2.5.1 (TVA 2017-TN5387) based on direct field examination of outcrops and features, as well as rock core samples. These confirmatory activities, along with discussions with the applicant during these activities, supported the applicant's conclusion that karst is the primary geologic hazard at the CRN Site. Confirmation of the applicant's characterization of karst at the site was important for the staff's findings regarding this potential hazard. The staff also clarified the basis for the applicant's interpretation of the distinction between thrust faults and shear-fracture zones based on direct examination and analysis of the two features in core samples and discussions with the applicant. It was clear that the thrust faults are tectonic in origin and formed during the Late Paleozoic Alleghanian orogeny with no indication of Quaternary deformation, and that the shear-fracture zones likely reflect both diagenetic effects and a Late Paleozoic tectonic overprint, but without major displacement along the zones as the thrust faults exhibit. Confirmation of the applicant's characterization of the shear-fracture zones and thrust faults was important for the staff's findings regarding these features to ensure that neither feature reflected Quaternary deformation. A trip report (NRC 2018-TN5941) describes the features observed and the information discussed during the January 2018 site visit.

The following FSER sections present the staff's evaluation of information provided by the applicant in SSAR Section 2.5.1 (TVA 2017-TN5387) and in the applicant's responses to RAIs

related to SSAR Section 2.5.1. The RAIs issued by the staff and discussed in the following FSER sections ensure the applicant's compliance with 10 CFR 52.17(a)(1)(vi) (TN251) and 10 CFR 100.23(c) (TN282), as well as conformance with SRP Section 2.5.1 (NRC 2018-TN5898). In addition to RAIs addressing specific technical issues for the CRN Site, discussed in detail below, the staff prepared a few editorial RAIs asking the applicant to more clearly define the locations of certain geologic features shown in SSAR figures. This technical evaluation does not include a discussion of the editorial RAIs, but staff examined the pertinent figures to ensure that the applicant had made the requested changes.

2.5.1.3.1 Regional Geology

The staff reviewed SSAR Section 2.5.1.1 (TVA 2017-TN5387), which included information provided by the applicant related to the following topics within 320 km (200 mi) of the CRN Site (i.e., the site region): physiography, topography, and geomorphic processes; fluvial processes; karst processes and occurrence; geologic history and tectonic evolution; stratigraphy; tectonic setting; and non-seismic geologic hazards. The staff focused its review on the applicant's descriptions of Valley and Ridge thrust faults that developed during the Late Paleozoic Alleghenian orogeny; potential Quaternary tectonic features, specifically possible faults and paleoliquefaction features that could be associated with the ETSZ, which falls within the CRN Site region; and karst processes and features resulting from limestone dissolution of carbonate rocks that the applicant qualified as being the dominant non-seismic geologic hazard in the CRN Site region.

2.5.1.3.1.1 *Regional Physiography, Topography, and Geomorphic Processes*

In SSAR Section 2.5.1.1.1, the applicant described the physiography, topography, and geomorphic processes of the site region, specifically including regional karst processes and occurrence in SSAR Section 2.5.1.1.1.3 (TVA 2017-TN5387). The staff focused its review of SSAR Sections 2.5.1.1.1 on the Valley and Ridge physiographic province because the CRN Site lies in that province.

Based on its review of information presented in SSAR Section 2.5.1.1.1 (TVA 2017-TN5387) and literature cited by the applicant in the SSAR related to regional physiography, topography, and geomorphic processes in the Valley and Ridge province; examination of regional topographic maps; and direct observation of physiographic, topographic, and geomorphic features at and around the CRN Site during the second site audit in May 2017 (NRC 2017-TN5908) and the site visit in January 2018 (NRC 2018-TN5941), the staff concludes that the underlying geology and tectonic structures characteristic of the site region strongly control the morphology of the surrounding landscape. The staff makes this conclusion because all existing data clearly support the concept of lithologic and structural control on landscape morphology.

In addition, based on its review of information presented in SSAR Section 2.5.1.1.1.1.3 (TVA 2017-TN5387) and literature cited by the applicant in the SSAR specifically related to regional karst processes and occurrence in the Valley and Ridge province, as well as direct observation of karst features in the folded and faulted Paleozoic carbonate rocks at and around the CRN Site during the second site audit in May 2017 (NRC 2017-TN5908) and the site visit in January 2018 (NRC 2018-TN5941), the staff concludes that sinkholes occur in carbonate strata of the Valley and Ridge province and caves are relatively short due to the deformation characteristics (i.e., folding and faulting) and compositional variations of rock units in the province. The staff makes these conclusions because all existing data support the existence of sinkholes and relatively short caves in the Valley and Ridge province.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.1.1 (TVA 2017-TN5387) as outlined in the above paragraphs, the staff finds that the applicant provided a thorough and accurate description of regional physiography, topography, and geomorphic processes, including regional karst processes and occurrence, in support of the CRN Site ESPA.

2.5.1.3.1.2 *Regional Geologic History and Tectonic Evolution*

In SSAR Section 2.5.1.1.2 (TVA 2017-TN5387), the applicant discussed the geologic history and tectonic evolution of the site region, which covered

- the three Paleozoic orogenies (i.e., the Taconic, Acadian/Neoacadian, and Alleghanian orogenies) that directly influenced the geology and structural features of the CRN Site region and, consequently, the CRN Site;
- the Mesozoic extension associated with continental rifting in the CRN Site region that formed the present-day Atlantic Ocean Basin; and
- the potential Miocene uplift of the southern and central Appalachians.

The applicant noted that the Alleghanian orogeny resulted in folding and faulting of stratigraphic units in the Valley and Ridge physiographic province.

The staff focused the review of SSAR Section 2.5.1.1.2 (TVA 2017-TN5387) on the discussion of the thrust faults and folds that developed during the Alleghanian orogeny because these structural features occur in the site region, site vicinity, site area, and at the CRN Site location. Based on the review of information presented in SSAR Section 2.5.1.1.2 and literature cited by the applicant in Section 2.5 of the SSAR (TVA 2017-TN5387), as well as examination of the Copper Ridge thrust fault in core samples from the site location, the staff concludes that geologic history and tectonic evolution in the site region are appropriately characterized by the applicant. The staff makes this conclusion because all existing data strongly support the descriptions of geologic history and tectonic evolution of the site region provided by the applicant in SSAR Section 2.5.1.1.2.

Based on the actions performed by the staff associated with its review of SSAR Section 2.5.1.1.2 (TVA 2017-TN5387) as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of regional geologic history and tectonic evolution in support of the CRN Site ESPA.

2.5.1.3.1.3 *Regional Stratigraphy*

In SSAR Section 2.5.1.1.3, the applicant discussed the stratigraphy of the site region, focusing primarily on rock units found in the Valley and Ridge physiographic province in which the site lies (TVA 2017-TN5387). The applicant stated that the site consists predominantly of a sequence of Paleozoic sedimentary rocks ranging in age from Lower Cambrian to Pennsylvanian comprising the Lower Cambrian Rome Formation; a thick, extensive Cambrian to Ordovician carbonate shelf sequence; a thin, laterally variable shelf sequence of Upper Ordovician to Lower Mississippian carbonate rocks and thin clastic units; and a Middle Mississippian to Pennsylvanian synorogenic clastic wedge.

The staff focused the review of SSAR Section 2.5.1.1.3 (TVA 2017-TN5387) on the discussion of stratigraphic units in the Valley and Ridge physiographic province because the CRN Site lies in that province. Based on its review of information presented in SSAR Section 2.5.1.1.3 and

literature cited by the applicant in Section 2.5 of the SSAR (TVA 2017-TN5387), as well as examination of core and outcrops of parts of the stratigraphic sequence at and around the CRN Site during the second site audit (NRC 2017-TN5908) and the site visit (NRC 2018-TN5941), the staff concludes that the site is underlain predominately by a sequence of Paleozoic rocks containing both carbonate (i.e., limestone and dolomite) and clastic lithologies. The staff makes this conclusion because all existing data, including field observations of outcrops and core samples, strongly support the interpretation that the site is underlain by Paleozoic carbonate and clastic rock units.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.1.3 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of regional stratigraphy in support of the CRN Site ESPA.

2.5.1.3.1.4 *Regional Tectonic Setting*

In SSAR Section 2.5.1.1.4, the applicant discussed the tectonic setting of the site region, presenting information regarding the subdivision of principal tectonic terranes and physiographic provinces; regional geophysical data; and distribution of seismicity and stress in the Eastern United States (TVA 2017-TN5387). Under SSAR Section 2.5.1.1.4.3, the applicant included discussions of the current stress regime in the Eastern United States and the distribution of seismicity in the ETSZ (TVA 2017-TN5387).

The staff focused its review of SSAR Section 2.5.1.1.4 (TVA 2017-TN5387) on information related to the age of thrust faults in the Valley and Ridge province and the discussion of the ETSZ. The staff maintained this focus because the age of major thrust faults in the Valley and Ridge province also reveals the age of faulting at the CRN Site. In addition, the site lies within the ETSZ, which makes understanding the occurrence of seismicity in the zone important in regard to potential seismic hazards for the site. Based on its review of information presented in SSAR Section 2.5.1.1.4 and literature cited by the applicant (TVA 2017-TN5387), the staff concludes that the age of major thrust faults in the site region and at the site is well-constrained to be Late Paleozoic (i.e., much older than Quaternary). The staff also concludes that the seismicity in the ETSZ has been reasonably assessed in light of existing data with due consideration of different potential interpretations of prehistoric earthquake magnitudes in the ETSZ. The staff makes these conclusions because the age of the major thrust faults is clearly documented to be Late Paleozoic, which indicates that the potential for these faults to pose a hazard for the CRN Site is negligible, and the applicant has considered all different potential interpretations related to characterization of seismicity in the ETSZ.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.1.4 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of regional tectonic setting in support of the CRN Site ESPA.

2.5.1.3.1.5 *Regional Non-Seismic Geologic Hazards*

In SSAR Section 2.5.1.1.5, the applicant discussed non-seismic geologic hazards in the site region, noting that carbonate rock dissolution and karst formation is the dominant non-seismic geologic hazard in the region (TVA 2017-TN5387). The applicant also noted that the CRN Site lies in an area of moderate susceptibility for and low incidence of landslides, while susceptibility for landslides in the surrounding site region ranges from high to moderate.

The staff focused its review of SSAR Section 2.5.1.1.5 (TVA 2017-TN5387) on information related to carbonate rock dissolution and karst formation because the applicant considers karst to be the primary non-seismic geologic hazard in the site region. Based on its review of information presented in SSAR Section 2.5.1.1.5 and literature cited by the applicant in SSAR Section 2.5 (TVA 2017-TN5387), and examination of karst features in outcrops and core samples during the second site audit (NRC 2017-TN5908) and the site visit (NRC 2018-TN5941), the staff concludes that karst resulting from dissolution of carbonate rock units is the dominant non-seismic geologic hazard in the site region as well as at the site. The staff makes this conclusion because all existing data support the interpretation that karst is the primary hazard.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.1.5 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of regional non-seismic geologic hazards in support of the CRN Site ESPA.

2.5.1.3.2 Local Geology

The staff reviewed SSAR Section 2.5.1.2, which included information provided by the applicant about the following topics within 40 km (25 mi), 8 km (5 mi), and 1 km (0.6 mi) of the CRN Site (i.e., the site vicinity, site area, and site location respectively): physiography and geomorphic processes, geologic history, stratigraphy and lithology, structural geology, geologic hazards, site engineering geology, site groundwater conditions, tsunami and seiche hazards, and relational analysis (TVA 2017-TN5387). The staff particularly concentrated on discussions provided by the applicant related to shear-fracture zones and their association with Paleozoic thrust faults, hypogene karst,; detection of voids using seismic reflection, field reconnaissance studies to assess the presence or absence of paleoliquefaction features related to earthquakes in the ETSZ, and current tectonic stresses that affect the state of stress in bedrock at the CRN Site.

2.5.1.3.2.1 <u>Local Physiography and Geomorphic Processes</u>

In SSAR Section 2.5.1.2.1, the applicant discussed physiography and geomorphic processes in the site vicinity, site area, and at the site location (TVA 2017-TN5387). The staff focused its review of SSAR Section 2.5.1.2.1 on information related to Late Tertiary and Pleistocene geomorphic processes because they have the highest likelihood of affecting karst development in the site area and controlling the erosional dissection of terraces, which the applicant used to assess the presence or absence of surface deformation at the site and discussed in SSAR Section 2.5.3.2.5 (TVA 2017-TN5387). Based on its review of information presented in SSAR Section 2.5.1.2.1 and literature cited by the applicant in the SSAR (TVA 2017-TN5387), the staff concludes that the applicant appropriately considered the potential effects of Late Tertiary and Pleistocene geomorphic processes on karst development and terrace dissection. The staff makes this conclusion because all data discussed by the applicant enabled the initial assessment of the potential effects of these processes.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.2.1 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of local physiography and geomorphic processes in support of the CRN Site ESPA.

2.5.1.3.2.2 *Local Geologic History*

In SSAR Section 2.5.1.2.2, the applicant described the geologic history of the CRN Site vicinity in relation to the three primary Paleozoic orogenic events that affected the Appalachian orogenic belt (i.e., the Middle Ordovician Taconic orogeny, the Early Devonian to Mississippian Acadian/Neoacadian orogeny, and the Pennsylvanian to Permian Alleghanian orogeny) (TVA 2017-TN5387). The applicant noted that the Alleghanian orogeny resulted in the physiographic and geomorphic expression of the Valley and Ridge foreland fold-and-thrust belt observed in the CRN Site vicinity. The applicant identified the Rome Formation as the basal stratigraphic unit overlying basement in the site vicinity, noting that sedimentary rocks of the Middle to Late Cambrian Conasauga Group overlie the Rome Formation and grade into predominantly carbonate rocks of the Late Cambrian to Early Ordovician Knox Group. The applicant stated that, following development of the Knox unconformity in the Middle Ordovician due to a sea level drop and subsequent erosion, a sea level rise resulted in continued carbonate deposition of the Middle Ordovician Chickamauga Group atop the Knox Group. The applicant noted that the Chickamauga Group dominates the stratigraphic sequence in the site area.

The staff focused its review of SSAR Section 2.5.1.2.2 (TVA 2017-TN5387) on descriptions of the Alleghanian thrust faults, in particular the Copper Ridge thrust fault, and stratigraphic units that occur in the site vicinity because certain thrust faults and all of the stratigraphic units also occur at the CRN Site. Based on its review of the information presented in SSAR Section 2.5.1.2.2 and literature cited by the applicant in the SSAR (TVA 2017-TN5387), as well as examination of stratigraphic units in core samples and outcrops and a thrust fault in core samples during the second site audit (NRC 2017-TN5908) and the site visit (NRC 2018-TN5941), the staff concludes that the Copper Ridge thrust lies immediately south of the CRN Site and the stratigraphic units described for the site vicinity exist in the subsurface at the CRN Site. The staff makes this conclusion because all existing data document the existence of thrust faults and verify the stratigraphic sequence in the site vicinity, site area, and at the site location.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.2.2 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of local geologic history in support of the CRN Site ESPA.

2.5.1.3.2.3 *Local Stratigraphy and Lithology*

In SSAR Section 2.5.1.2.3, the applicant discussed stratigraphy and lithology of the CRN Site, including information about stratigraphic nomenclature and the evaluation of karst (TVA 2017-TN5387). The applicant cross-referenced SSAR Sections 2.5.3 and 2.5.4, respectively, regarding details about Quaternary terrace deposits and unconsolidated soils and fill (TVA 2017-TN5387). Regarding stratigraphic units, the applicant stated that 76 geotechnical boreholes drilled at the CRN Site encountered the following sedimentary sequence: the Rome Formation; the Newala Formation of the Knox Group; and the Blackford Formation, Eidson and Fleanor Members of the Lincolnshire Formation, Rockdell Formation, Benbolt Formation, Bowen Formation, and Moccasin Formation of the Chickamauga Group. FSER Figure 2.5.1-2 shows the stratigraphic units that underlie the CRN Site, and the applicant described these units in SSAR Section 2.5.1.2.3.3 (TVA 2017-TN5387).

Regarding the evaluation of karst, in SSAR Section 2.5.1.2.3.4, the applicant stated that the largest and highest frequency of dissolution cavities at the CRN Site occur in the Rockdell Formation and the Eidson Member of the Lincolnshire Formation of the Chickamauga Group

(TVA 2017-TN5387). The applicant noted that these two stratigraphic units also contain the greatest thickness of pure limestone compared to other Chickamauga Group strata at the site.

The staff focused its review of SSAR Section 2.5.1.2.3 (TVA 2017-TN5387) on the applicant's description of stratigraphic units in the Chickamauga Group and the evaluation of karst in the Chickamauga Group because Chickamauga formations underlie the CRN Site and will compose the foundation material for the proposed CRN Site facility. Based on its review of information presented in SSAR Section 2.5.1.2.3 and literature cited by the applicant in the SSAR (TVA 2017-TN5387), as well as examination of stratigraphic units in core samples and outcrops during the second site audit (NRC 2017-TN5908) and the site visit (NRC 2018-TN5941), the staff concludes that the applicant appropriately described stratigraphic units and karst in the formations composing the Chickamauga Group. The staff makes this conclusion because all existing data confirm the applicant's descriptions of the stratigraphic units and karst features that occur in the Chickamauga Group.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.2.3 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of local stratigraphy and lithology in support of the CRN Site ESPA.

2.5.1.3.2.4 *Local Structural Geology*

In SSAR Section 2.5.1.2.4, the applicant discussed the structural geology of the CRN Site vicinity, site area, and site, including macroscopic-scale folds and 12 individual faults in the site vicinity; macroscopic-scale faults in the site area (i.e., the Whiteoak Mountain, Copper Ridge, and Chestnut Ridge faults) and seismic reflection and refraction data; mesoscopic-scale structures in the site vicinity and at the site location (i.e., folds, fractures, and shear-fracture zones); and Alleghanian foreland fold-and-thrust structures in the site area (TVA 2017-TN5387). The applicant stated that geologic structures in the site vicinity and site area and at the site location are a function of the position of the site in the foreland fold-and-thrust belt that composes the Valley and Ridge province.

Regarding the macroscopic-scale folds and faults in the site vicinity discussed in SSAR Section 2.5.1.2.4.1, the applicant provided information documenting that they are Late Paleozoic in age (TVA 2017-TN5387). Concerning the macroscopic-scale faults in the site area discussed in SSAR Section 2.5.1.2.4.2, the applicant noted that the Whiteoak Mountain, Copper Ridge, and Chestnut Ridge faults are also Late Paleozoic in age (TVA 2017-TN5387). The applicant stated that materials indicative of fault displacement (i.e., fault gouge, breccia, and cataclasite) occur in association with the Copper Creek fault at the CRN Site and in the site area, and that $^{40}Ar/^{39}Ar$ age dates on gouge samples collected from the fault in northeastern Tennessee gave an age of 279.5 +/-11.3 Ma.

In SSAR Section 2.5.1.2.4.3, the applicant described mesoscopic-scale structures in the site vicinity and at the site, including folds, bedding, fractures, and shear-fracture zones (TVA 2017-TN5387). The applicant stated that the descriptions of mesoscopic structures include information derived for the CRN Site from geologic field investigations, boreholes, and seismic reflection and refraction surveys. The applicant noted that the shear-fracture zones contain both nontectonic diagenetic and tectonic stylolites indicative of a complex strain history.

The staff focused its review of SSAR Section 2.5.1.2.4 on the applicant's discussion of shear-fracture zones and the relationship between these zones and the Late Paleozoic (i.e.,

Alleghanian) Whiteoak Mountain and Copper Creek faults (TVA 2017-TN5387). The staff maintained this focus because it is important to understand the origin of shear-fracture zones to clarify the relationship between Alleghanian thrust faults and the zones and to ensure that the zones do not represent Quaternary tectonic deformation features. In eRAI-8991 (RAI No. 5) (NRC 2017-TN5926), Questions 02.05.01-04(a) and (b), the staff asked the applicant to clarify the relationship between diagenetic and tectonic stylolites in the shear-fracture zones with regard to timing of development of the stylolites. In Question 02.05.01-04(d), the staff asked the applicant to explain the relationship between the shear-fracture zones, the Whiteoak Mountain and Copper Ridge faults, and the site tectonic setting, to specify the timing of the formation of the faults and the shear-fracture zones. In Question 02.05.01-04(c), staff asked the applicant to provide a justification for why the applicant considered a "shear zone" in the excavation for the CRBRP, previously mapped and described by Drakulich (1984-TN5940), to be equivalent to the "shear-fracture zones" found in the subsurface at the CRN Site location.

The applicant responded to eRAI-8991 (RAI No. 5), Questions 02.05.01-04(a) through (d), in Response Letter CNL-17-114 dated October 19, 2017 (TVA 2017-TN5927). In Revision 1 of the SSAR (TVA 2017-TN5387), the applicant incorporated information cited in the responses to Questions 02.05.01-04(a), (b), and (d) in SSAR Section 2.5.1.2.4.3.4 to clarify that the shear-fracture zones contain both nontectonic diagenetic stylolites oriented subparallel to bedding and tectonic stylolites oriented at higher angles to bedding, neither of which reflect pressure solution effects or deformation younger than Late Paleozoic. The applicant explained that the tectonic stylolites resulted from pressure solution related to Late Paleozoic Alleghanian thrust faulting, and that the nontectonic stylolites formed earlier due to diagenetic pressure solution. The applicant stated that the tectonic and nontectonic stylolites developed at distinctly different times in two different strain regimes. The applicant pointed out that the abundance of pressure solution features and the paucity of evidence for mechanical grain-size reduction suggest that the shear-fracture zones mainly accommodated strain by pressure solution resulting from both nontectonic and tectonic effects, but with limited cataclastic deformation during the tectonic event (i.e., Alleghanian thrust faulting). This tectonic event included emplacement of the Whiteoak Mountain and Copper Ridge thrust faults in the site area. The applicant also incorporated information cited in the response to eRAI-8991 (RAI No. 5), Questions 02.05.01-04(c) in SSAR Section 2.5.1.2.4.3.4 to clarify that the "shear zone" previously mapped and described by Drakulich (1984-TN5940) in the CRBRP excavation, which has been filled such that the "shear zone" is no longer visible, likely has an origin similar to shear-fracture zones observed in boreholes at the CRN Site (TVA 2017-TN5387). The applicant stated that the description of the "shear zone" clearly reflects certain attributes of the shear-fracture zones found at the CRN Site.

Based on its review of information presented in SSAR Section 2.5.1.2.4, literature cited by the applicant in the SSAR (TVA 2017-TN5387), and the applicant's responses to eRAI-8991 (RAI No. 5), Questions 02.05.01-04(a) through (d), as well as examination of a shear-fracture zone and gouge related to the Copper Ridge fault in core during the second site audit (NRC 2017-TN5908) and the site visit (NRC 2018-TN5941), the staff concludes that the applicant adequately described local structural geology, including the development of shear-fracture zones and the timing of the development of the zones in relation to Late Paleozoic thrust faulting. The staff makes this conclusion because information provided by the applicant supports the interpretation that the shear-fracture zones contain both diagenetic, bedding-parallel stylolites resulting from pressure solution due to lithostatic loading during burial and tectonic stylolites oriented at high angles to bedding resulting from pressure solution due to Alleghanian thrust faulting. This interpretation suggests the bedding-parallel diagenetic stylolites formed under a vertical maximum compressive stress that did not result in cataclasis

and the stylolites oriented at high angles to the bedding developed under a horizontal maximum principal compressive stress, which possibly resulted in localized minor cataclasis. The information provided by the applicant reinforced the concept that the stylolites formed at two different times and in two distinctly different strain regimes. The staff's direct examination of a shear-fracture zone and the Copper Ridge fault in core samples during the second site audit (NRC 2017-TN5908) and the site visit (NRC 2018-TN5941) enabled the staff to confirm the applicant's interpretations of these structures and make the conclusion as stated. Accordingly, the staff considers eRAI-8991 (RAI No. 5), Questions 02.05.01-04(a) through (d), resolved.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.2.4 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of local structural geology in support of the CRN Site ESPA.

2.5.1.3.2.5 *Local Geologic Hazards*

In SSAR Section 2.5.1.2.5, the applicant discussed geologic hazards for the CRN Site vicinity, site area, and site location, including karst hazards, other local geologic hazards, and evaluation of local geologic hazards (TVA 2017-TN5387). The applicant stated that karst features and active karst processes are common throughout the site vicinity and karst dissolution of carbonate bedrock, which underlies all proposed plant facilities, is the primary geologic hazard of concern for the CRN Site.

The staff focused its review of SSAR Section 2.5.1.2.5 (TVA 2017-TN5387) on the potential for hypogene karst systems at the CRN Site and understanding the applicant's technical basis for not using seismic reflection data to determine the presence or absence of dissolution voids at the site. The staff maintained the focus on hypogene karst because Nativ (1986-TN6188) and Nativ et al. (1997-TN6010) documented evidence of deep groundwater flow at the ORR based on the presence of brines that had geochemical signatures indicative of partial recharge by recent waters at depths of more than 91 m (300 ft), as well as the occurrence of contaminants at a depth of approximately 268 m (880 ft). In eRAI-8991 (RAI No. 5), Question 02.05.01-05(b) (NRC 2017-TN5926), the staff asked the applicant to discuss the potential for the occurrence of hypogene karst systems at the CRN Site. In addition, the staff sought to understand why seismic reflection data were generally not successful at detecting voids, as reported by the applicant based on Doll et al. (2005-TN6139), who evaluated seismic reflection data at the ORR. In eRAI-8991 (RAI No. 5), Question 02.05.01-03, the staff asked the applicant to explain why seismic reflection data could not be used to determine the presence or absence of subsurface dissolution voids at the CRN Site (NRC 2017-TN5926).

The applicant provided a response to eRAI-8991 (RAI No. 5), Question 02.05.01-05(b), in Response Letter CNL-77-100 dated September 29, 2017 (TVA 2017-TN5928). In Revision 1 of the SSAR, the applicant incorporated information cited in the response to eRAI-8991 (RAI No. 5), Question 02.05.01-05b in SSAR Section 2.5.1.2.5.1 to clarify that direct evidence of hypogene dissolution is not documented at the CRN Site or within the ORR (TVA 2017-TN5387). The applicant noted that most evidence is consistent with dissolution by epigenetic processes in the vadose and phreatic zones. The applicant stated that this evidence includes a decrease in the frequency of fractures and dissolution cavities with depth in boreholes; phreatic passage geometry and morphology of known caves and solution conduits within the ORR; and a lack of secondary minerals characteristic of hypogene processes. The applicant noted further that a lack of definitive evidence for present-day active hypogene karst development does not indicate hypogene processes were inactive in the past or could not occur in the future.

The applicant provided a response to eRAI-8991 (RAI No. 5), Question 02.05.01-03, in Response Letter CNL-17-100 dated September 29, 2017 (TVA 2017-TN5928). In Revision 1 of the SSAR, the applicant incorporated information cited in the response to eRAI-8991 (RAI No. 5), Question 02.05.01-03 in SSAR Section 2.5.1.2.5.1 to clarify that seismic reflection data, used successfully to detect geologic structures, did not readily detect voids because characteristics of the karst features (i.e., steeply dipping boundary surfaces and rough and laterally discontinuous interfaces) directly affected the quality of the stacked reflection profiles (TVA 2017-TN5387). In addition, in SSAR Section 2.5.1.2.4.2.1, "Geophysical Data," the applicant stated that the primary objectives of the seismic reflection surveys, which were achieved, were to interpret the contact between the Knox Group and the overlying stratigraphic units of Chickamauga Group; interpret the dip of bedding between boreholes; and identify potential subsurface faults beneath the survey lines (TVA 2017-TN5387). The applicant stated that, for a future COLA, detailed geologic mapping and a subsurface exploration program would be implemented to characterize the excavations for safety-related structures at the CRN Site with regard to the presence or absence of karst features in and below the floor of those excavations. These activities are captured by Permit Condition 2.5-1 (Permit Condition 3), as discussed in FSER Section 2.5.3.4.

Based on its review of information presented in SSAR Section 2.5.1.2.5, literature cited by the applicant in the SSAR (TVA 2017-TN5387), and the applicant's responses to eRAI-8991 (RAI No. 5), Questions 02.05.01-05(b) and 02.05.01-03 (TVA 2017-TN5928), the staff concludes that the applicant clarified the lack of evidence for hypogene dissolution at the CRN Site and on the ORR, and clearly explained why seismic reflection investigations likely cannot be used to detect the presence of dissolution voids at the CRN Site. The staff makes the conclusion regarding hypogene dissolution because, based on existing data, no unequivocal evidence exists for the presence of hypogene karst (i.e., frequency of subsurface fractures and dissolution cavities decrease with depth based on borehole data; passage morphology of caves and solution conduits within the ORR exhibit characteristics of phreatic dissolution; and secondary minerals characteristic of hypogene processes are not found). Likewise, the staff makes the conclusion regarding the applicability of seismic reflection surveys to detect subsurface voids because the results of studies conducted at the ORR indicate physical characteristics of dissolution voids unavoidably affect the quality of the survey results. Accordingly, the staff considers eRAI-8991 (RAI No. 5), Questions 02.05.01-05(b) and 02.05.01-03 resolved.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.2.5 (TVA 2017-TN5387), as outlined in the previous paragraph, the staff finds that the applicant provided a thorough and accurate description of local geologic hazards in support of the CRN Site ESPA.

2.5.1.3.2.6 _Site Engineering Geology_

In SSAR Section 2.5.1.2.6, the applicant discussed geologic features of bedrock units beneath the power block area at the CRN Site, noting that the Knox and Chickamauga Groups comprise the bedrock units beneath the site (TVA 2017-TN5387). The applicant presented a summary of subsurface conditions and then discussed rock mass characterization for each stratigraphic unit beneath the site, fracture zones, deformational zones (i.e., shear-fracture zones), karst features, prior earthquake effects, residual stresses in bedrock, effects of human activities, construction groundwater control, and unforeseen geologic conditions.

The staff focused its review of SSAR Section 2.5.1.2.6 (TVA 2017-TN5387) on the applicant's investigation of potential paleoliquefaction features within the CRN Site vicinity and the

discussion of current tectonic forces that might affect the site. The staff maintained the focus on potential paleoliquefaction features because the applicant initially reported primarily on reconnaissance investigations for such features conducted within 80.5 km (50 mi) of the CRN Site and did not include details regarding investigations performed within the 40 km (25 mi) radius of the CRN Site (i.e., the site vicinity). In eRAI-8991 (RAI No. 5), Question 02.05.01-01 (NRC 2017-TN5926), staff asked the applicant to discuss the evaluation of potential paleoliquefaction features within the site vicinity. The staff particularly focused on the need for any additional information collected by the applicant during field reconnaissance studies conducted for the CRN Site along the Clinch River arm of the Watts Bar and Tellico Reservoirs. The applicant examined Pleistocene and Holocene (i.e., Quaternary) fluvial terrace deposits in those locations for definitive evidence of paleoliquefaction related to Quaternary seismic events in the ETSZ. In addition, the staff sought to better understand the applicant's interpretation of current tectonic forces in the area because the applicant initially discussed only previous tectonic forces and weight of the rock (i.e., overburden) for assessing the natural state of stress at the site. In RAI No. 5, Question 02.05.01-02, staff asked the applicant to discuss current tectonic forces and how these forces might affect residual stress in bedrock at the site (NRC 2017-TN5926).

The applicant provided a response to eRAI-8991 (RAI No. 5), Question 02.05.01-01 (NRC 2017-TN5926), in Response Letter CNL-17-099 dated September 15, 2017 (TVA 2017-TN5910). In Revision 1 of the SSAR (TVA 2017-TN5387), the applicant incorporated information cited in the response to eRAI-8991 (RAI No. 5), Question 02.05.01-01, in SSAR Section 2.5.1.2.6.6. In the response, the applicant explained its conclusions derived from the paleoseismic reconnaissance investigations performed for studying Pleistocene and Holocene fluvial terrace deposits along the shorelines of the Watts Bar and Tellico Reservoirs. The applicant stated that the reconnaissance did not reveal any evidence of paleoseismic features around these two reservoirs and cross-referenced SSAR Sections 2.5.3.1.2 and 2.5.3.2 (TVA 2017-TN5387) for details supporting this statement.

The applicant also provided a response to eRAI-8991 (RAI No. 5), Question 02.05.01-02 (NRC 2017-TN5926), in Response Letter CNL-17-099 dated September 15, 2017 (TVA 2017-TN5910). In Revision 1 of the SSAR (TVA 2017-TN5387), the applicant incorporated information cited in the response to eRAI-8991 (RAI No. 5), Question 02.05.01-02, in SSAR Section 2.5.1.2.6.7. In its response, the applicant discussed the current tectonic forces that likely influence the state of stress in rock units at the CRN Site in addition to previous tectonic forces and weight of the rock. The applicant explained that upper mantle buoyancy forces combined with ridge-push forces from the Mid-Atlantic Ridge provide a viable explanation for the orientation of the current regional stress field in the site region and, consequently, the current tectonic forces that influence the state of stress in bedrock at the CRN Site. The applicant cited Biryol et al. (2016-TN6119) for an explanation of upper mantle buoyance forces, which generate vertical forces, and Zoback and Zoback (1989-TN6120) for an explanation of ridge-push forces, which produce horizontal forces.

Based on its review of information presented in SSAR Section 2.5.1.2.6, cross-referenced SSAR Sections 2.5.3.1.2 and 2.5.3.2, literature cited by the applicant in the SSAR (TVA 2017-TN5387), and the applicant's responses to eRAI-8991 (RAI No. 5), Questions 02.05.01-01 and 02.05.01-02 (TVA 2017-TN5910), the staff presents the following two conclusions: (1) the applicant provided an adequate discussion of the results of the field reconnaissance studies conducted for the CRN Site along the Clinch River arm of the Watts Bar and Tellico Reservoirs to search for paleoliquefaction features, and (2) the applicant provided an adequate discussion regarding interpretations related to current tectonic forces that might affect residual stress in

bedrock at the site. The staff makes the conclusion regarding the field reconnaissance studies because, in SSAR Sections 2.5.3.1.2 and 2.5.3.2 (TVA 2017-TN5387), the applicant documented the logic for concluding that no field data clearly indicate the presence of paleoseismic features related to earthquakes in the ETSZ. The staff makes the conclusion regarding current tectonic forces because the applicant presented information that explained the interpretation that both vertical and horizontal forces influence the state of stress in rock units at the CRN Site. Accordingly, the staff considers eRAI-8991 (RAI No. 5), Questions 02.05.01-01 and 02.05.01-02 resolved.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.2.5 (TVA 2017-TN5387), as outlined in the previous paragraph, the staff finds that the applicant provided a thorough and accurate description of local geologic hazards in support of the CRN Site ESPA.

2.5.1.3.2.7 *Site Groundwater Conditions and Tsunami and Seiche Hazards*

In SSAR Section 2.5.1.2.7, the applicant cross-referenced SSAR Section 2.4.12 for a detailed discussion of groundwater at the CRN Site (TVA 2017-TN5387). In SSAR Section 2.5.1.2.8, the applicant cross-referenced SSAR Section 2.4.6 for a detailed discussion of potential tsunami and seiche hazards (TVA 2017-TN5387). The staff evaluation of SSAR Sections 2.4.6 and 2.4.12 are covered in Section 2.4 of the FSER.

2.5.1.3.2.8 *Relational Analysis*

In SSAR Section 2.5.1.2.9, the applicant discussed the relationships between the proposed CRN Site and the CRBRP site regarding stratigraphic units, structural geology, and karst features (TVA 2017-TN5387). The applicant noted that the stratigraphic units in the CRBRP excavation and the northernmost part of the proposed CRN Site power block area (i.e., Location B as shown in the cross section in Figure 2.5.1-2) are identical. In addition, regarding karst features based on the quality and compatibility of data derived from both boring programs, the applicant determined that the two data sets can be combined for analysis of subsurface cavities at the CRN Site. The applicant stated that the results of the geologic mapping and subsurface investigations performed for the CRBRP site can be used to enhance understanding of the geologic characteristics of foundation rock units at the CRN Site and cross-referenced SSAR Section 2.5.1.2.4 (TVA 2017-TN5387) for details about local structural geology.

The staff focused its review of SSAR Section 2.5.1.2.9 (TVA 2017-TN5387) on the applicant's comparison of data from the CRN Site with that from the CRBRP site because the applicant used the data from the CRBRP site to enhance the understanding of geologic characteristics at the CRN Site. Based on its review of information presented in SSAR Section 2.5.1.2.9 and literature cited by the applicant in the SSAR (TVA 2017-TN5387), particularly the report prepared by Drakulich (1984-TN5940) presenting data and conclusions derived from his geologic mapping of foundation units, geologic structures, and karst features in the CRBRP excavation, the staff concludes that the applicant's statement regarding similarities between the two sites is appropriate and the data derived for the CRBRP site can be used to enhance understanding of the geologic characteristics of foundation rock units at the CRN Site. The staff makes this conclusion because the detailed descriptions provided for both sites clearly illustrate the similarities.

Based on the actions performed by staff associated with its review of SSAR Section 2.5.1.2.9 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant

provided a thorough and accurate description of the similarities between the proposed CRN Site and the CRBRP site in support of the CRN ESPA.

2.5.1.4 *Permit Conditions*

There are no Permit Conditions related to SSAR Section 2.5.1 (TVA 2017-TN5387). However, in FSER Section 2.5.3.4, the staff identified a Permit Condition related to detailed geologic mapping of excavations for safety-related engineered structures at the CRN Site as the responsibility of the COL applicant. This Permit Condition relates to the assessment of both tectonic and nontectonic (i.e., karst-induced collapse and subsidence) surface deformation features at the site.

2.5.1.5 *Conclusions*

As documented in Sections 2.5.1.1 through 2.5.1.4 of this FSER, the staff reviewed and evaluated the detailed geologic characterization information submitted by the applicant in SSAR Section 2.5.1 of the CRN Site ESPA (TVA 2017-TN5387). The review and evaluation process, which included the staff's direct examination of geologic characteristics in core and outcrops during site audits and a field visit, provided a sound basis for staff to confirm that no tectonic features occur in the site region, site vicinity, site area, or at the site location that have a potential to adversely affect the suitability and safety of the CRN Site (i.e., no data suggest the presence of tectonic features of Quaternary age). These activities also enabled the staff to confirm that the potential for development of nontectonic karst features resulting from dissolution of subsurface carbonate rocks is the primary geologic hazard at the site. The staff consider the applicant's plan to geologically map future excavations for safety-related engineered structures in detail to be necessary for documenting the presence or absence of undetected dissolution features; confirming or refining interpretations of subsurface geology initially determined from borehole data; and verifying the absence of active tectonic faults. The mapping is identified as a Permit Condition in FSER Section 2.5.3.4, as stated above.

The staff concludes that the applicant identified and appropriately characterized all seismic sources of potential significance for determining the SSE for the CRN Site in accordance with regulatory requirements stated in 10 CFR 100.23(c) (TN282) and guidance provided in RG 1.208 (NRC 2007-TN5858) and SRP Section 2.5.1 (NRC 2018-TN5898). In addition, based on the results of the investigations discussed in SSAR Section 2.5.1 (TVA 2017-TN5387), the staff concludes that the applicant appropriately characterized the geology of the site region (including physiography, topography, and geomorphic processes; fluvial processes; karst processes and occurrence; geologic history and tectonic evolution; stratigraphy; tectonic setting; geophysical data; distribution of seismicity and stress in the Eastern United States; and non-seismic geologic hazards) as well as the local geology of the site vicinity, site area, and site location (including physiography and geomorphic processes, geologic history, stratigraphy and lithology, karst evaluation, structural geology, geologic hazards, and site engineering geology).

The staff further concludes that the applicant appropriately assessed the potential for detrimental effects of human activity, including natural gas wells, coal mines, and quarries, within 8 km (5 mi) of the CRN Site. The applicant documented a lack of any of these activities in the site area, and the staff concludes that negligible potential exists for detrimental effects at the site location as a result of human activity.

Based on results of the review and evaluation of the detailed information presented in SSAR Section 2.5.1 (TVA 2017-TN5387), supplemented by knowledge gained through direct

examination of geologic characteristics in core and outcrops during site audits and a site visit, the staff concludes that the applicant provided a thorough and accurate description of the geologic characteristics of the CRN Site region, site vicinity, site area, and site location in full compliance with regulatory requirements stated in 10 CFR 52.17(a)(1)(vi) (TN251) and 10 CFR 100.23(c) (TN282) and in accordance with guidance in RG 1.208 (NRC 2007-TN5858).

2.5.2 Vibratory Ground Motion

Vibratory ground motion for a site is evaluated based on seismological, geological, geophysical, and geotechnical investigations carried out to determine the site-specific GMRS, which must meet the regulations for a SSE provided in 10 CFR 100.23, “Geologic and seismic siting criteria”(TN282). The GMRS is defined as the free-field horizontal and vertical ground motion response spectra at the plant site. The development of the GMRS is based upon a detailed evaluation of earthquake potential, taking into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the site subsurface material. The specific investigations necessary to determine the GMRS include the seismicity of the site region and the correlation of earthquake activity with seismic sources. Seismic sources are identified and characterized, including the rates of occurrence of earthquakes associated with each seismic source. Seismic sources that are located within 320 km (200 mi) of the site must be identified. Seismic sources can be capable tectonic sources or seismogenic source zones. The staff’s review covers the following specific areas: (1) seismicity; (2) geologic and tectonic characteristics of the site and region; (3) correlation of earthquake activity with seismic sources; (4) probabilistic seismic hazard analysis (PSHA) and controlling earthquakes; (5) seismic wave transmission characteristics of the site; and (6) site-specific GMRS.

2.5.2.1 *Summary of Application*

In SSAR Section 2.5.2, “Vibratory Ground Motion” (TVA 2016-TN5018), the applicant describes the potential vibratory ground motion at the CRN Site. To estimate the vibratory ground motion at the site, the applicant used the NUREG–2115 (NRC 2012-TN3810), “Central and Eastern United States Seismic Source Characterization for Nuclear Facilities,” seismic source model and the Electric Power Research Institute (EPRI) 2013 Ground Motion Model (GMM) (EPRI 2013-TN6143) in its PSHA. The applicant stated that it developed the GMRS based on the performance-based approach recommended by RG 1.208, “A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion” (NRC 2007-TN5858) In the SSAR, the applicant presented the information presented in the following sections related to vibratory ground motion at the CRN Site.

2.5.2.1.1 Seismicity

In SSAR Section 2.5.2.1 (TVA 2016-TN5018), the applicant states that it used the most recent earthquake catalog published as part of NUREG–2115 (NRC 2012-TN3810) for its seismic hazard assessment of the CRN Site. The NUREG–2115 earthquake catalog covers earthquakes in the Central and Eastern United States (CEUS) region from 1568 through 2008. Because the NUREG–2115 earthquake catalog covers only through 2008 (NRC 2012-TN3810), the applicant developed a separate earthquake catalog covering from 2009 through the mid-September 2013 (TVA 2016-TN5018). After declustering the new catalog, the applicant merged the two catalogs and used the updated catalog in its seismic hazard evaluation at the CRN Site (TVA 2016-TN5018). The updated catalog identified nine additional mainshock earthquakes of magnitude **M**2.9 and greater in the 320 km (200 mi) site region. The applicant indicated that

among the earthquakes listed in the earthquake catalog, six small to moderate size earthquakes ranging in magnitude from **M**4.01 to **M**5.8 are of particular significance to the site. The largest of these is the **M**5.8 Mineral, Virginia, earthquake that occurred on August 23, 2011. The epicenter of the Mineral earthquake was located 615 km (382 mi) away from the CRN Site, but is considered here because of its influence on scientific understanding of the seismicity in the CEUS. Closer to the site, two small earthquakes (**M**4.01 and **M**4.57) are highlighted because they represent the largest observed earthquakes in the ETSZ, a southwest to northeast trending region of elevated seismicity that extends from northern Alabama through portions of Georgia and North Carolina to East Tennessee (Figure 2.5.2-1).

The applicant noted in SSAR Section 2.5.2.1.3 (TVA 2016-TN5018) that recent U.S. Geological Survey (USGS) studies of induced earthquakes identified 17 regions of apparent induced seismicity that have occurred over the last 50 years (USGS 2015-TN5859). None of the 17 regions are located within 320 km (200 mi) of the site.

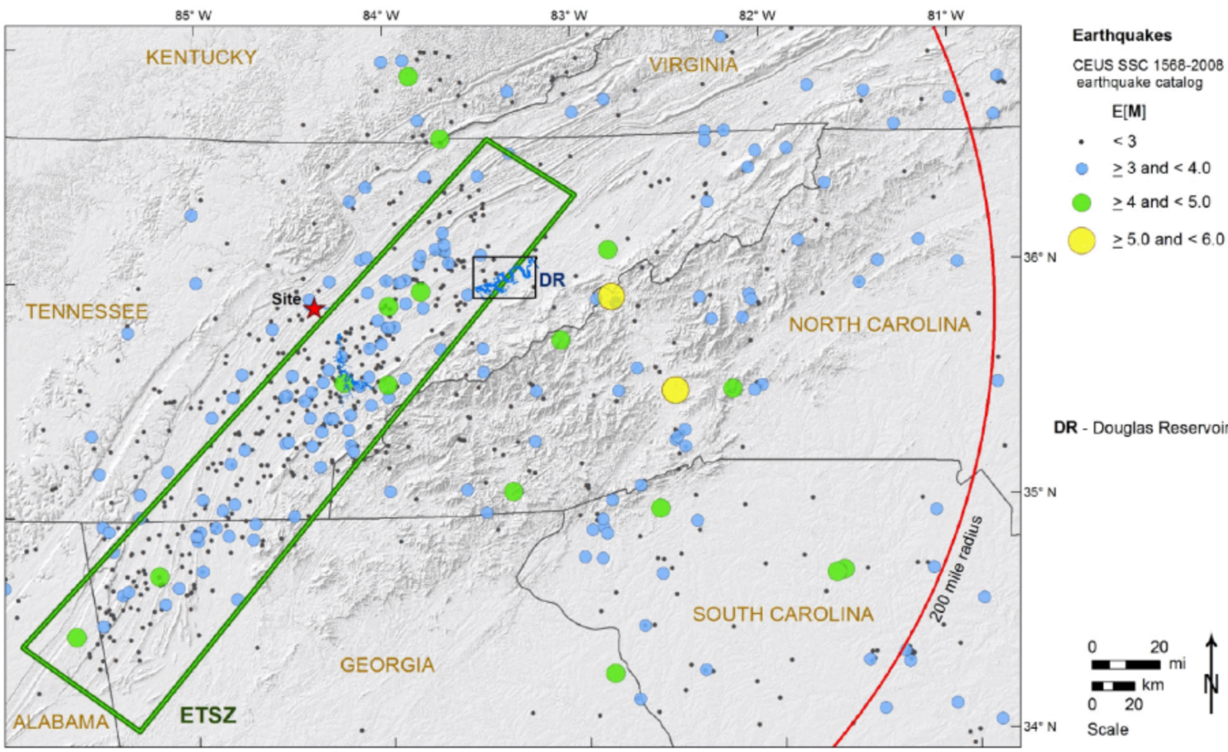


Figure 2.5.2-1 Map of Seismicity in the CEUS Surrounding the CRN Site (reproduced from SSAR Figure 2.5.2-26 [TVA 2016-TN5018]). Colored circles are earthquakes in the NUREG–2115 (NRC 2012-TN3810) earthquake catalog. The red circle denotes the 320 km (200 mi) radius. The green box outlines the ETSZ.

2.5.2.1.2 Geologic and Tectonic Characteristics of the Site and Region

In SSAR Section 2.5.2.2, the applicant describes the seismic sources and seismic model parameters used to calculate the seismic ground motion hazard at the CRN Site (TVA 2016-TN5018). The applicant used the NUREG–2115 (NRC 2012-TN3810) regional seismic source characterization model developed for the CEUS region as a starting point for its seismic source characterization (SSC) model. The NUREG–2115 seismic source model was published in

January 2012. The model development followed the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 procedures as outlined in NUREG/CR-6372 (Budnitz et al. 1997-TN5860), "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and the Use of Experts." NUREG–2115 states that this regional seismic source model is to be used as a starting model in seismic hazard calculations for nuclear facilities in the CEUS region (NRC 2012-TN3810). The applicant stated that it conducted a review of the CEUS-SSC model to identify whether there is a need to update any of the seismic sources. Based on its review results, the applicant stated that the regional model, as published, is adequate for use in seismic hazard calculations for the CRN Site. The CEUS-SSC model (NRC 2012-TN3810) is summarized below.

2.5.2.1.2.1 *Summary of the NUREG–2115 Seismic Source Model*

In the ESPA, the applicant stated that the CEUS-SSC model described in NUREG–2115 contains two types of seismic sources: (1) distributed seismicity sources and (2) repeated large magnitude earthquake (RLME) sources (NRC 2012-TN3810). While the distributed seismicity sources were developed based on available earthquake locations and regional geologic/tectonic characterizations, the RLME sources are based on geologic and paleo-earthquake records. The RLME sources (e.g., New Madrid Fault System) represent zones of repeated (two or more) large magnitude earthquakes (**M**>6.5) in the CEUS region.

The CEUS-SSC model categorizes the distributed seismicity sources into two subgroups: maximum magnitude (M_{max}) zones and seismotectonic zones. These subgroups capture the uncertainties in source characterizations and differences of opinions in seismic source identification in the region. For the CEUS-SSC model (NRC 2012-TN3810), the M_{max} and seismotectonic sources are weighted by 40 percent and 60 percent, respectively, to determine their relative contribution to the total seismic hazard at the site. The M_{max} zones are broad seismic sources identified based on limited tectonic information, and they represent potential seismic sources of future earthquakes. The seismotectonic zones are those developed by extensive analysis of regional geology, tectonics, and seismicity in the CEUS region. Both the M_{max} and the seismotectonic zones include alternative source geometries, thereby accommodating uncertainty in SSC. The RLME sources are superimposed on these distributed seismicity sources.

2.5.2.1.3 Correlation of Earthquake Activity with Seismic Sources

SSAR Section 2.5.2.3 (TVA 2016-TN5018) describes the applicant's correlation of updated seismicity with the NUREG–2115 (NRC 2012-TN3810) seismic source model. The applicant provided the following conclusions regarding the correlation of earthquake activity with the seismic sources:

- The updated seismicity catalog does not contain any earthquakes within the site region that can be positively associated with a known geologic structure.
- The updated seismicity catalog does not show a pattern of seismicity different from that of the CEUS-SSC catalog that would suggest a new seismic source in addition to those included in the CEUS-SSC characterization.
- The updated seismicity catalog shows a spatial distribution of earthquakes similar to that of the CEUS-SSC catalog, suggesting that no significant revisions to the geometry of the seismic sources in the CEUS-SSC are required.

- The updated seismicity catalog does not contain any earthquakes that suggest significant revisions to the M_{max} distributions for CEUS-SSC zones is required.
- Seismicity rates determined from the updated catalog range from a decrease of 5.5 percent to an increase of 12.5 percent compared to the rates published in the CEUS-SSC for the host cell.

2.5.2.1.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

SSAR Section 2.5.2.4 presents the results of the applicant's PSHA for the CRN Site (TVA 2016-TN5018). In performing the analysis, the applicant followed the guidance provided in RG 1.208 (NRC 2007-TN5858) to determine the seismic hazard curves and controlling earthquakes for the CRN Site. The applicant based its analysis on the CEUS-SSC model (NRC 2012-TN3810) and the EPRI (2013-TN6143) GMM. The PSHA curves generated by the applicant represent reference hard rock conditions characterized by a shear wave velocity (V_S) in excess of 2.8 km/s (9,200 fps). The applicant also described the earthquake potential for the site in terms of a Uniform Hazard Response Spectra (UHRS) and the controlling earthquakes, as defined in RG 1.208 (NRC 2007-TN5858). The applicant determined the low-frequency (LF) and high-frequency (HF) controlling earthquakes by deaggregating the PSHA curves at selected mean annual frequency-of-exceedance levels. A summary of the applicant's PSHA study is provided below.

2.5.2.1.4.1 *PSHA Inputs*

To conduct the PSHA and obtain the UHRS at the site, it is necessary to study the site location and its surrounding regions to determine the geological and seismological properties, as outlined in RG 1.208 (NRC 2007-TN5858). This requires determinations of active seismic source zones in the area, the seismic sources' model parameters, and an appropriate GMM for the region. The following subsections summarize the applicant's efforts in these areas.

2.5.2.1.4.1.1 Seismic Source Models and Parameters.

The input source model for the CRN Site PSHA study is primarily the CEUS-SSC (NRC 2012-TN3810). The applicant updated the earthquake recurrence rates and b-values for the distributed seismicity sources that contribute significantly to the hazard.

SSAR Section 2.5.2.2.1 (TVA 2016-TN5018) describes how the applicant updated its seismicity catalog to create a comprehensive list of earthquakes for the CRN Site to assess the overall seismicity in the region and also assess the validity of the earthquake recurrence rates used for the CEUS-SSC model (NRC 2012-TN3810). The applicant found that minor changes to seismicity rates from those used for the CEUS-SSC model were warranted based upon the updated seismicity catalog.

2.5.2.1.4.1.2 Ground Motion Models

In SSAR Section 2.5.2.1.2 (TVA 2016-TN5018), the applicant stated that it used the CEUS GMM developed by EPRI in 2013 for its PSHA calculations (EPRI 2013-TN6143). This model, which consists of 12 individual ground motion prediction equations (GMPEs), was reviewed by the staff as part of prior COLA reviews (e.g., North Anna COL; William States Lee III COL) and the staff concluded that it adequately represents the expected ground motion in the CEUS region.

2.5.2.1.4.2 *PSHA Methodology and Calculation*

Using the CEUS-SSC model (NRC 2012-TN3810) and the EPRI GMPEs (EPRI 2013-TN6143), the applicant performed PSHA calculations for peak horizontal ground acceleration (PGA) and horizontal spectral acceleration at ground motion frequencies of 0.5, 1.0, 2.5, 5, 10, and 25 Hz. The applicant performed PSHA calculations for the CRN Site assuming generic hard rock conditions at the site with a V_S of 2.8 km/s (9,200 fps). The applicant first calculated mean and fractile rock seismic hazard curves at the spectral frequencies noted above and annual frequencies of exceedance (10^{-4}, 10^{-5}, and 10^{-6}). The applicant then deaggregated the results as described in RG 1.208 (NRC 2007-TN5858) to calculate the controlling earthquakes for LF and HF ground motions. Finally, the applicant used the CRN Site controlling earthquakes, and hard rock spectral shapes for CEUS earthquake ground motions recommended in NUREG/CR-6728 (McGuire et al. 2001-TN5861) to calculate the hard rock UHRS.

2.5.2.1.4.3 *PSHA Results*

In SSAR Section 2.5.2.4.3, the applicant stated that local earthquakes are the major contributor to seismic hazard at the CRN Site for both HFs (5 and 10 Hz) and LFs (1 and 2.5 Hz) (TVA 2016-TN5018). However, there is some contribution from the large seismic sources outside the site region, such as the New Madrid Fault System RLME. The applicant demonstrated that the other large seismic sources in the CEUS region, such as the Charleston and Wabash Valley seismic sources, make a minimal contribution to the total hazard.

Table 2.5.2-1 shows the controlling earthquake magnitude and distance combinations for low and high spectral frequencies for the CRN Site. Following guidance in RG 1.208 (NRC 2007-TN5858), the applicant developed LF inputs for the 10^{-4} and 10^{-5} UHRS for distances greater than 100 km. As shown in Table 2.5.2-1, the applicant reported the nearby, smaller magnitude, controlling earthquake because the 10^{-6} UHRS is not used to calculate the GMRS.

Table 2.5.2-1 Controlling Earthquakes for the CRN Site (From SSAR, Table 2.5.2-18 [TVA 2016-TN5018])

	Mean 10^{-4}	Mean 10^{-5}	Mean 10^{-6}
Low-frequency **M**[(a)]	7.5[(b)]	7.6[(b)]	6.7
Low-frequency R (km)[(a)]	380[(b)]	330[(b)]	13
High-frequency **M**[(c)]	5.9	6.1	6.3
High-frequency R (km)[(c)]	16	12	11

(a) Based on 1 and 2.5 Hz results.
(b) **M** and R are calculated for R > 100 km per RG 1.208 (NRC 2007-TN5858).
(c) Based on 5 and 10 Hz.

Following the calculations of the controlling earthquake distances and magnitudes, the applicant determined the smoothed UHRS at the reference elevation beneath the site, as shown in Figure 2.5.2-2.

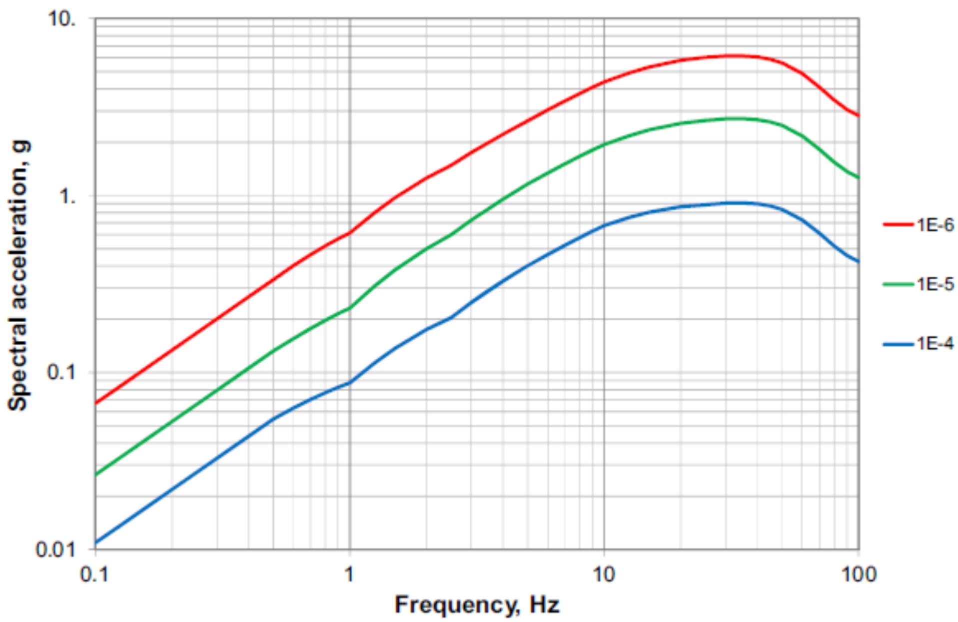


Figure 2.5.2-2 Mean Rock Uniform Hazard Response Spectra for the CRN Site. (Reproduced from SSAR Figure 2.5.2-53 [TVA 2016-TN5018].)

2.5.2.1.5 Seismic Wave Transmission Characteristics of the CRN Site

SSAR Section 2.5.2.5 describes the applicant's development of a site-specific seismic velocity model to characterize the seismic wave transmission characteristics of the CRN Site (TVA 2016-TN5018). The EPRI GMPEs (EPRI 2013-TN6143) are representative of ground motion at very stiff hard rock sites, which are characterized as sites with a V_S of 2.8 km/s (9,200 fps). For the CRN Site, the applicant states that these hard rock conditions are encountered at a depth of greater than 3,650 m (12,000 ft) beneath the ground surface; while rock of lower V_S exists above in the upper 3,650 m (12,000 ft). The applicant conducted a site response analysis to determine the impacts of the lower V_S rocks on the calculated seismic hazard values. The applicant first developed a site response model and then used the random vibration theory (RVT) methodology (Idriss et al. 1968-TN6140) to calculate the site amplification functions to transfer the generic hard rock hazard curves to the near-surface GMRS elevation. The following sections summarize the applicant's site response calculation procedures.

2.5.2.1.5.1 _Site Response Model_

The applicant stated that the subsurface of the CRN Site is characterized by rock strata that have a dip angle of greater than 30 degrees. As such, the applicant developed a site-specific mean V_S profile for the upper 3,650 m (12,000 ft) beneath the ground surface for two locations (Location A and Location B) at the CRN Site to account for the dipping subsurface and to accommodate the relatively small footprint of small modular reactors. The applicant stated that the shallow subsurface V_S was determined using downhole suspension logging data collected at the site. In addition, the applicant stated that data collected at nearby TVA dam sites were reviewed and used as appropriate.

The applicant stated that geologic profiles for Locations A and B (with similar subsurface geology) were developed using stratigraphic cross sections (SSAR Figures 2.5.4-12 and 2.5.4-13 [TVA 2016-TN5018]) and that separate geologic profiles were developed for each

location. The applicant developed a base-case V_S profile for each location using available geophysical data. These profiles extended to depths of between 91 and 106 m (300–350 ft) beneath the GMRS elevation. Below this depth, the applicant stated that there are no data for rock units at the site. Therefore, the applicant used available data from the Watts Bar 2 Nuclear Plant, which has the same (similar) age rock strata and considered the depth-dependent nature of seismic velocities using generic relationships for the CEUS to develop deeper portions of the V_S profiles. The applicant used regional stratigraphic cross sections to define layer boundaries at depths greater than 100 m (300 ft). Figure 2.5.2-3 shows the applicant's base case V_S profiles for Locations A and B.

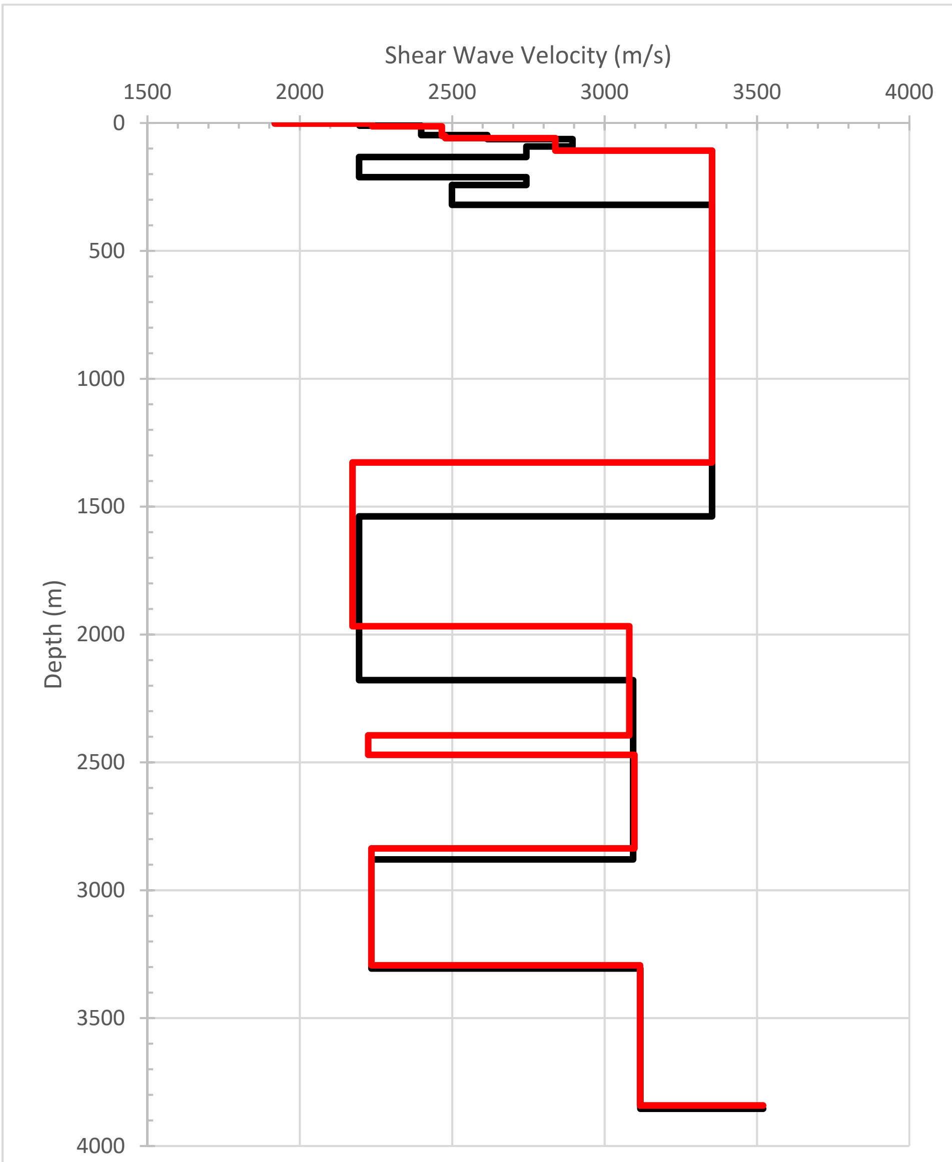


Figure 2.5.2-3 Base Case Velocity Profiles for Area A (Black) and Area B (Red) Used by the Applicant in the Site Response Analysis Based on SSAR Tables 2.5.4-30 and 2.5.4-31 (TVA 2016-TN5018)

The applicant developed these profiles considering the variability of all available profiles for the site. The applicant determined that a lognormal standard deviation of 0.15 was appropriate for conditions at the site and determined a 5 and 95 percentile (lower and upper, respectively) case velocity profile based on this standard deviation. SSAR Figures 2.5.4-20 and 2.5.4-21 show all three base cases for Locations A and B, respectively (TVA 2016-TN5018). The applicant gave the lower (0.2), base (0.6), and upper (0.2) V_S profiles different weights in the site response evaluation. The applicant also considered nonlinear and linear responses, which it gave equal weight in the site response evaluation. For the nonlinear case, the applicant used modified EPRI rock (Silva et al. 1996-TN5862) damping and shear modulus degradation (G/G_{max}) curves with the low-strain damping adjusted to 2 percent to account for the firm nature of the rocks. For the linear case, the applicant used a constant damping value of 1.25 percent. For rock layers deeper than 150 m (500 ft), the applicant used site kappa (low-strain damping) values determined from earthquake spectra recorded at the nearby Tellico Dam site to constrain the total amount of site damping.

2.5.2.1.5.2 _Site Response Methodology and Results_

Consistent with RG 1.208 (NRC 2007-TN5858), the applicant performed its site response analysis using Approach 3 as described in NUREG/CR-6728 (McGuire et al. 2001-TN5861). Approach 3 is a fully probabilistic approach to incorporating site response into the PSHA. The applicant first generated 60 random profiles for each site profile and associated shear moduli and damping parameters. The applicant computed the site amplification factors as characterized by a mean and distribution for each set of site profiles using the RVT methodology (Idriss et al. 1968-TN6140). As input to the RVT methodology, the applicant selected an **M**5.5 and an **M**7.5 earthquake spectrum to represent HF and LF inputs. These two spectra were given frequency dependent weights in determining the amplification factors. The applicant finally integrated the fractile and mean hazard curves for the reference hard rock conditions with the site amplification factors to arrive at a set of site-specific hazard curves for the CRN Site.

In summary, the applicant's site response calculations resulted in a suite of amplification functions that are combined with the site-specific hard rock seismic hazard curves to generate site-specific hazard curves at the GMRS elevation. As shown in Figure 2.5.2-4, the amplification factors for the CRN Site do not differ significantly from 1 at frequencies lower that 20 Hz. The dip in amplification factors at HFs varies as a function of input ground motion and is an effect of nonlinearity on site response.

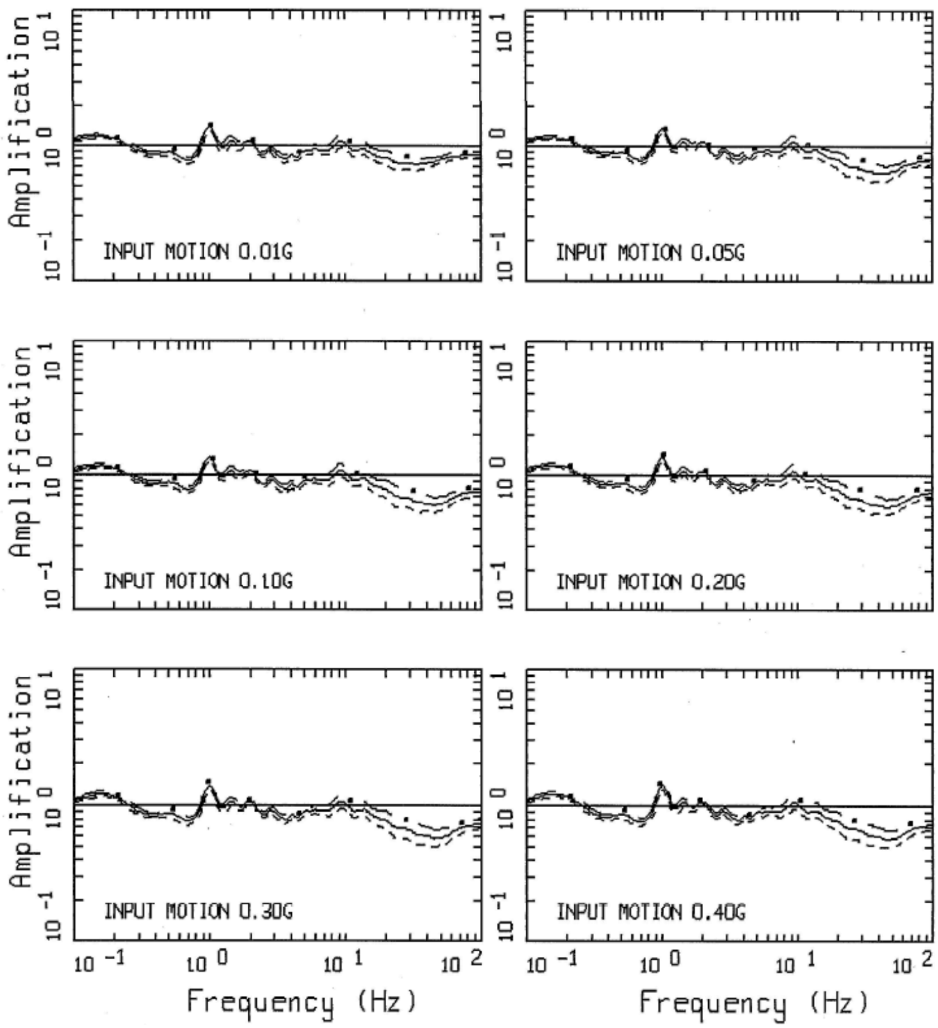


Figure 2.5.2-4 Horizontal Amplification Factors for Base Case Profile at Area A considering an M5.5 input response spectrum. (Reproduced from SSAR Figure 2.5.2-62 [TVA 2016-TN5018])

2.5.2.1.6 Two-Dimensional Sensitivity Analysis

To investigate the impact of the 30-degree dip of rock layers on site response results, the applicant performed a two-dimensional (2D) sensitivity analysis. The applicant stated that the sensitivity analysis was performed to investigate how the simplifying nature of the traditional one-dimensional (1D) analysis impacts site response results and ensures that the epistemic uncertainty considered in the 1D analysis adequately accounts for potential 2D effects.

The applicant developed a 2D finite element model using the stratigraphic model considered when developing the 1D site response inputs. The applicant performed the analysis using Structural Dynamics Engineering-System for Analysis of Soil Structure Interaction (SDE-SASSI) Version 2.0 with input basement rock time histories consistent with the seismic hazard at the site. The applicant stated that the 2D sensitivity results for the best-estimate profile indicate no significant differences from the 1D response. Based on this result, the applicant determined that 2D effects at the CRN Site were negligible.

2.5.2.1.7 Ground Motion Response Spectra

SSAR Section 2.5.2.8 (TVA 2016-TN5018) describes the method the applicant used to develop the horizontal and vertical site-specific GMRS. The applicant first developed the horizontal GMRS and then obtained the vertical GMRS using vertical to horizontal (V/H) ratios.

2.5.2.1.7.1 *Horizontal GMRS*

The applicant calculated a horizontal, site-specific, performance-based GMRS using the method described in RG 1.208 (NRC 2007-TN5858). The performance-based method achieves the annual target performance goal (P_F) of 10^{-5} per year for frequency of the onset of significant inelastic deformation. This damage state represents a minimum structural damage state, or essentially elastic behavior, and falls well short of the damage state that would interfere with functionality. The GMRS is calculated using the following relationship.

$$GMRS = UHRS * DF$$

where

$$UHRS = UHRS_{10^{-4}}$$

$$DF = max\{1.0, 0.6(A_R)^{0.8}\}$$

$$A_R = \frac{UHRS_{10^{-5}}}{UHRS_{10^{-4}}}$$

RG 1.208 also states, if A_R, as defined above, is greater than 4.2, then this relationship is no longer valid (NRC 2007-TN5858). In this case, RG 1.208 recommends setting the GMRS to 45 percent of the 10^{-5} site-specific surface UHRS curve. Figure 2.5.2-5 shows the horizontal GMRS curve calculated for the CRN Site by the applicant for both Locations A and B, as well as the envelope of these two spectra.

2.5.2.1.7.2 *Vertical GMRS*

In SSAR Section 2.5.2.7, the applicant used the V/H ratios from NUREG/CR-6728 (McGuire et al. 2001-TN5861) and incorporated epistemic uncertainty determined from a literature survey, similar to the approach taken to develop the horizontal amplification factors (TVA 2016-TN5018). The applicant used the site-specific horizontal hazard curves and integrated V/H ratios and their associated uncertainties to develop site-specific vertical seismic hazard curves. Figure 2.5.2-5 shows the vertical GMRS curve calculated for the CRN Site by the applicant.

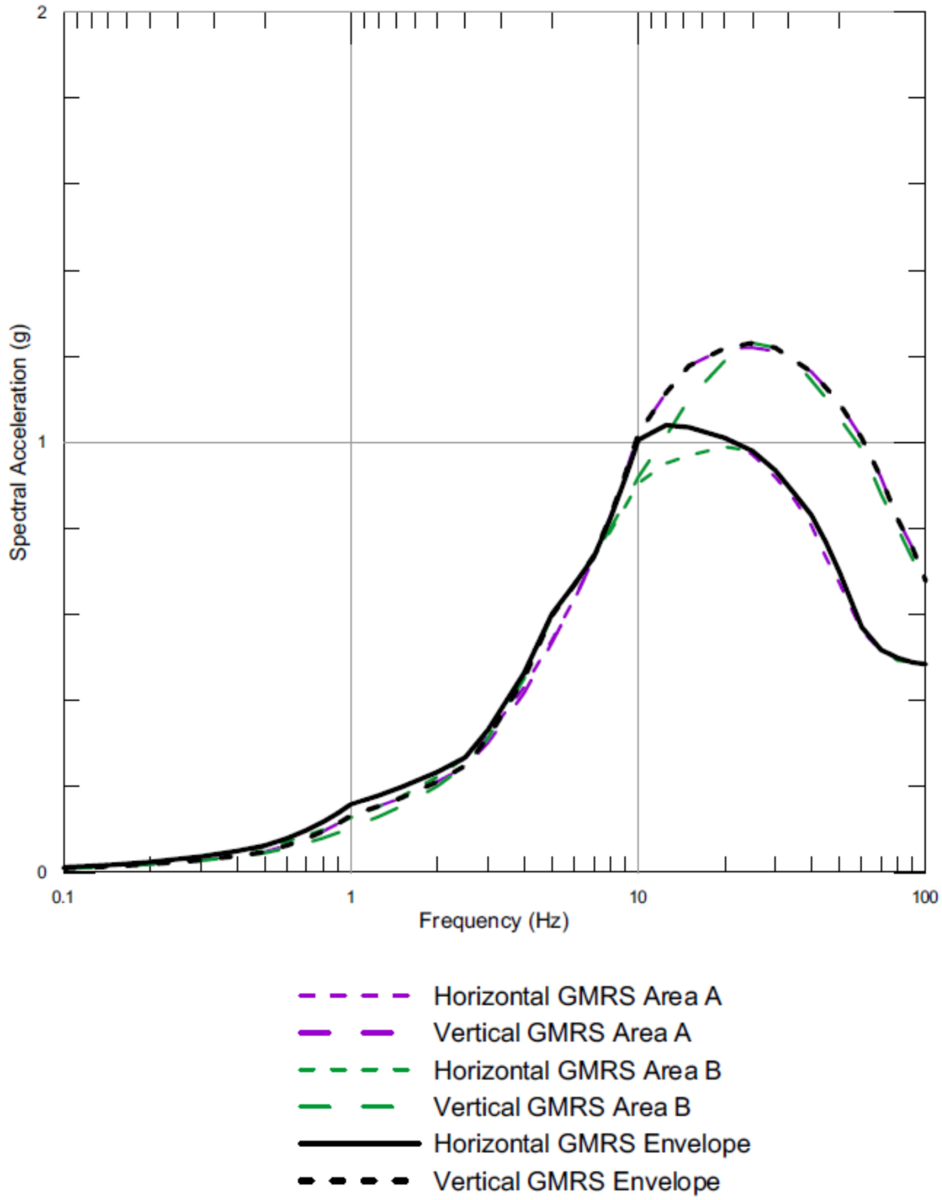


Figure 2.5.2-5 Horizontal (solid black) and Vertical (dashed black) GMRS for the CRN Site. (Reproduced from SSAR Figure 2.5.2-78 [TVA 2016-TN5018])

2.5.2.2 *Regulatory Basis*

The applicable regulatory requirements for reviewing the applicant's discussion of vibratory ground motion are as follows:

- 10 CFR 100.23(c) (TN282), as it relates to obtaining sufficient geological and seismological information to support the estimates of the SSE ground motion;
- 10 CFR 100.23(d)(1) (TN282), as it relates to the establishment of the SSE ground motion considering appropriate uncertainties through an appropriate analysis such as a PSHA or suitable sensitivity analyses; and

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

In addition, the related acceptance criteria from SRP Section 2.5.2 (NRC 2007/2018-TN5898) are summarized as follows:

- Seismicity: To meet the requirements of 10 CFR 100.23 (TN282), this SSAR section is accepted when the complete historical record of earthquakes in the region is listed and when all available parameters are given for each earthquake in the historical record.
- Geologic and Tectonic Characteristics of the Site and Region: Seismic sources are identified and characterized.
- Correlation of Earthquake Activity with Seismic Sources: To meet the requirements of 10 CFR 100.23 (TN282), acceptance of this SSAR section is based on the development of the relationship between the history of earthquake activity and seismic sources of a region.
- Probabilistic Seismic Hazard Analysis and Controlling Earthquakes: For CEUS sites relying on NUREG–2115 methods and data bases (NRC 2012-TN3810), the staff will review the applicant's PSHA, including the underlying assumptions and how the results of the site investigations are used to update the existing sources in the PSHA, how they are used to develop additional sources, or how they are used to develop a new data base.
- Seismic Wave Transmission Characteristics of the Site: In the PSHA procedure described in RG 1.208 (NRC 2007-TN5858), the controlling earthquakes are determined for generic rock conditions.
- Ground Motion Response Spectra: In this section, the staff reviews the applicant's procedures to determine the GMRS. In addition, the geological and seismic characteristics should be consistent with appropriate sections of RG 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants" (NRC 2014-TN5937), RG 1.132 (NRC 2003-TN5902); RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)" (NRC 2007-TN3035), and RG 1.208 (NRC 2007-TN5858).

2.5.2.3 *Technical Evaluation*

The staff reviewed Section 2.5.2 of the ESPA to verify that the information represented the complete scope of information related to the characterization of vibratory ground motion for the CRN Site. The staff's review confirmed that the CRN Site ESPA addresses the required information related to the vibratory ground motion.

FSER Section 2.5.2.3 provides the staff's evaluation of the seismic, geologic, geophysical, and geotechnical investigations carried out by the applicant to determine the site-specific GMRS leading to the estimation of the SSE ground motion for the CRN Site. The development of the GMRS is based upon a detailed evaluation of earthquake potential, taking into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the CRN Site subsurface material.

On July 17–18, 2013, during the early site investigation stage, the staff visited the site and interacted with the applicant regarding the geologic, seismic, and geotechnical investigations for the ESPA (NRC 2013-TN5925). The staff made an additional visit to the CRN Site in May 2017 to confirm interpretations, assumptions, and conclusions presented by the applicant related to

potential geologic and seismic hazards (NRC 2017-TN5908). As discussed in Section 2.5 of this chapter, “Geology, Seismology, and Geotechnical Engineering”, the staff issued several RAIs to the applicant and evaluated the responses received during the review process.

2.5.2.3.1 Seismicity

SSAR Section 2.5.2.1 (TVA 2016-TN5018) states that the earthquake catalog used for the CRN Site seismic hazard assessment is the CEUS-SSC earthquake catalog (NRC 2012-TN3810), supplemented with data from earthquakes that occurred between 2009 and mid-September of 2013 (TVA 2016-TN5018). The earthquake catalog, published as part of the CEUS-SSC model, covers the entire CEUS region from 1568 through 2008 and includes a uniform moment magnitude scale for all earthquakes listed in the catalog (NRC 2012-TN3810). Because the staff reviewed the CEUS-SSC earthquake catalog previously, the staff technical evaluation of SSAR Section 2.5.2.1 (TVA 2016-TN5018) focused on the applicant’s efforts to update the CEUS-SSC earthquake catalog for use in the CRN Site PSHA. The CEUS-SSC earthquake catalog covers the seismicity of the region through 2008 (NRC 2012-TN3810); hence, the applicant provided a quantitative analysis in the SSAR of earthquakes occurring within 320 km (200 mi) of the site from 2009 through mid-September 2013 (TVA 2016-TN5018). In addition to documenting the seismic activity in the site region, the applicant updated the seismicity rates and b-values developed in the CEUS-SSC model to account for potential changes in seismicity patterns since 2008.

As part of its confirmatory analysis, the staff developed a supplementary earthquake catalog covering the CEUS region from 2013 through July 30, 2017. The staff used the USGS National Earthquake Information Center[2] earthquake catalog for this analysis. The staff reviewed its confirmatory catalog to determine whether new earthquakes have occurred in the CEUS region since the submission of the CRN Site ESPA that might impact either the M_{max} of the seismic sources identified in the CEUS-SSC model or the earthquake recurrence rates calculated for each of the CEUS-SSC seismic sources used for the CRN Site PSHA. In its confirmatory catalog, the staff searched for earthquakes of magnitude 2.9 and above within the time window from October 2013 through July 30, 2017, and within 500 km (311 mi) of the CRN Site. Figure 2.5.2-6 shows the results of the staff’s earthquake search. As shown in Figure 2.5.2-6, there are no recent significant earthquakes within 500 km (311 mi) of the site nor are there any new clusters of seismic activity not captured by the CEUS-SSC model. The staff’s catalog showed that 31 earthquakes occurred between October 2013 and July 30, 2017. None of these earthquakes have magnitudes greater than **M**5.0 and the majority of the earthquakes identified by the staff in its supplementary catalog are small (**M** < 4.0). Therefore, the staff concludes from its confirmatory analysis that the earthquakes in the staff’s supplementary catalog support the information used in the applicant’s catalog for its PSHA.

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

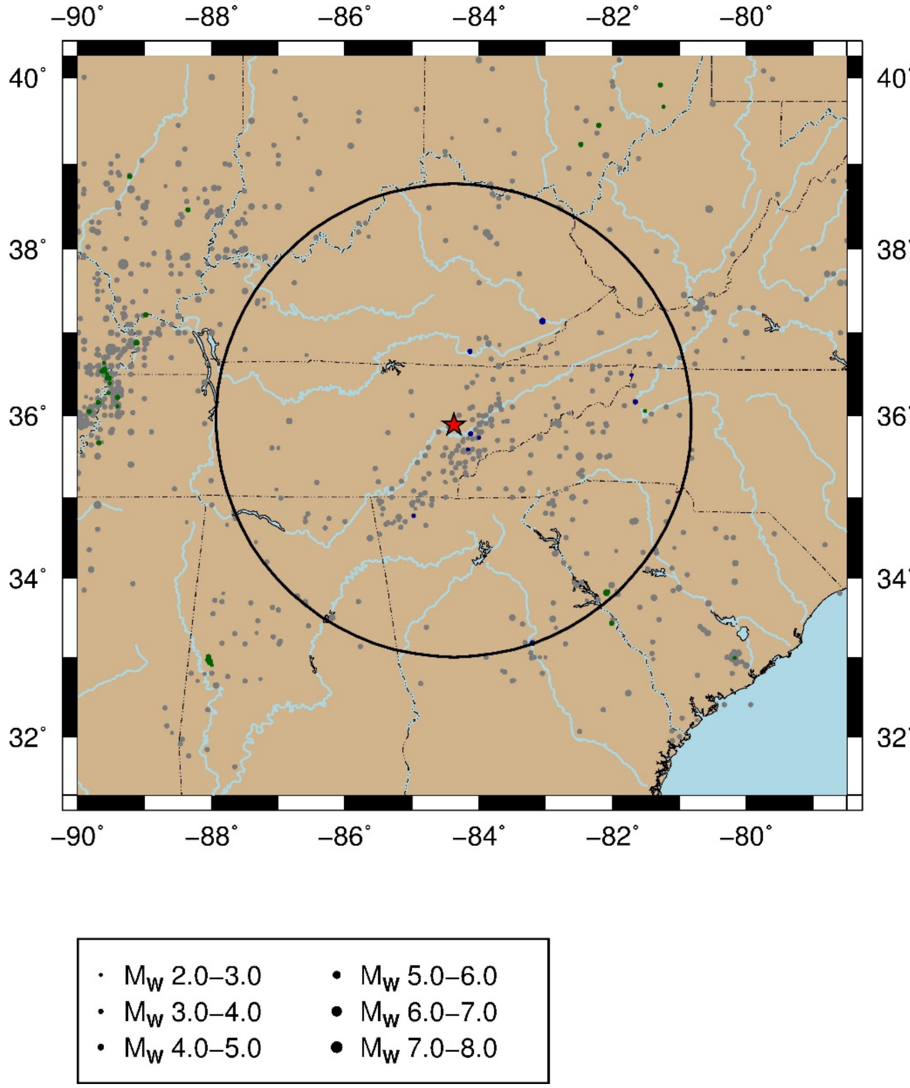


Figure 2.5.2-6 Map of the Staff's Supplementary Earthquake Search. Grey dots are earthquakes included in the NUREG–2115 (NRC 2012-TN3810) catalog (M > 2.9). Dark blue dots are M > 2.9 earthquakes added by the applicant to the catalog between 2009 and mid-September 2013. Dark green dots are the staff-identified M > 2.9 earthquakes identified that occurred between October 2013 and July 30, 2017. The black circle marks the 320 km (200 mi) radius from the CRN Site.

2.5.2.3.1.1 *Staff Conclusions Regarding Seismicity*

Based on its review of the applicant's SSAR Section 2.5.2.1 (TVA 2016-TN5018) and the staff's confirmatory assessment of the CEUS-SSC seismicity catalog (NRC 2012-TN3810), the staff concludes that the applicant developed a complete and accurate earthquake catalog for the region surrounding the CRN Site. The staff concludes that the seismicity catalog, as described by the applicant in SSAR Section 2.5.2.1 (TVA 2016-TN5018), forms an adequate basis for the seismic hazard characterization of the site and meets the requirements of 10 CFR 52.17(a)(1)(vi) (TN251) and 10 CFR 100.23 (TN282).

2.5.2.3.2 *Geologic and Tectonic Characteristics of the Site and Region*

SSAR Section 2.5.2 describes the seismic sources and seismicity parameters used by the applicant to calculate the seismic ground motion hazard for the CRN Site (TVA 2016-TN5018). Specifically, the applicant described the CEUS-SSC model, published as NUREG–2115 in 2012 (NRC 2012-TN3810).

The staff previously reviewed the CEUS-SSC seismic source model and approved its use as a starting regional model for NPP applications. However, the CEUS-SSC model is a regional model and NUREG–2115 (NRC 2012-TN3810) specifically states that it should be compared against potential nearby local seismic sources to determine if refinements of the CEUS-SSC model are necessary to account for changes in earthquake magnitude, location, or recurrence rates. Hence, the staff primarily focused on the applicant's investigation of potential local seismic sources and source parameter adjustments to the CEUS-SSC model.

2.5.2.3.2.1 *Modifications to CEUS-SSC Model Due to the Updated Earthquake Catalog*

The applicant's updated earthquake catalog (2009–2013) identified six earthquakes that had the potential to impact the site hazard (TVA 2016-TN5018). Of the six earthquakes, five occurred within 320 km (200 mi) of the site. The largest earthquake was the **M**5.9 Mineral, Virginia earthquake, which was 615 km (380 mi) from the CRN Site and occurred on August 23, 2011. Studies of the Mineral, Virginia earthquake resulted in minor changes to the CEUS-SSC model, particularly an increase in the minimum M_{max} value for one of the CEUS-SSC source zones (Extended Continental Crust – Atlantic Margin).

The applicant evaluated its updated seismicity catalog (TVA 2016-TN5018) to determine whether changes in the recurrence rates developed for the sources in the CEUS-SSC model are necessary. Based on its evaluation, the applicant determined that minor changes to the seismicity rates and b-values were warranted for 10 of the CEUS-SSC sources. To update the recurrence parameters for the CEUS-SSC sources, the applicant used the same methodology that was originally used for the published model.

To assess the applicant's update of the recurrence parameters for the CEUS-SSC models, the staff reviewed the applicant's methodology, updated parameters, and performed its own independent confirmatory analysis, discussed in FSER Section 2.5.2.3.4.2. In considering the applicant's updated recurrence parameters, the staff reviewed the updated catalog and the applicant's maps of updated recurrence parameters (e.g., SSAR Figure 2.5.2-27 [TVA 2016-TN5018]). The updates to the recurrence parameters as a result of catalog updates are minimal and have a negligible impact on the PSHA results, as shown in Figure 2.5.2-7. Based on the staff's review and confirmatory analysis, the staff has determined that the applicant's updates are acceptable.

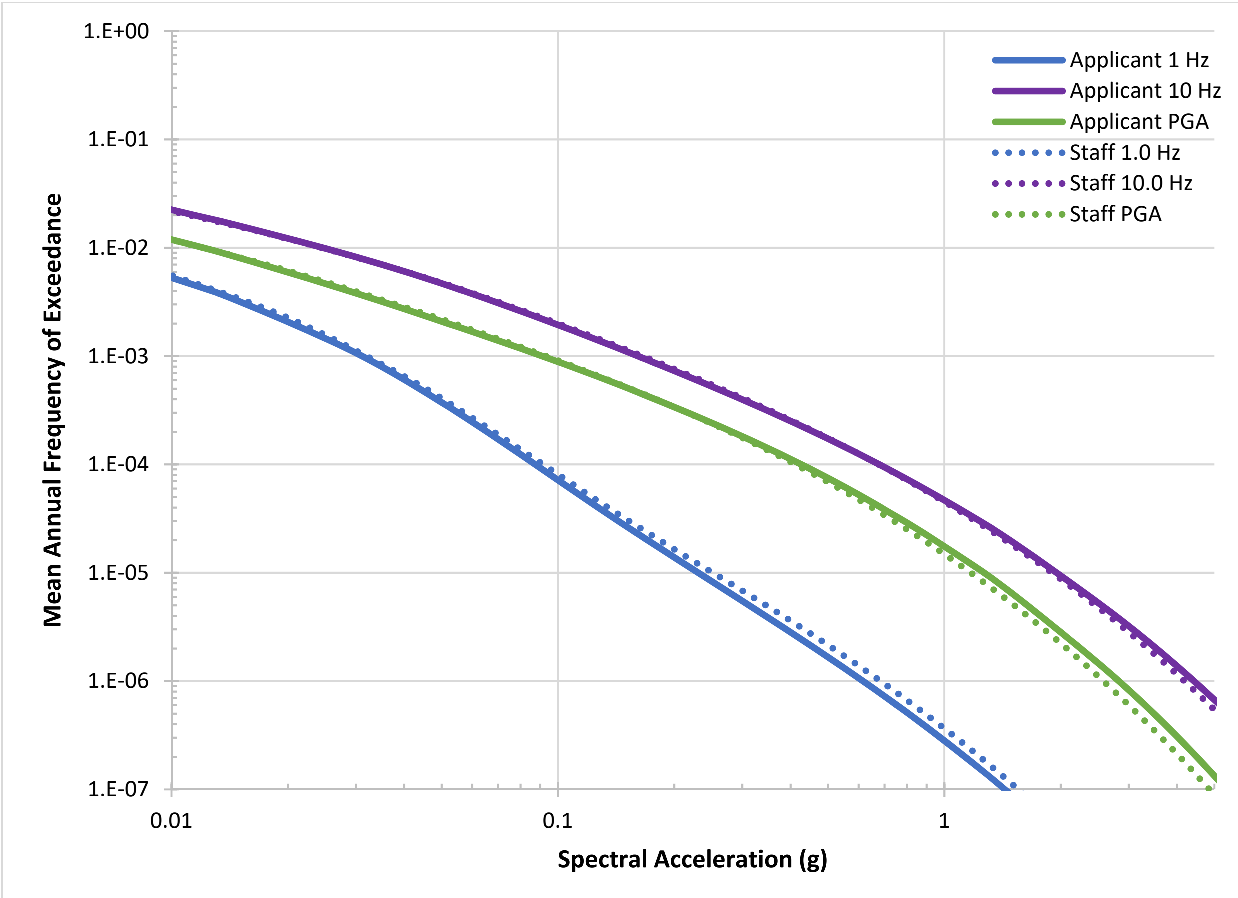


Figure 2.5.2-7 Comparison of the Applicant's Base Rock Hazard Curves with the Staff's Confirmatory Hazard Curves for the CRN Site

2.5.2.3.2.2 *Modifications to CEUS-SSC Seismic Source Model*

In NUREG–2115, Chapter 9, "Use of the CEUS-SSC Model in PSHA," describes the approximations or simplifications that applicants may implement when using the CEUS-SSC model (NRC 2012-TN3810). The primary simplification used by the applicant was to model the CEUS-SSC background seismic sources as point sources rather than as finite ruptures with multiple fault orientations, dips, and crustal thicknesses. The applicant noted that a sensitivity study performed during the development of the CEUS-SSC model found that these simplifications had a minor impact on the overall hazard results. However, as recommended in NUREG–2115 (NRC 2012-TN3810), the applicant did include the finite fault ruptures for the CEUS-SSC New Madrid and Charleston RLME sources. The applicant also included the simplifications needed to combine the CEUS-SSC (NRC 2012-TN3810) with the EPRI GMM (EPRI 2013-TN6143), such as exclusion of the sense of fault slip and simplification of the depth distribution to a single value. Based on the fact that the above simplifications are determined to be acceptable in the CEUS-SSC, necessary for use with the EPRI GMM (EPRI 2013-TN6143), and have been demonstrated to have a small impact on the overall hazard (e.g., NUREG–2202), the staff deems these simplifications acceptable.

2.5.2.3.2.3 *Consideration of the Eastern Tennessee Seismic Zone*

SSAR Section 2.5.2.2 (TVA 2016-TN5018) discusses analyses performed by the applicant to assess the CEUS-SSC source models developed to characterize the seismicity associated with the ETSZ. The ETSZ is located to the east of the CRN Site and is a defined region approximately 300 km (186 mi) long and less than 100 km (62 mi) wide. It is one of the most active seismic regions in eastern North America in terms of seismic rate. The ETSZ is associated with small (**M** < 5.0) earthquakes; the 1973 **M**4.6 Fort Payne, Alabama, earthquake was the largest historical earthquake. The CEUS-SSC models do not characterize the ETSZ as an RLME because definitive paleoseismic evidence of previous ruptures has not yet been discovered. Instead, the CEUS-SSC characterizes the ETSZ using background source zones. The Paleozoic Extended Crust source zone, which is the highest weighted CEUS-SSC zone that covers the ETSZ, has a M_{max} distribution that ranges from **M**5.9 to **M**7.9 and **M**6.8 receives the most weight. Because the ETSZ is covered by a background source zone, Chapter 5.3 of NUREG–2115 (NRC 2012-TN3810) describes the sensitivity studies conducted by the model developers to ensure that the distributed seismicity approach does not artificially dilute the seismic hazard for sites near the ETSZ. The CEUS-SSC model (NRC 2012-TN3810) is based on the assumption that the spatial stationarity of seismicity in the CEUS will persist for time periods of interest for well-engineered critical facilities (i.e., approximately the next 50 years). However, because the locations of the generally small- to moderate-magnitude CEUS earthquakes that are covered by the CEUS-SSC background zones are not tightly constrained, a moderate amount of spatial smoothing is used in the CEUS-SSC models to allow for the occurrence of earthquakes over a broader area.

A recent geologic study of potential paleoseismic features within the ETSZ (Hatcher et al. 2013-TN6118) has hypothesized that the ETSZ has produced at least two **M** ≥ 6.5 earthquakes in the last approximately 73 to 112 thousand years. Due to this recent study, the applicant undertook a SSHAC Level 2 assessment of potential paleoseismic features associated with the ETSZ. The applicant performed two sensitivity studies to determine if the ETSZ needs to be considered as an RLME rather than as a background zone for the CRN Site PSHA.

In its first study, the applicant investigated the implications of the Hatcher et al. (2013-TN6118) study with respect to the CEUS-SSC M_{max} distributions for the sources that encompass the ETSZ. The applicant compared the M_{max} suggested by Hatcher et al. (2013-TN6118), which is approximately **M** = 7.5, with the M_{max} distributions for the CEUS-SSC source zones that encompass the ETSZ. The M_{max} distributions for the CEUS-SSC source zones that encompass the ETSZ range from **M**5.9 to **M**8.1 and the highest weights are for **M**6.8 to **M**7.3. Based on this comparison of M_{max} values, the applicant concluded that no update to this parameter is required for any of the CEUS-SSC sources.

For the second study, the applicant used the magnitude-frequency distributions assigned to the CEUS-SSC sources to determine if these sources produced large earthquakes frequently enough to account for the recently postulated paleoseismic features. The applicant’s analysis showed that the CEUS-SSC Paleozoic Extended Zone seismotectonic source (the highest weighted host zone for the ETSZ) produces **M**6.5 earthquakes approximately every 13,000 years and **M**7.0 earthquakes approximately every 88,000 years. These recurrence intervals are broadly consistent with the proposed rates from the Hatcher et al. (2013-TN6118) study. Therefore, the applicant determined that no updates to the magnitude recurrence rates of the CEUS-SSC models are required.

The staff reviewed both of the applicant's sensitivity studies and the Hatcher et al. (2013-TN6118) study (and associated references) regarding the potential for large earthquakes in the ETSZ. Based on the preliminary nature of the geologic studies and the fact that CEUS-SSC model (NRC 2012-TN3810) adequately accounts for the potential for large earthquakes at expected recurrence rates, the staff agrees with the applicant's assertion that no modifications to the CEUS-SSC model are required to explicitly model the seismicity associated with the ETSZ.

2.5.2.3.2.4 _Staff Conclusions Regarding Geologic and Tectonic Characteristics of the Site and Region_

Based on its review of SSAR Sections 2.5.2.2 and 2.5.2.4 (TVA 2016-TN5018), the staff concludes that the applicant adequately assessed the CEUS-SSC models as input to its PSHA for the CRN Site. In addition, the staff concludes that the applicant adequately considered modifications to the CEUS-SSC model for the CRN Site. The staff concludes that the applicant's use of the CEUS-SSC models, as described by the applicant in SSAR Sections 2.5.2.2 and 2.5.2.4 (TVA 2016-TN5018), forms an adequate basis for the seismic hazard characterization of the site and meets the requirements of 10 CFR 52.17(a)(1)(vi) (TN251) and 10 CFR 100.23 (TN282).

2.5.2.3.3 Correlation of Earthquake Activity with Seismic Sources

SSAR Section 2.5.2.3 (TVA 2016-TN5018) describes the correlation of seismicity in the region with the seismic source model used in the CRN Site PSHA study. The applicant noted that the CEUS-SSC model uses earthquake locations and characteristics in defining the seismic source geometries. The applicant compared the CEUS-SSC seismicity catalog (NRC 2012-TN3810) with its updated catalog to assess any changes in patterns of seismicity. The applicant also examined the catalogs to determine if any correlation exists between geologic structures and seismicity not identified in the CEUS-SSC study that needs to be accounted for at the CRN Site. Based on the staff's review of the applicant's assessment, its updated seismicity catalog, and the staff's confirmatory analysis described in FSER Section 2.5.2.3.5.3, the staff concludes that the applicant's characterization of the correlation of earthquake activity is adequate.

2.5.2.3.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

In SSAR Section 2.5.2.4, the applicant stated that it used the CEUS-SSC model and the EPRI GMM (EPRI 2013-TN6143) to develop base hard rock seismic hazard curves for the CRN Site (TVA 2016-TN5018). Subsequently, using the hard rock seismic hazard curves, the applicant obtained UHRS at annual frequency of exceedances of 10^{-4}, 10^{-5}, and 10^{-6}. In addition, using the procedures outlined in RG 1.208 (NRC 2007-TN5858), the applicant determined the controlling earthquake magnitude and distance combinations for both LF and HF ground motions. The following subsections describe the staff's assessment of the applicant's PSHA and its determination of the controlling earthquakes.

2.5.2.3.4.1 _PSHA Inputs_

As described in FSER Section 2.5.2.3.4, the applicant implemented the CEUS-SSC model (NRC 2012-TN3810) with updated seismicity parameters, consistent with guidance provided in RG 1.208 (NRC 2007-TN5858). The applicant also considered the potential impact of the ETSZ on seismic hazard and determined that the CEUS-SSC model adequately captures the hazard from this region of elevated seismicity. The applicant's PSHA inputs, including its decision to

update the seismicity parameters for the CEUS-SSC sources, are consistent with RG 1.208 (NRC 2007-TN5858); therefore, the staff concludes that the applicant's PSHA inputs are adequate.

2.5.2.3.4.2 *PSHA Calculation and Confirmatory Analysis*

Using the CEUS-SSC model (NRC 2012-TN3810) and the EPRI GMM (EPRI 2013-TN6143), the applicant performed PSHA calculations for PGA and ground motion frequencies of 25, 10, 5, 2.5, 1, and 0.5 Hz. As described in FSER Section 2.5.2.3.2, the applicant implemented a simplification in the seismic hazard calculations of the background seismic sources used to determine total seismic hazard at the site. The applicant's simplification was to implement the point source model as described in Section 9.3.1.11 of NUREG–2115 (NRC 2012-TN3810) when calculating the hazard of background seismic sources. As described in FSER Section 2.5.2.3.2.2, the staff determined that the applicant's simplification was acceptable and would result in the adequate calculation of seismic hazard at the CRN Site.

As part of its confirmatory analysis, the staff used the CEUS-SSC model background (distributed seismicity) sources (NRC 2012-TN3810) and independently calculated the seismic hazard curves at the CRN Site for all seven ground motion frequencies defined in the EPRI (2013-TN6143) GMPEs. The staff's confirmatory calculations also included RLME sources. From the CEUS-SSC model (NRC 2012-TN3810), the staff first selected all background seismic sources that are within 640 km (400 mi) of the site, which is consistent with the applicant's approach. Also consistent with the approach taken by the applicant, the staff included all RLME sources within 1,000 km (620 mi) of the site. For its confirmatory PSHA, the staff used the original seismicity rates specified in the CEUS-SSC model (NRC 2012-TN3810) rather than the updated rates used by the applicant. Figure 2.5.2-7 shows the staff's results compared to those of the applicant for PGA and ground motion frequencies of 10 and 1 Hz. The staff confirmatory calculations show that for the annual exceedance frequencies of 10^{-4}, 10^{-5}, and 10^{-6}, the staff's seismic hazard curves are in good agreement with the applicant's seismic hazard curves. Hence, the staff concludes that the applicant's update of the seismicity rates for the CEUS-SSC sources does not have a significant impact on the final base rock hazard results. Based on its confirmatory analysis, the staff concludes that the applicant adequately characterized the mean seismic hazard at the CRN Site.

2.5.2.3.4.3 *Controlling Earthquakes*

To determine the LF and HF controlling earthquakes' magnitudes and distances, the applicant used a procedure called deaggregation. The applicant followed the deaggregation procedures outlined in RG 1.208, Appendix D (NRC 2007-TN5858). The deaggregation results showed that local seismic sources within 100 km (62 mi) of the CRN Site are the primary contributors to the HF seismic hazard at the site, while the RLME sources as well as regional sources were contributors to the LF seismic hazard at the site. Table 2.5.2-1 shows the applicant's deaggregation results for the mean 10^{-4}, 10^{-5}, and 10^{-6} PSHA results. As shown in Table 2.5.2-1, for the HF hazard, the controlling earthquakes are those with magnitudes of approximately **M**6.0 that occur near the site. For the LF hazard, the controlling earthquakes are several hundred kilometers away and have magnitudes of approximately **M**7.5. As such, the applicant selected the magnitudes of **M**5.5 and **M**7.5 to use for the development of input motions for its site response analysis, as described below in Section 2.5.2.3.5.

Because the applicant used the guidance outlined in RG 1.208 (NRC 2007-TN5858) to determine the controlling earthquake magnitude and distance, the staff concludes that the

procedures used by the applicant are adequate and the resultant controlling earthquake parameters are representative of the controlling earthquakes in the region.

2.5.2.3.4.4 *Staff Conclusions Regarding PSHA and Controlling Earthquakes*

Based on its review of the applicant's PSHA and independent confirmatory PSHA, the staff concludes that the applicant's PSHA adequately characterizes the seismic hazard for the CRN Site and that the controlling earthquakes determined by the applicant are representative of the earthquakes that would be expected to contribute the most to the hazard.

2.5.2.3.5 Seismic Wave Transmission Characteristics of the Site

SSAR Section 2.5.2.5 describes the method the applicant used to develop the CRN Site amplification functions and the control point elevation seismic hazard curves (TVA 2016-TN5018). For its site response analysis, the applicant selected the control point elevation to be at depth of 42 m (138 ft) below the surface grade elevation of 250 m (821 ft) above mean sea level. As described above in Section 2.5.2.3.4, the base rock seismic hazard curves calculated by the applicant were developed assuming the EPRI GMM (EPRI 2013-TN6143) reference rock V_S of 2.8 km/s (9,200 fps). The applicant stated that these hard rock conditions are encountered at a depth of 92 m (302 ft) beneath Location A and at a depth of 50 m (161 ft) beneath Location B at the site. However, because there are minor V_S reversals for some of the deeper rock strata beneath the site, the applicant extended its V_S profiles down to a depth of approximately 3,650 m (12,000 ft) below the GMRS elevation at the CRN Site. To determine the amplification of this 3,650 m (12,000 ft) profile of rock with respect to the base rock, the applicant performed a site response analysis. The output of the applicant's site response analysis is the site amplification functions, which are then convolved with the base rock seismic hazard curves to determine the control point seismic hazard curves at the GMRS elevation.

2.5.2.3.5.1 *Site Response Inputs and Methodology*

In SSAR Sections 2.5.4.2, 2.5.4.4, and 2.5.4.7, the applicant described its base case rock profiles in terms of the V_S, layer thicknesses, material damping, and strain-dependent properties, which the applicant used as the input models to its site response calculations (TVA 2016-TN5018). The applicant stated that the upper portions of the profiles for the CRN Site subsurface are based on the numerous site geophysical and geotechnical investigations, which are described in detail in SSAR Section 2.5.4 (TVA 2016-TN5018). For the deeper portions of the profiles, the applicant used geophysical measurements of the same rock strata (Conasauga shale, Rome Formation sandstone, and Pumpkin Valley shale) made for the Watts Bar 2 site, located approximately 50 km (31 mi) to the southwest as a guide.

The applicant accounted for dip in the rock strata beneath the site through the development of multiple base case profiles. In eRAI-8893 (RAI No. 3), Question 2.5.2-2 (NRC 2017-TN5938), the staff requested that the applicant provide a more explicit explanation of the manner in which the use of multiple profiles was expected to account for dipping layers in the subsurface. In the applicant's response to eRAI-8893 (RAI No. 3), Question 2.5.2-2, dated July 19, 2017 (TVA 2017-TN5939), the applicant stated that its development of three base cases for each site profile (Location A and Location B) account for the fact that each geologic unit is encountered at a different depth across the footprint of the site as well as potential 2D site effects in the upper 91 m (300 ft). The staff reviewed the applicant's response to Question 2.5.2-2 (TVA 2017-TN5939) and concluded that the applicant's approach effectively smears the geology across the footprint of the site through the use of two base case profiles and then accounts for the dipping

layers through the use of the lower and upper profiles about the two base case profiles for Locations A and B. Based on the results of the staff's independent confirmatory analysis (described below in Section 2.5.2.3.5.3) and applicant's 2D sensitivity study (described below in Section 2.5.2.3.5.2), the staff considers the applicant's approach to modeling the effects of the dipping rock layers beneath the site to be acceptable. The staff confirmed that SSAR Revision 1, dated December 15, 2017 (TVA 2017-TN5387), was revised as committed in the RAI response. Accordingly, the staff considers eRAI-8893 (RAI No. 3), Question 2.5.2-2, closed.

In SSAR Section 2.5.2.5.2, the applicant described its development of site-specific kappa values for the CRN Site (TVA 2016-TN5018). Kappa is a measure of the seismic energy lost to the anelastic behavior of rocks and wave scattering due to small-scale heterogeneities in rock structure. In its kappa analysis, the applicant used seismic recordings of small earthquakes at a seismograph located at Tellico Dam, approximately 16.7 km (10 mi) from the site. The applicant applied two methods for determining kappa using the information contained in these ground motion recordings. Based on the similar geology of the Tellico Dam site and the CRN Site, the applicant determined that the site kappa value ranged from 0.006 sec to 0.016 sec. The applicant used these kappa values to constrain the amount of damping in the site profiles used in its site response analysis.

The applicant used the RVT methodology (Idriss et al. 1968-TN6140) to calculate the site response amplification functions at the CRN Site. The use of RVT in site response calculations is specified in RG 1.208 (NRC 2007-TN5858) as an acceptable alternative to the time-series approach. For the input to its site response analysis, the applicant used a suite of 11 input response spectra, ranging from a PGA of 0.01 to 1.5 g. The applicant developed a set of input spectra for both **M**5.5 and **M**7.5 based on the controlling earthquakes for the site. For each of the six site profiles— lower, base case, and upper for Location A and Location B—the applicant generated 60 randomized profiles using a natural log standard deviation of 0.25 over the upper 15.2 m (50 ft) and 0.15 below for each of the layers. These profiles are combined with the input response spectra to develop a suite of amplification functions in terms of the median and natural log standard deviation for each of the seven spectral frequencies (0.5, 1, 2.5, 5, 10, 25 Hz, and PGA) covered by the EPRI GMM (EPRI 2013-TN6143). The applicant then convolved these amplification functions with the rock hazard curves to determine seismic hazard curves at the control point or GMRS elevation. The staff reviewed the applicant's site response methodology and inputs and performed its own independent confirmatory analysis, as described in FSER Section 2.5.2.3.5.3. Based on this, the staff determined that the applicant's site response inputs are adequate for use at the CRN Site.

2.5.2.3.5.2 *2D Sensitivity Analysis*

RG 1.208 recommends a 2D site response analysis or sensitivity study for sites that have a significantly dipping subsurface (NRC 2007-TN5858). In SSAR Section 2.5.2.6, the applicant presents its results for a 2D sensitivity analysis (TVA 2016-TN5018). The applicant developed a 2D model for the site using regional geologic cross sections and site-specific data. The applicant performed a finite element analysis using the SDE-SASSI Version 2.0 software. The applicant compared its 2D amplification factors beneath the site to an amplification factor developed for the best-estimate profile using a method different from that used for determining the site-specific hazard. In eRAI-8893 (RAI No. 3), Question 2.5.2-1 (NRC 2017-TN5938), the staff requested that the applicant provide its comparison of its 2D results to those actually calculated for determining the site-specific GMRS. In the applicant's response to eRAI-8893 (RAI No. 3), Question 2.5.2-1, dated July 19, 2017 (TVA 2017-TN5939), the applicant made the relevant comparison and proposed SSAR modifications. The applicant's response showed that

the 2D amplification factors are generally lower than those developed using the 1D method. The applicant noted minor exceedances of the 1D results at a few frequencies. The staff notes that these exceedances are low in amplitude, and the overall comparison shows that the 1D approach adequately accounts for potential 2D effects. 2D effects at the CRN Site are likely limited by the relatively high seismic velocities and low impedance contrast at layer boundaries. Therefore, the staff considers the applicant's response to eRAI-8893 (RAI No. 3), Question 2.5.2-1 (TVA 2017-TN5939) acceptable. The staff confirmed that SSAR Revision 1, dated December 15, 2017 (TVA 2017-TN5387), was revised as committed to in the RAI response. Accordingly, the staff considers eRAI-8893 (RAI No. 3), Question 2.5.2-1 closed.

2.5.2.3.5.3 *NRC Site Response Confirmatory Analysis*

The staff performed a confirmatory site response analysis to determine the adequacy of the applicant's site response calculations. As input, the staff used the available geophysical data to develop three site response input models. In contrast to the approach taken by the applicant, the staff explicitly modeled the dipping layers by incorporating an up-dip, center, and down-dip profile for each location. Because the site-specific kappa values developed by the applicant are consistent with literature values for similar rock types and thickness (e.g., Campbell 2009-TN6141), the staff used the applicant's values in its confirmatory analysis. To represent the input rock motions, the staff used a magnitude of **M**6.5 with 11 input PGAs ranging from 0.1 to 1.5 g. The staff convolved the results of its amplification function with its confirmatory PSHA results to develop site-specific hazard curves at the GMRS elevation.

The staff's site-specific GMRS is compared to the applicant's in Figure 2.5.2-8. Given the high seismic velocities and relatively low impedance contrasts at the site, the staff considered a bounding analysis using a generic hard rock velocity of 2.8 km/s (9,200 fps). As shown in Figure 2.5.2-8, the applicant's and the staff's GMRS are consistent, demonstrating that amplification factors determined by the staff and the applicant are consistent even when considering differences in site response inputs and methodologies. In addition, a GMRS calculated using generic hard rock conditions is consistent with both the applicant's and the staff's GMRS developed using site-specific information. This comparison further demonstrates the relative insensitivity of the site-to-site response inputs due to high seismic velocities and low impedance contrast between layers in the subsurface. Based on the above assessment, the staff concludes that the applicant's site response calculations adequately characterize the site effects at the CRN Site.

2.5.2.3.5.4 *Staff Conclusions Regarding Seismic Wave Transmission Characteristics of the Site*

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 (NRC 2007-TN5858) in its site response calculations and used an adequate range of input parameters. The staff's confirmatory analysis also showed that the applicant's calculations are acceptable.

2.5.2.3.6 Ground Motion Response Spectra

SSAR Section 2.5.2.5.8 describes the method the applicant used to develop the horizontal and vertical, site-specific, GMRS (TVA 2016-TN5018). To obtain the horizontal GMRS, the applicant used the performance-based approach described in RG 1.208 (NRC 2007-TN5858) and the American Society of Civil Engineers/Structural Engineering Institute Standard 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities" (ASCE/SEI 2005-TN6142). SSAR Section 2.5.2.5.8 (TVA 2016-TN5018) states that the

horizontal GMRS (for each spectral frequency) is obtained by scaling the 10^{-4} soil UHRS by the design factor specified in RG 1.208 (NRC 2007-TN5858). A comparison of the applicant's and the staff's confirmatory horizontal GMRS is shown in Figure 2.5.2-8.

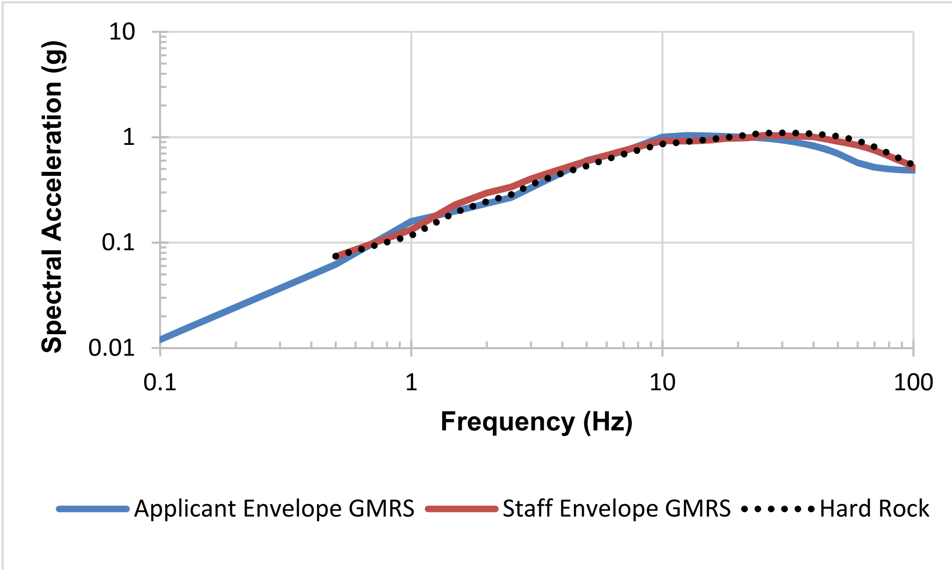


Figure 2.5.2-8 Comparison of the Applicant's (blue) and the Staff's Confirmatory GMRS (red) for the CRN Site. The generic hard rock (V_S = 2.8 km/s [9,200 fps]) GMRS (black dotted) is shown for comparison.

In SSAR Section 2.5.2.5.6, the applicant describes its approach to developing the vertical GMRS (TVA 2016-TN5018). The applicant used an approach similar to that used for developing the site-specific hazard curves to develop the V/H ratios. The applicant used the V/H ratios from NUREG/CR-6728 (McGuire et al. 2001-TN5861) and incorporated the epistemic uncertainty in the ratios by evaluating the uncertainty in several V/H ratio models taken from the literature. The staff compared the applicant's V/H ratios to those found in NUREG/CR-6728, Appendix J (McGuire et al. 2001-TN5861), and found that the applicant's approach, which incorporates epistemic uncertainty, generally results in ratios that exceed those suggested by NUREG/CR-6728. Because the applicant used an approach to determining V/H ratios that is conservative relative to the approach suggested by NUREG/CR-6728 (McGuire et al. 2001-TN5861), the staff finds the applicant's V/H ratios and resulting vertical GMRS adequate.

2.5.2.3.6.1 *Staff Conclusions Regarding Ground Motion Response Spectra*

Because the applicant used the standard procedures outlined in RG 1.208 (NRC 2007-TN5858) to calculate the final horizontal GMRS, and conservatively estimated the vertical GMRS, the staff concludes that the applicant's GMRS adequately represents the site ground motion and that the GMRS calculated meets the requirements of 10 CFR 100.23 (TN282) for the establishment of the SSE ground motion.

2.5.2.4 *Conclusion*

As set forth above, the staff reviewed the seismic information submitted by the applicant in SSAR Section 2.5.2 (TVA 2016-TN5018). On the basis of its review of SSAR Section 2.5.2, the staff finds that the applicant provided a thorough characterization of the seismic sources

surrounding the site, as required by 10 CFR 100.23 (TN282). In addition, the staff finds that the applicant adequately addressed the uncertainties inherent in the characterization of these seismic sources through a PSHA, and that this PSHA follows the guidance provided in RG 1.208 (NRC 2007-TN5858). The staff concludes that the controlling earthquakes and associated ground motion derived from the applicant's PSHA are consistent with the seismogenic region surrounding the CRN Site. In addition, the staff finds that the applicant's GMRS, which was developed using the performance-based approach, adequately represents the regional and local seismic hazards and accurately includes the effects of the local site subsurface properties. The staff concludes that the proposed GMRS for the CRN Site adequately establishes the site SSE ground motion at the GMRS elevation and meets the requirements of 10 CFR 52.17(a)(1)(vi) (TN251) and 10 CFR 100.23 (TN282).

2.5.3 Surface Deformation

SSAR Revision 1 (TVA 2017-TN5387), Section 2.5.3, "Surface Deformation," evaluates the potential for tectonic and non-tectonic surface deformation at the CRN Site. The applicant stated that SSAR Section 2.5.3 demonstrates compliance with regulatory requirements in 10 CFR 100.23, "Geologic and seismic siting criteria" (TN282) by providing information about the following topics: geological, seismological, and geophysical investigations; geologic evidence, or absence of evidence, for surface deformation; correlation of earthquakes with capable tectonic sources; ages of most recent deformation; relationship of tectonic structures in the site area to regional tectonic sources; characterization of capable tectonic sources; designation of zones of Quaternary deformation in the site region; and the potential for tectonic or non-tectonic deformation at the site. Based on this information, the applicant concluded that no faults within the site vicinity can generate both tectonic surface deformation and vibratory ground motion, which the applicant indicated would represent a capable fault (i.e., a capable tectonic source) in accordance with the definition in RG 1.208, Appendix A, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion" (NRC 2007-TN5858). The applicant reported that the primary non-tectonic surface deformation hazard at the CRN Site is karst dissolution.

2.5.3.1 *Summary of Application*

The applicant developed SSAR Section 2.5.3 (TVA 2017-TN5387) based on the review of existing information in the following primary sources related to the potential for tectonic and non-tectonic surface deformation at the CRN Site: geologic maps published by the USGS, state geological surveys, and other researchers; literature published in journals and field trip guidebooks, with emphasis on materials published since the 1986 studies conducted by EPRI, including instrumental and historical seismicity data; reports on previous site investigations for the CRBRP; and the CEUS SSC model presented in NUREG–2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities" (NRC 2012-TN3810). In addition to reviewing the existing information, the applicant performed the following activities to further assess the potential for tectonic and non-tectonic surface deformation within the site area: examination and interpretation of aerial photographs, LiDAR, and remote-sensing imagery; geologic field reconnaissance; analysis of terraces to assess the ETSZ; and collection of subsurface and geophysical data from boreholes. FSER Sections 2.5.3.1.1 through 2.5.3.1.8 summarize the information described by the applicant in SSAR Section 2.5.3 (TVA 2017-TN5387).

2.5.3.1.1 Geological, Seismological, and Geophysical Investigation*s*

In SSAR Section 2.5.3.1, the applicant described the available information compiled to address the potential for tectonic and non-tectonic surface deformation at the CRN Site (TVA 2017-TN5387). Primary sources included geologic mapping published by the Tennessee Division of Geology, previous geologic studies of the site and site vicinity, and unpublished geologic mapping studies. Several other detailed geologic and hydrogeologic investigations from the ORR and the Melton Hill Dam included the CRN Site and vicinity within their scope. The applicant incorporated data from the previous CRBRP investigations relevant to ground deformation, including seismic and non-seismic hazard data from regional studies, in the CRN Site ESPA.

Recent studies of Quaternary terrace deposits surrounding the Douglas Reservoir in East Tennessee, approximately 80 km (50 mi) from the CRN Site, evaluated potential evidence of Quaternary surface deformation and paleoliquefaction features associated with the ETSZ (Hatcher et al. 2013-TN6118; Warrell et al. 2012-TN6115; Warrell 2013-TN6116; Howard et al. 2011-TN6145). The applicant stated that it could not definitively confirm or rule out a seismic origin for many of the observed features in these studies and that alternate hypotheses, such as pedogenic processes, karst collapse, and slope failure, could also explain their origins. The applicant referred to SSAR Section 2.5.2.2.6.1.3 (TVA 2017-TN5387) for a discussion of the ETSZ M_{max} sensitivity studies.

In addition to existing data, the applicant conducted the following investigations to assess the potential for tectonic and non-tectonic surface deformation in the 8 km (5 mi) site area:

- interpretation of aerial photography
- geologic field reconnaissance mapping
- detailed geomorphic analysis of high-resolution LiDAR digital elevation data acquired during this investigation
- subsurface borehole and downhole shear wave velocity investigation
- analysis and interpretation of seismic reflection data
- review of the CEUS SSC (NUREG–2115 [NRC 2012-TN3810]).

2.5.3.1.2 Geologic Evidence, or Absence of Evidence, for Surface Deformation

SSAR Section 2.5.3.2 addresses the presence or absence of evidence of tectonic and non-tectonic surface deformation in the site vicinity and site area (TVA 2017-TN5387). The SSAR and the following sections of this FSER specifically address Late Paleozoic (360 to 252 Ma) bedrock faults, shear-fracture zones at the CRN Site, carbonate dissolution features (karst), slope failure, longitudinal terrace profiles along the Clinch River, and proposed Quaternary (2.6 Ma to present) deformation features along the Douglas Reservoir.

2.5.3.1.2.1 *Bedrock Faults*

In SSAR Section 2.5.3.2.1, the applicant stated that the CRN Site is between the Whiteoak Mountain and Copper Creek thrust faults (TVA 2017-TN5387). SSAR Sections 2.5.1.1 and 2.5.1.2 discuss the evidence suggesting that bedrock thrust faults in the Valley and Ridge physiographic province were active during the Late Paleozoic Alleghanian orogeny (TVA 2017-TN5387). The applicant summarized the geochronologic analyses performed on fault gouge from the Copper Creek fault that estimated ages of 290 to 279 Ma. The applicant also noted that Carboniferous (359 to 299 Ma) strata are the youngest offset by the Valley and Ridge faults

and that Mesozoic (252 to 66 Ma) diabase dikes cross-cut Valley and Ridge structures without offset, suggesting that offset by the Valley and Ridge structures is not younger than the Late Paleozoic.

2.5.3.1.2.2 *Shear-Fracture Zones*

SSAR Section 2.5.3.2.2 refers to previous discussions in SSAR Section 2.5.1.2 related to the shear-fracture zones at the CRN Site (TVA 2017-TN5387). The applicant observed the shear-fracture zone in 39 boreholes from the CRBRP investigations and 18 boreholes from the CRN Site investigations. The applicant identified several zones in rock core samples from the current subsurface investigation and the CRBRP investigation and noted that the average thickness of the shear-fracture zone is about 10.7 m (35 ft). The CRBRP investigation reported a surface exposure of the shear-fracture zone in the northeastern portion of the site. As observed in rock core samples, the applicant characterized the shear-fracture zones as a zone of interbed slippage on the order of inches with no demonstrable stratigraphic offset and notable for the combination of slickensides, calcite veins, and segments no greater than 0.3 m (1 ft) that are either severely warped or brecciated (PMC 1982-TN6190). SSAR Section 2.5.1.2.4.3.4 provides additional description of the shear-fracture zones, including the attributes used to classify the shear-fracture zones (TVA 2017-TN5387).

2.5.3.1.2.3 *Karst*

SSAR Section 2.5.3.2.3 discusses carbonate dissolution features at the CRN Site from the perspective of surface deformation (TVA 2017-TN5387). The applicant evaluated newly acquired LiDAR data for karst features within the site area and observed that all stratigraphic units underlying the site are to some degree calcareous and contain karst features. However, the applicant also noted that cavities are most frequent near the ground surface and decrease in frequency with increasing depth in the boreholes. Based on borehole data, a site karst model, and an understanding of the origin and nature of these cavities, the applicant suggested that cavities might be present in carbonate beds projected downdip toward the excavations and below the base of the planned excavations. SSAR Section 2.5.1.2.5.1 provides a more detailed evaluation of karst (TVA 2017-TN5387).

The local lithology of relatively pure carbonate rocks, such as the Knox Group dolomites and the more pure limestones of the Chickamauga and Conasauga Groups, controls the occurrence of karst depressions. The applicant identified a total of 2,797 karst-related surface features within the 8 km (5 mi) site area during the CRBRP and CRN Site ESP investigations, including large funnel- and dish-shaped sinkholes and small holes in the ground. Figure 2.5.3-1 (SSAR Figure 2.5.1-47 [TVA 2017-TN5387]) shows the locations of the karst features in the site area. The applicant identified 24 caves in the karst inventory of the site area, all of which formed in the Copper Ridge Dolomite, Chepultepec Dolomite, or Maynardville Limestone. Within the 0.6 mi (1 km) site radius, the applicant identified two major sinkhole clusters—one between the Kingsport Formation and Mascot Dolomite in the Knox Group, and the other in the Witten Formation of the Chickamauga Group. SSAR Section 2.5.1.2.5.1 provides additional information about karst hazards in the site area (TVA 2017-TN5387).

2.5.3.1.2.4 *Slope Failure*

In SSAR Section 2.5.3.2.4, the applicant summarized the site investigations for slope failure (TVA 2017-TN5387). In Revision 2 of the ESPA (NRC 2019-TN5929), the applicant identified one small, shallow landslide along the east-northeast part of the site location. Because the

exact location and magnitude of the landslide were not specified in this submittal, the NRC arranged for a March 1, 2019 public meeting with the applicant to get clarification on those matters, as well as the geologic material affected. During the public meeting, the applicant indicated that the landslide involved approximately 2 m^3 of weathered rock of the Blackford/Five Oaks Formation. With respect to context and location, the applicant noted that the small landslide, or slump, is associated with a road cut along the east-northeast margin of the site and the slumped material is likely a consequence of the over-steepened bank caused by human activities. The applicant stated that the site location is situated in an area of moderate susceptibility and low incidence of landslides. Additional details of the public meeting interactions are captured in a summary of the public meeting (NRC 2019-TN5929), and TVA provided supplemental material on the docket that supports the information discussed during the public meeting (TVA 2019-TN6147).

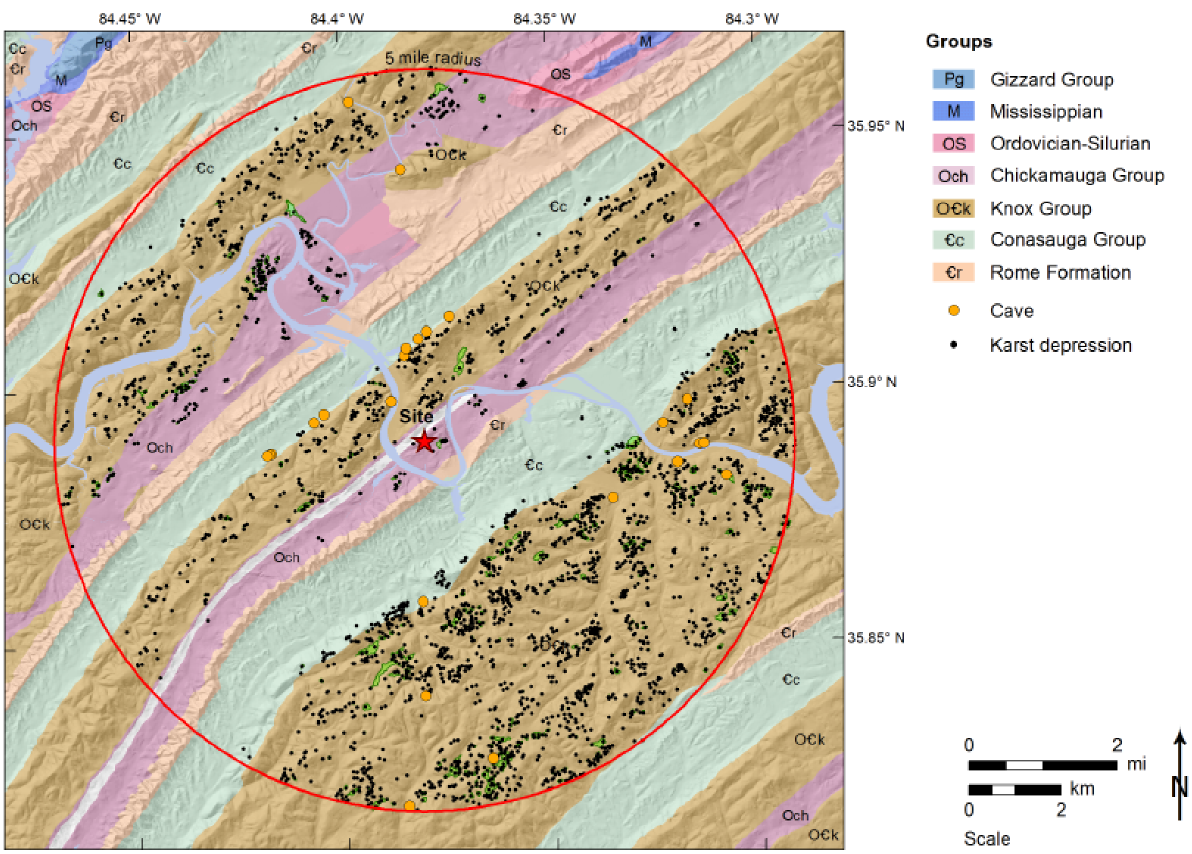


Figure 2.5.3-1 Distribution of Mapped Karst Features in the CRN Site Area (reproduced from SSAR Figure 2.5.1-47 [TVA 2017-TN5387])

2.5.3.1.2.5 *Evaluation of the Presence or Absence of Surface Deformation Along the Clinch River Arm of the Watts Bar Reservoir*

SSAR Section 2.5.3.2.5 evaluates potential surface deformation features through a detailed geomorphic investigation supplemented by geologic field reconnaissance along fluvial terraces (TVA 2017-TN5387). The applicant used longitudinal stream and terrace profiles to identify any potential irregularities that could be associated with reactivation of faults and possible surface deformation. The applicant characterized the youngest geologic units found in the site vicinity—Quaternary deposits—and discussed the delineation of the river terraces.

In SSAR Section 2.5.3.2.5.1, the applicant mapped Holocene (11,700 years to present) through Pleistocene (2.6 Ma to 11,700 years) alluvial terrace deposits along larger tributary valleys in the site area and delineated terraces along the Clinch River using high-resolution LiDAR digital elevation data (TVA 2017-TN5387). The applicant summarized the observations made during field reconnaissance, noting differences in soil development between the Holocene and Pleistocene terraces. The applicant used geomorphology and relative topographic position to assign levels to Holocene terraces representing the historical floodplain to the highest and oldest terrace level.

In SSAR Section 2.5.3.2.5.2, the applicant reported that the history of incision recorded in the Clinch River terraces dates back to the early Pleistocene (2.6 Ma) and possibly into the Tertiary (5.3 to 2.6 Ma) (TVA 2017-TN5387). The applicant developed baseline longitudinal profiles to represent the modern Clinch River prior to the construction of the Watts Bar Dam and determined terrace elevations from LiDAR digital elevation data projected onto the baseline. There is limited absolute age control available; therefore, the applicant used regional terrace studies and terrace ages from analogous rivers to estimate the Clinch River terrace ages. The applicant used morphological correlation and longitudinal profiling to determine the oldest Holocene-age terrace (Qht3) and noted that the oldest and highest terraces in the site area, Qpt5 and Qpt6, are at least 200 thousand years old. SSAR Figure 2.5.3-4 shows the longitudinal profiles of the modern Clinch River baseline and terraces Qht1 through Qpt6 (TVA 2017-TN5387). The applicant evaluated longitudinal profiles of terrace levels for irregularities that could be associated with repeated fault surface rupture, noting that repeated thrust faulting and relative uplift would result in increased incision and terrace formation in the hanging wall of the faults. The applicant concluded that the consistent number of terrace levels with similar longitudinal profile slopes correlated across the site area indicate the absence of discernible Quaternary displacement on the Alleghanian thrust faults in the site area.

SSAR Section 2.5.3.2.5.3 discusses evidence of Quaternary surface faulting in the site area (TVA 2017-TN5387). The applicant examined Pleistocene terrace surfaces that directly overlie the mapped trace of faults and longitudinal terrace profiles for irregularities suggestive of repeated fault displacements. The applicant reported that fluvial terraces overlie the five mapped Alleghanian thrust faults and the projected trace of the shear-fracture zone at the CRN Site. The applicant concluded that there are no linear topographic features or warping of the terrace profile suggestive of surface deformation as a result of faulting.

2.5.3.1.2.6 *Proposed Quaternary Deformation Features Along Douglas Reservoir, Tennessee*

SSAR Section 2.5.3.2.6 discusses the ETSZ and the recent field investigations in the area that reported possible surface faults and paleoliquefaction features associated with one or more Late Quaternary earthquakes (TVA 2017-TN5387). The applicant indicated that the CEUS SSC (NRC 2012-TN3810) described the ETSZ in general terms as a zone of elevated seismicity, but modeled the ETSZ as part of the Paleozoic Extended Zone areal source rather than as a unique seismic source. The applicant also discussed the established criteria for evaluating evidence of paleoliquefaction and other paleoseismic features, and recent terrace mapping and field reconnaissance studies around Douglas Reservoir.

In SSAR Section 2.5.3.2.6.1, the applicant discussed the criteria used to determine whether a feature should be included in the CEUS SSC paleoliquefaction database as an earthquake-induced liquefaction feature (TVA 2017-TN5387). In SSAR Section 2.5.3.2.6.2, the applicant described the morphological correlation and longitudinal profiling of terrace elevations completed along approximately 95 km (59 mi) of the French Broad River as part of the CRN Site

investigation to better constrain the relative ages of terraces along Douglas Reservoir (TVA 2017-TN5387). SSAR Figures 2.5.3-10 and 2.5.3-11 show the terrace maps and longitudinal profiles, respectively. The applicant correlated location and elevation data for the eight identified terraces, performed a linear regression, and compared the results to a baseline longitudinal profile developed to represent the incised French Broad River prior to the construction of Douglas Dam. The applicant noted that the linear regressions for the modern French Broad River and terraces have similar slopes, the number of terrace levels are consistent, and longitudinal profiles are similar. As such, there was no Quaternary displacement along Douglas Reservoir.

In SSAR Section 2.5.3.2.6.3 (TVA 2017-TN5387), the applicant described a recent pilot study to locate paleoseismic features in the ETSZ (Hatcher et al. 2013-TN6118). These potential paleoseismic features include possible faults, fissures, bleached clay fractures, evidence of paleoliquefaction, shale "boils," and disturbed sediments at six different sites within fluvial terraces of the French Broad River at Douglas Reservoir. Warrell et al. (2012-TN6115) studied potential paleoliquefaction features at the six sites presented by Hatcher et al. (2013-TN6118) and one additional site.

The applicant implemented a SSHAC Level 2 study, as described in SSAR Section 2.5.2.2.5 (TVA 2017-TN5387) and discussed in FSER Section 2.5.2.3.2.3. As part of the SSHAC process, the applicant considered potential paleoseismic features associated with the ETSZ. The Technical Integration team, accompanied by the principal researchers, observed the potential paleoseismic features in the field and summarized the interpretations of and conclusions about the features observed at each of the seven sites in SSAR Section 2.5.3.2.6.3 (TVA 2017-TN5387). Based on the observations, interpretations, and evaluations made by the Technical Integration team during field reconnaissance, the applicant noted that there is not sufficient evidence to support determination of the seismic origin of any of the features examined in the field. The Technical Integration team further noted that the features observed at each site could be the result of commonly occurring non-seismic geomorphic and pedogenic processes.

2.5.3.1.2.7 *Evaluation of the Presence of Absence of Surface Deformation Along the Tellico Reservoir*

SSAR Section 2.5.3.2.7 summarizes the terrace surfaces mapped along the Tellico Reservoir on the Little Tennessee River (TVA 2017-TN5387). The applicant developed longitudinal topographic profiles for these terraces but noted that the construction of the Tellico Dam flooded many of the terrace surfaces. Based on available pre-impoundment topographic data and observation of exposed terraces, the applicant concluded that there is no Quaternary displacement or evidence of potential paleoseismic features in the terrace deposits observed along the Tellico Reservoir.

2.5.3.1.3 Correlation of Earthquakes with Capable Tectonic Sources

SSAR Section 2.5.3.3 addresses the possible correlation of earthquakes with capable tectonic sources (TVA 2017-TN5387). The applicant noted that the ETSZ has the second highest rate of small magnitude earthquakes in the Eastern United States—28 earthquakes between **M**2.9 and **M**4.0 were recorded in the site vicinity, of which four occurred in the site area. The majority of earthquake hypocenters occur at depths of 5 to 26 km (3 to 16 mi), with a mean focal depth of approximately 15 km (9 mi) in Neoproterozoic (approximately 1.1 Ga) basement rocks overlain by the 5 km (3 mi) thick Paleozoic foreland fold-thrust belt, which is below the basal detachment

surface that underlies the Valley and Ridge province. The applicant noted that there is no reported unequivocal evidence of historic surface rupture (Powell and Beavers 2009-TN6113). The applicant reported that ETSZ earthquakes have been correlated with potential aeromagnetic anomalies, like the New York-Alabama lineament, but observed that none of these earthquakes correlate with known faults exposed near the ground surface. SSAR Sections 2.5.1.1.4.3.2, 2.5.3.2.6, and 2.5.2 provide more details regarding the ETSZ (TVA 2017-TN5387).

2.5.3.1.4 Ages of Most Recent Deformation

SSAR Section 2.5.3.4 evaluates the ages of most recent deformations within the site area including bedrock faults, shear-fracture zones, and karst collapse (TVA 2017-TN5387). With regard to bedrock faults, the applicant stated that evidence suggests bedrock thrust faults in the Valley and Ridge province were active during the Late Paleozoic Alleghanian orogeny and referred to previous discussions in SSAR Sections 2.5.3.2.1, 2.5.1.1.2, 2.5.1.1.4, and 2.5.1.2.4 (TVA 2017-TN5387). The applicant constrained the timing of the formation of the shear-fracture zone using the orientation and crosscutting relationships of stylolites within the shear-fracture zones. The applicant concluded that the truncation of the shear-fracture zones and calcite veins within the zones by bedding-parallel stylolites suggests pre- to syn-diagenetic formation of the shear-fracture zones, while truncation by steeply dipping and subvertical stylolites suggests a tectonic overprint, most likely due to Alleghanian shortening associated with the emplacement of Valley and Ridge thrust faults. Finally, the applicant stated that carbonate dissolution and the development of karst features are ongoing processes and subsidence of Quaternary terrace material overlying carbonate units indicates these processes have been locally active through the Holocene.

2.5.3.1.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Sources

In SSAR Section 2.5.3.5, the applicant stated that the Copper Creek and Whiteoak Mountain bedrock faults that occur within the CRN Site area are part of the regional Valley and Ridge foreland fold-thrust belt system (TVA 2017-TN5387). These bedrock faults are Late Paleozoic in age, whereas the earthquakes associated with the ETSZ occur in crystalline basement rocks below the Appalachian detachment, 5 to 26 km (3 to 16 mi) deep. Therefore, the applicant concluded that there is no evidence to definitively relate the Alleghanian bedrock thrust faults exposed in the CRN Site area to seismicity in the ETSZ.

2.5.3.1.6 Characterization of Capable Tectonic Sources

In SSAR Section 2.5.3.6, the applicant stated that based on material presented in SSAR Sections 2.5.1, 2.5.3.2, and 2.5.3.5, there is no evidence of significant neotectonic features within the 320 km (200 mi) radius CRN Site region that have the potential to affect site safety (TVA 2017-TN5387). The applicant noted that the Alleghanian Valley and Ridge bedrock faults are Late Paleozoic in age. The applicant also observed that regional geologic mapping and development of longitudinal profiles along the Clinch River, based on high-resolution LiDAR data presented in SSAR Section 2.5.3.2.5 (TVA 2017-TN5387), indicate no observable Quaternary displacement along faults in the site area. Furthermore, the applicant concluded that there is no evidence relating ETSZ earthquakes to faults at the ground surface.

The applicant also reported that recent investigations of potential tectonic features associated with the ETSZ and the applicant's field inspection support the conclusion that nearly all the

features interpreted as paleoseismic in origin can be plausibly explained by other non-seismic processes (Hatcher et al. 2013-TN6118; Warrell 2013-TN6116; Warrell et al. 2012-TN6115).

2.5.3.1.7 Designation of Zones of Quaternary Deformation in the Site Region

In SSAR Section 2.5.3.7, the applicant stated that, although there are no zones of Quaternary deformation associated with tectonic faults that require detailed investigation within the CRN Site vicinity or site area, there are three possible Quaternary fault systems within the CRN Site region (TVA 2017-TN5387). These fault systems are the Kentucky River fault system in northeastern Kentucky approximately 201 km (125 mi) north of the CRN Site; the Rough Creek-Shawneetown fault system in west-central Kentucky about 201 km (125 mi) northwest of the CRN Site; and several unnamed Quaternary faults in western North Carolina approximately 190 km (118 mi) southeast of the CRN Site.

The applicant noted that the Kentucky River fault system was possibly active during the Carboniferous period (360 to 300 Ma; Zeng et al. 2013-TN6124) and the faults appear to offset Pliocene-Pleistocene (5.3 Ma to 11,700 years) terrace deposits based on several exploratory trenches in north-central Kentucky (VanArsdale 1986-TN6123). Crone and Wheeler (2000-TN6117) suggest evidence of Quaternary deformation from the exploratory trenches could be related to karst collapse of underlying carbonate bedrock and classified the Kentucky River fault system as a Class B feature, suggesting that there is either not enough evidence for it to be classified as A or C, or the fault is too shallow to produce significant earthquakes.

The applicant reported that the Rough Creek-Shawneetown fault system is likely Paleozoic (541 to 252 Ma) in age, but Crone and Wheeler (2000-TN6117) interpreted the bedrock steps beneath Pliocene to Holocene (5.3 Ma to present) alluvium as Holocene reactivation of Neoproterozoic to early Paleozoic Rough Creek graben normal faults. Crone and Wheeler (2000-TN6117) classified this fault system as Class C, suggesting there is insufficient evidence to conclude this is a tectonic fault or a feature associated with Quaternary slip or deformation.

Prowell (1983-TN6148) identified three small faults near Saluda, North Carolina, described as reverse, strike-slip, tear and normal faults, with vertical offsets of 4 m (reverse) and 5 m (normal). Although Prowell (1983-TN6148) reported that the faults appear to offset Quaternary alluvial and colluvial deposits, Crone and Wheeler (2000-TN6117) did not evaluate these features in their assessment of Quaternary faults.

2.5.3.1.8 Potential for Tectonic Deformation or Non-tectonic Deformation at the Site

SSAR Section 2.5.3.8 assesses the potential for tectonic and non-tectonic surface deformation at the CRN Site (TVA 2017-TN5387). The applicant stated that the potential for tectonic surface deformation at the CRN Site is negligible. Although the CRN Site lies within the ETSZ, the applicant concluded that earthquakes occur below the Paleozoic foreland fold-thrust belt and there are no Quaternary tectonic faults exposed within the site area or site vicinity.

The applicant stated that the potential for non-tectonic surface deformation as a result of karst activity represents the most significant geologic hazard to the CRN Site. The applicant identified four specific types of hazards to the proposed construction: collapse or subsidence from sinkholes, cavities in the excavation walls below the groundwater table, cavities below the base of the foundation, and cavities enabling the movement of groundwater through underground karst drainage systems. The applicant stated that detailed geologic mapping of

the excavations and geophysical surveys at foundation level will form the basis of the final conclusions regarding karst hazard at the CRN Site.

The applicant stated that there is one small landslide at the site, but landslides or other slump-related hazards would not affect the CRN Site. The applicant also considered anthropogenic activities (e.g., mining) that may cause non-tectonic surface deformation but concluded that there is no potential hazard from mine collapse. The applicant stated that it will evaluate the previous grading/excavation of the CRBRP for any future development.

2.5.3.2 *Regulatory Basis*

The applicable regulatory requirements for tectonic and non-tectonic surface deformation that must be considered in an ESPA are as follows:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to the requirement for an ESP applicant to prepare an SSAR that contains information about geologic and seismic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR 100.23(c) (TN282), as it relates to the requirement for an ESP applicant to investigate the geologic, seismic, and engineering characteristics of a site and its environs in sufficient scope and detail to permit an adequate evaluation of the proposed site; and to permit adequate engineering solutions for actual or potential geologic and seismic effects at the proposed site.
- 10 CFR 100.23(d) (TN282), as it relates to the requirement for an ESP applicant to consider geologic and seismic siting factors for the “determination of the potential for surface tectonic and nontectonic deformations. Sufficient geological, seismological, and geophysical data must be provided to clearly establish whether there is a potential for surface deformation.”

The information about tectonic and non-tectonic surface deformation provided by the applicant in compliance with the above regulatory requirements should also be sufficient to allow a determination in the COLA regarding whether the proposed facility complies with the following requirements in 10 CFR Part 50, Appendix A, “General Design Criteria for Nuclear Power Plants” (TN249), and 10 CFR Part 50, Appendix S, Section IV, “Application to Engineering Design” (TN249):

- General Design Criterion 2 of 10 CFR Part 50, Appendix A (TN249), requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their safety functions.
- 10 CFR Part 50, Appendix S, Section IV (TN249), requires that the potential for surface deformation be taken into account in the design of the NPP.

The staff applied methods and approaches specified in SRP Section 2.5.3, “Surface Faulting” (NRC 2007/2018-TN5898). As recommended in RG 1.208 (NRC 2007-TN5858), the applicant provided information characterizing tectonic and non-tectonic surface deformation at the proposed site in SSAR Section 2.5.3. SRP Section 2.5.3 (NRC 2007/2018-TN5898), defines the acceptance criteria for the tectonic and non-tectonic surface deformation information presented in SSAR Section 2.5.3, as follows. In addition, information provided by the applicant

in SSAR Section 2.5.3 should be consistent with appropriate sections of RG 1.208 (NRC 2007-TN5858). As applicable to an ESP, SRP Section 2.5.3 (Revision 5, July 2014 [NRC 2007/2018-TN5898]) defines the acceptance criteria for information about tectonic and non-tectonic surface deformation presented in SSAR Section 2.5.3 (TVA 2017-TN5387) as follows.

- Geologic, Seismic, and Geophysical Investigations: Requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.23(c) (TN282), and 10 CFR 100.23(d)(2) (TN282) are met and guidance in RGs 1.208 (NRC 2007-TN5858) and 4.7 (NRC 2014-TN3550) is followed for this area of review if discussions of Quaternary tectonics, structural geology, stratigraphy, geochronologic methods used for age dating, paleoseismology, and geologic history of the site vicinity, site area, and site location are complete; compare reasonably with studies conducted by others in the same area; and are supported by detailed investigations performed by the applicant. Site vicinity, site area, and site location-specific geologic maps and cross sections constructed at scales adequate to clearly illustrate surficial and bedrock geology, structural geology, topography, and the relationship of power plant foundation and site boundaries to these features, should be included in the application. For sites located near bodies of water, the application should address how investigations have been conducted to detect possible surface deformation features that might be located beneath the water.

- Geologic Evidence for Surface Tectonic Deformation: Requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.23(c) (TN282), and 10 CFR 100.23(d)(2) (TN282), are met and guidance in RGs 1.208 (NRC 2007-TN5858) and 4.7 (NRC 2014-TN3550) is followed for this area of review if the applicant provides sufficient surface and subsurface information for the site vicinity, area, and location to confirm and characterize the presence or absence of surface deformation (e.g., faulting, growth faulting, subsidence or collapse related to dissolution of limestone, salt or gypsum deposits, or salt diapirism and paleoliquefaction) features. The applicant should also take into account the potential for blind faults.

- Timing of Deformation: Requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.23(c) (TN282), and 10 CFR 100.23(d)(2) (TN282) are met for this area of review if recognized surface deformation features (e.g., tectonic faults and non-tectonic features including growth faults) and features associated with a blind fault are investigated in sufficient detail to constrain the age of the most recent deformation event, and, if applicable, the ages of preceding deformation events. The application shall also provide an acceptable evaluation of the sensitivity and resolution of the exploratory geologic and geophysical techniques used to determine whether or not appropriate techniques were applied to assess the age of the most recent displacement.

- Correlation of Earthquakes with Tectonic Features: Requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.23(c) (TN282), and 10 CFR 100.23(d)(2) (TN282) are met for this area of review if the applicant evaluates all reported historical earthquakes within the site vicinity with respect to the accuracy of hypocenter location and source of origin, and with respect to correlation to tectonic features. The applicant shall evaluate the potential for historical activity on tectonic features in the site vicinity. The application should include a plot of earthquake epicenters superimposed on a map showing the tectonic features in the site vicinity.

- Relationship of Geologic Features in the Site Vicinity to Regional Geologic Features: The requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.23(c) (TN282), and 10 CFR 100.23(d)(2) (TN282) are satisfied for this area of review if the applicant evaluates the relationships between faults or other deformation features in the site vicinity and the regional

framework. The application should provide an acceptable evaluation of the relationships between the regional (tectonic and non-tectonic) framework and deformation features in the site vicinity, including growth faults and growth fault systems. The applicant should show how this information is used in the evaluation of potential for future surface deformation at the site.

- Potential for Surface Tectonic Deformation at the Site Location: To meet requirements of 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.23(c) (TN282), and 10 CFR 100.23(d)(2) (TN282) for this area of review, the applicant should assess the potential future tectonic and non-tectonic surface deformation at the site. The applicant should provide sufficient geological, seismological, and geophysical information to clearly establish whether there is a potential for future surface deformation at the site.

2.5.3.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.5.3 of the CRN Site ESPA (Revision 1) to ensure that the materials provided by the applicant present the information required to assess the potential for tectonic and non-tectonic surface and near-surface deformation (TVA 2017-TN5387). The staff's review of SSAR Section 2.5.3 confirmed that the applicant provided the data and analysis required for topics in SSAR Section 2.5.3.

The technical information presented in SSAR Section 2.5.3 (TVA 2017-TN5387) resulted from the applicant's review of geologic maps published by the USGS, state geological surveys, and other research workers; literature published in journals and data included in field guides; geophysical data and reports on previous site investigations for the CRBRP; current site investigations for the CRN Site; and the CEUS SSC model presented in NUREG–2115 (NRC 2012-TN3810). The applicant also collected information by performing the following activities to assess the potential for tectonic and non-tectonic surface deformation within the site area: examination and interpretation of aerial photographs, LiDAR, and remote-sensing imagery; aerial and geologic field reconnaissance, including terrace studies related to the assessment of the ETSZ; subsurface borehole and downhole shear wave velocity investigation; and interpretation of seismic reflection data. Through the review of SSAR Section 2.5.3 (TVA 2017-TN5387), the staff determined whether the applicant complied with applicable regulatory requirements in 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.23(c) (TN282), and 10 CFR 100.23(d) (TN282) and conducted the site characterization investigations at the appropriate levels of detail in accordance with guidance in RG 1.208 (NRC 2007-TN5858).

RG 1.208 recommends that an applicant evaluate any significant new geologic, seismic, and geophysical data to determine whether revisions to existing seismic source models and ground motion attenuation relationships are necessary (NRC 2007-TN5858). In SSAR Section 2.5.3 (TVA 2017-TN5387), the applicant included geologic and seismic information to support the analysis of vibratory ground motion and development of the site-specific GMRS, as discussed in SSAR Section 2.5.2. RG 1.208 also recommends that an applicant evaluate faults encountered at a site to determine whether they are seismogenic or may cause surface deformation (NRC 2007-TN5858). SSAR Section 2.5.3 specifically includes information related to the applicant's assessment of the potential for future tectonic and non-tectonic surface deformation at the site location (TVA 2017-TN5387).

The staff visited the CRN Site on June 17–18, 2013, to observe pre-application subsurface investigation activities (NRC 2013-TN5925). After the applicant submitted the ESPA, the staff conducted a site audit on May 8–9, 2017, to examine selected portions of borehole rock core

samples, observe karst features and geomorphic land forms relative to known mapped thrust faults resulting from the Alleghanian orogeny, and to discuss various aspects of the geologic, seismic, geophysical, and geotechnical investigations conducted to characterize the CRN Site (NRC 2017-TN5908). Within the CRN Site area, the staff visited several sinkholes, Melton Hill water cave, Copper Ridge Cave, and a large exposure of pinnacle and cutter type karst. The staff also visited the CRN Site on January 30–31, 2018 (NRC 2018-TN5941), to examine karst features, shear-fracture zones, thrust faults, and other geomorphic features in the site area and vicinity. During the January 2018 site visit, the staff examined selected rock core samples to view the characteristics of the Copper Creek fault, the shear-fracture zone, karst-related cavities from subsurface locations, and the stratigraphic boundary at the Knox unconformity (NRC 2018-TN5941). This examination of rock core allowed the staff to better understand and characterize the shear-fracture zones and how these zones compare to the deformation associated with the thrust faults at the CRN Site. The staff also viewed the surface projections of the Copper Creek fault, shear-fracture zone, and Chestnut Ridge fault, but noted that there are no observable surface exposures of these structures at the CRN Site. Based on direct examination and evaluation of these geologic features in rock core samples and in the field during the May 2017 site audit (NRC 2017-TN5908) and the January 2018 site visit (NRC 2018-TN5941), the staff concludes that there is no evidence of recent deformation or surface offset at the CRN Site location.

The following FSER sections present the staff's evaluation of information provided by the applicant in SSAR Section 2.5.3 (TVA 2017-TN5387) and the applicant's responses to RAIs for that SSAR section. The information provided by the applicant and discussed in the following sections of this report provide reasonable assurance of the applicant's compliance with 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.23(c) (TN282), and 10 CFR 100.23(d) (TN282), as well as conformance to SRP Section 2.5.3 (NRC 2007/2018-TN5898).

2.5.3.3.1 Geological, Seismological, and Geophysical Investigations

The staff focused its review of SSAR Section 2.5.3.1 (TVA 2017-TN5387) on information presented by the applicant related to published geologic maps, regional geologic studies, seismicity data, previous site investigations, aerial imagery analysis, field reconnaissance, and current and past site subsurface investigations. The staff focused on the description of site vicinity geologic studies, previous site investigations, current site investigations, and field reconnaissance for evaluating the potential for surface tectonic and non-tectonic deformation in the site vicinity, site area, and at the site location.

The staff noted that primary sources of information in the CRN Site ESPA include geologic maps previously published by the Tennessee Geological Survey, previous geologic studies of the site and site vicinity, and geomorphic analysis of high-resolution LiDAR digital elevation data acquired during the CRN Site investigation. The applicant provided several other detailed geologic and hydrogeologic investigations from the ORR and the Melton Hill Dam for staff's review. The applicant also incorporated data from the CRBRP investigations relevant to surface deformation and seismic and non-seismic hazard data from regional studies into the ESPA. The applicant performed a detailed assessment of Quaternary terrace deposits around Douglas Reservoir to evaluate the potential for Quaternary surface deformation near the CRN Site.

The staff considered the applicant's assessment of recent studies in East Tennessee conducted on Quaternary terrace deposits surrounding Douglas Reservoir, approximately 80 km (50 mi) from the CRN Site. These studies evaluated evidence of potential Quaternary surface deformation and paleoliquefaction interpreted to be associated with earthquakes and seismicity

in the ETSZ. The staff also observed some of these potential Quaternary surface deformation features in the field, including potential evidence of faulting and paleoliquefaction. Based on field observations, the staff considered the features unrelated to surficial primary faults associated with earthquakes and seismicity in the ETSZ. The staff noted that the observed surficial features are most likely secondary and not primary, even if they are related to earthquakes and resultant seismicity in the ETSZ. The staff noted that the CEUS SSC (NRC 2012-TN3810) quantifies a reasonable M_{max} for the ETSZ by including the ETSZ in the Paleozoic Extended Zone areal source. The staff considers the existing data in which multiple alternative hypotheses can explain the origin of these features as the result of either seismic or non-seismic mechanisms or processes that could result in the potential Quaternary surface deformation and possible paleoliquefaction features observed around Douglas Reservoir. Therefore, the staff could not definitively confirm or rule out a seismic origin for many of the observed features given the present state of knowledge and available information.

Based on actions performed by the staff associated with the review of SSAR Section 2.5.3.1 (TVA 2017-TN5387), as outlined in the above paragraphs, the staff finds that the applicant provided a thorough and accurate description of geological, seismological, and geophysical investigations in support of the CRN ESPA.

2.5.3.3.2 Geologic Evidence, or Absence of Evidence, for Surface Deformation

In the evaluation of geologic evidence for surface deformation, the staff considered the information provided in SSAR Section 2.5.3.2 (TVA 2017-TN5387) to characterize the geological evidence for surface deformation near the CRN Site. The applicant assessed the bedrock thrust faults and shear-fracture zones and the projected surface exposures of the bedrock thrust faults and shear-fracture zones on the river terraces along the Clinch River; surface and subsurface karst features at the CRN Site and in the site vicinity; slope failure; and potential surface deformation on the Clinch River Arm of the Watts Bar Reservoir and along Douglas Reservoir, Tennessee.

2.5.3.3.2.1 *Bedrock Faults and Shear-Fracture Zones*

In SSAR Sections 2.5.3.2.1 and 2.5.3.2.2, the applicant discussed the bedrock thrust faults and shear-fracture zones that occur at the CRN Site with an emphasis on evidence of surface deformation (TVA 2017-TN5387). The staff considered information the applicant provided regarding the Whiteoak Mountain, Copper Creek, and Chestnut Ridge faults, and the shear-fracture zones. The staff focused its review on information regarding fault traces that the applicant mapped at the ground surface or at the surface of bedrock but overlain by Quaternary sediments or landforms. The staff particularly focused on borehole data related to faults and the shear-fracture zone.

The staff considered information presented in the SSAR (TVA 2017-TN5387) and, based on observations in the field, identified the Copper Creek fault in two rock core samples from the CRBRP program (CC-B1 and CC-B2). The staff examined these rock core samples during the 2017 site audit (NRC 2017-TN5908) and 2018 site visit (NRC 2018-TN5941) and observed that the fault zone is up to 2 m thick in the core. The staff further noted that the core is composed of highly weathered siltstone and shale derived from hanging wall Rome Formation strata with minor footwall Moccasin Formation limestone. Based on high-resolution LiDAR data, undisturbed or undeformed Quaternary river terrace deposits overlie the Copper Creek fault.

The applicant stated that the Chestnut Ridge fault is a minor fault associated with Alleghanian deformation. During its site visits, the staff did not observe the Chestnut Ridge fault exposed at the surface at the CRN Site. The staff viewed a surface projection that the applicant determined from thickened or repeated stratigraphic units in the Knox Group and from surface float of chert from the Kingsport Formation.

The CRBRP program identified shear-fracture zones in plant excavations, in borehole core, and at one outcrop in the northeast corner of the CRN Site. The applicant did not find this surface evidence of the shear-fracture zone during more recent field work at the CRN Site. During the May 2017 site audit (NRC 2017-TN5908), and the subsequent January 2018 site visit (NRC 2018-TN5941), the staff observed two distinct orientations of stylolites in the shear-fracture zones in core but did not see features associated with shear-fracture zones in outcrop. The staff examined shear-fracture zones in core, and noted that the cataclastic character of the fault gouge, produced by mechanical grinding and crushing (i.e., cataclasis) during displacement along the Copper Creek fault, contrasts with material properties of rock units in the shear-fracture zones that show evidence of pressure solution without extensive crushing and grinding. The staff observed that both non-tectonic diagenetic (bedding-parallel) and post-diagenetic (tectonic overprinting – high angles to bedding) stylolites occur to paint a complex picture of developmental history of the shear-fracture zones, but without intense cataclasis, suggest there is no evidence of post-Alleghanian tectonic deformation or pressure solution. The staff also noted that stylolites at high angles to bedding were likely produced during fault displacement due to pressure solution resulting from near-horizontal maximum principal compressive stress. The staff also noted that the overall fabric of rock units in the shear-fracture zones suggests that little bedding-parallel shearing displacement occurred in the zones during post-diagenetic tectonic overprinting.

In eRAI-8991 (RAI No. 5), Question 02.05.01-4(c) (NRC 2017-TN5926), the staff asked the applicant to clarify the logic for equating the shear-fracture zone observed in the CRBRP excavation and mapped by Drakulich (1984-TN5940) with the shear-fracture zone observed in the subsurface. The applicant provided a response to Question 02.05.01-04(c), in Response Letter CNL-17-114 dated October 19, 2017 (TVA 2017-TN5927). The applicant revised SSAR Sections 2.5.3.2.2 and 2.5.3.4.2 (TVA 2017-TN5387) to provide additional description of the shear-fracture zones, including the relationship of stylolites within the shear-fracture zone. The applicant also clarified that the shear-fracture zone is not a fault breccia or fault zone, but represents the accommodation of localized strain during the Alleghanian orogeny. The staff reviewed the applicant’s response, which states that the correlation of the shear-fracture zone is warranted due to the similar descriptions of the surficial and subsurface observations of the shear-fracture zones. The staff concluded the response to Question 02.05.01-4(c) (TVA 2017-TN5927) is acceptable, as discussed in FSER Section 2.5.1.3.2.4.

Based on the review of the information provided by the applicant regarding bedrock thrust faults and shear-fracture zones, and the staff’s examination of those features in core, the staff concludes that there is no evidence of Quaternary deformation due to the thrust faults or shear-fracture zones. Accordingly, the staff concludes that there is no evidence to support potential site hazard from these features at the CRN Site.

2.5.3.3.2.2 _Karst_

SSAR Section 2.5.3.2.3 discusses carbonate dissolution features at the CRN Site and site area from the perspective of evidence of surface deformation (TVA 2017-TN5387). The applicant

stated that while there is some evidence of phreatic dissolution in the CRN Site area, there is no clear evidence of hypogene dissolution documented in the site area.

The staff focused the review of this section on the applicant's use of the available data to characterize karst at the site. The staff noted that although the applicant used seismic refraction surveys to characterize carbonate dissolution features, the initial SSAR submittal (TVA 2016-TN5018) did not include the data used for this characterization. Therefore, the staff asked the applicant in eRAI-8991 (RAI No. 5), Question 02.05.01-05(a) (NRC 2017-TN5926), to discuss the evaluation of the seismic refraction surveys used to identify carbonate dissolution features.

The applicant provided a response to eRAI-8991 (RAI No. 5), Question 02.05.01-05(a) (NRC 2017-TN5926), in Response Letter CNL-17-100 dated September 29, 2017 (TVA 2017-TN5928). In Revision 1 of the SSAR (TVA 2017-TN5387), the applicant incorporated information cited in the response to Question 02.05.01-05(a), to clarify that the primary objective of the seismic refraction surveys was to identify the surface of bedrock beneath the site. The applicant also used the data to identify potential karst features in the subsurface. However, the applicant also noted that seismic refraction data are not the most effective for assessing karst features in the CRN Site area because of the presence and thickness of fill. The applicant provided the seismic refraction tomography profiles and a markup of the SSAR to include additional information related to the use of seismic refraction surveys to characterize karst.

The staff reviewed the tomography profiles and the updated SSAR sections, which the applicant incorporated in Revision 1 of the SSAR (TVA 2017-TN5387). The staff concludes that, although the primary objective of the seismic refraction surveys was to map the bedrock surface at depth, it is appropriate for the applicant to use any available data to identify anomalies that could potentially indicate the presence of large dissolution features in the subsurface. For the CRN Site, the staff reviewed the seismic refraction tomography profiles but did not identify any features clearly attributable to karst. Accordingly, the staff considers eRAI-8991 (RAI No. 5), Question 02.05.01-05(a) (NRC 2017-TN5926), resolved. The staff concludes that, due to the presence of carbonate rocks in the subsurface, direct observation of karst features in core as indicated by missing segments, and the ongoing dissolution processes, karst has the potential to cause surface deformation at the CRN Site.

2.5.3.3.2.3 _Slope Failure_

SSAR Section 2.5.3.2.4 summarizes the applicant's assessment of potential surface deformation due to slope failure at the CRN Site (TVA 2017-TN5387). The applicant concluded that there is one small, shallow landslide at the CRN Site, which displaces about 2 m^3 of weathered Blackford /Five Oaks Formation. The staff considered the information provided in a public meeting held on March 1, 2019 (NRC 2019-TN5929) and a subsequent TVA submittal (TVA 2019-TN6147), which includes the location of the landslide—along a road cut on the east-northeastern section of the site location peninsula—the context for why the slump occurred (over-steepening of the materials at the edge of the site location due to a road cut), and the volume and origin of materials displaced by the feature. The staff reviewed the information provided, including landslide incidence and susceptibility maps, and noted that the landslide susceptibility is moderate and the incidence is low. Due to the distance from the proposed power block location, the small volume of material displaced (about 2 m^3) and the association of the landslide feature with the road cut, the staff concludes that the observed landslide is likely the result of human activities over-steepening the materials (roadcut) combined with ongoing natural erosion processes along the cutbank. Accordingly, the staff concludes that potential surface deformation due to slope failure is unlikely to affect the safety of the CRN Site.

2.5.3.3.2.4 *Evaluation of the Presence or Absence of Surface Deformation Along the Clinch River Arm of the Watts Bar Reservoir*

SSAR Section 2.5.3.2.5 describes a detailed geomorphic investigation of exposed Quaternary fluvial terraces (TVA 2017-TN5387). The applicant considered Quaternary deposits and Clinch River terraces in the assessment of surface deformation along the Clinch River Arm of the Watts Bar Reservoir. The staff reviewed the information in the SSAR and directly observed the Quaternary deposits and Clinch River terraces during the May 2017 site audit (NRC 2017-TN5908) and January 2018 site visit (NRC 2018-TN5941). Based on field reconnaissance and the observation of no notable offset or deformation of Quaternary deposits or terraces, the staff concludes that there is no evidence of Quaternary surface deformation along the Clinch River Arm of the Watts Bar Reservoir.

2.5.3.3.2.5 *Proposed Quaternary Deformation Features Along Douglas Reservoir, Tennessee*

In SSAR Section 2.5.3.2.6, the applicant summarized the potential evidence for paleo-liquefaction or other paleoseismic features near the CRN Site (TVA 2017-TN5387). The applicant also summarized the criteria for including features in the paleoliquefaction database of the CEUS SSC (NRC 2012-TN3810). SSAR Section 2.5.3.2.6.3 summarizes the field reconnaissance and terrace mapping completed for proposed Quaternary deformation features along Douglas Reservoir on the French Broad River east of the CRN Site (TVA 2017-TN5387).

Quaternary deformation or faulting can be expressed by subtle deformation of geomorphic landforms (i.e., river terraces), and can be identified in anomalies in longitudinal stream and terrace profiles. The applicant reviewed the various criteria currently used to interpret paleoliquefaction and other paleoseismic features and completed a morphological correlation and longitudinal profile of the French Broad River and the associated terraces based on extracted digital elevation model elevation points. The applicant concluded that the re-constructed terrace profiles have slopes similar to the baseline longitudinal profile, which implies no deformation of these terraces since the latest Pleistocene. The staff noted that this method of linear-regressed profile slopes would not show small amounts of uplift or localized deformation and that erroneous inclusion of unrelated terrace surfaces under a single profile might affect the slope of the line. Therefore, in eRAI-8991 (RAI No. 5), Question 02.05.01-06, the staff asked the applicant to describe possible tectonic uplift and displacement rates that could be detected with the terrace deformation method described in the SSAR (TVA 2017-TN5387); provide a minimum deformation rate that could be present but undetected by this method; and discuss how uncertainties for projection and grouping errors are evaluated and propagated in the analysis and how these uncertainties affect the minimum deformation rate in the analysis.

In response to eRAI-8991 (RAI No. 5), Question 02.05.01-06, the applicant explained that the longitudinal river terrace profiles can constrain deformation rates (TVA 2017-TN5927). The applicant used the Qpt6 terrace level, the oldest and highest of the Clinch River terraces, because it provides the longest temporal baseline. The applicant noted that movement along the site area faults would increase the gradient, thereby allowing for the calculation of the vertical separation rate along the site area faults. The applicant determined that the steepest terrace gradient was 0.00014 m/m (0.00048 ft/ft), which corresponds to a relative separation of ± 1.9 m (6.1 ft) and a maximum vertical separation rate of less than 0.02 mm/yr (0.0008 in./yr). The applicant stated that a vertical separation rate of 0.02 mm/yr (0.0008 in./yr) or greater would result in an observable steepening of the terrace, while a rate less than 0.02 mm/yr (0.0008 in./yr) would be undetectable. Due to the low gradient of the modern Clinch River

baseline of 0.00014 m/m (0.0002 ft/ft), the applicant noted that the vertical error for a terrace projected 3,048 m (10,000 ft) too far upstream or downstream would result in a vertical error of 0.6 m (2 ft); therefore, the applicant concluded that vertical errors are minimal. However, the applicant also noted that horizontal uncertainties may occur where terraces overlap, but did not quantify these uncertainties. The applicant noted that horizontal uncertainties where terraces overlap are likely due to differential erosion of terrace surfaces and other factors that may result in minor changes to the local gradients. The applicant also updated the SSAR to include additional discussions of terrace mapping, grouping, and ages. The applicant incorporated these changes into Revision 1 of the SSAR (TVA 2017-TN5387).

Based on the review of information provided in response to eRAI-8991 (RAI No. 5), Question 02.05.01-06, and Revision 1 of the SSAR (TVA 2017-TN5387), the staff concludes that the applicant adequately described the deformation rate of possible tectonic uplift or displacements and appropriately identified the errors and uncertainties associated with the deformation rate. The staff makes this conclusion because the applicant determined the rate based on measured changes in the terrace gradient and described the error and uncertainty associated with these measurements. The staff further agrees with the applicant's conclusion that horizontal errors are more likely due to the spatial orientation of the terraces used to estimate the vertical separation rate.

Based on actions performed by the staff associated with the review of SSAR Section 2.5.3.2 (TVA 2017-TN5387), as outlined in the previous sections, the staff finds that the applicant provided a thorough and accurate description of geologic evidence, or absence of evidence, for surface deformation, in support of the CRN Site ESPA.

2.5.3.3.3 Correlation of Earthquakes with Capable Tectonic Sources

SSAR Section 2.5.3.3 addresses the possible correlation of earthquakes with capable tectonic sources (TVA 2017-TN5387). The applicant explained that the CRN Site is located within the ETSZ. The applicant correlated the earthquakes occurring in the ETSZ with potential aeromagnetic anomalies, like the New York-Alabama lineament, but the applicant did not correlate any earthquakes with known faults exposed at the ground surface.

The staff reviewed the information provided by the applicant, including regional geologic maps, LiDAR data, longitudinal terrace profiles, and potential tectonic features observed in the field. The staff also reviewed the work of Hatcher et al. (2013-TN6118) and the applicant's evaluation for potential paleoseismic features in the ETSZ in FSER Section 2.5.3.3.2, "Geologic Evidence for Surface Deformation." The staff considered the discussion of the ETSZ in the CEUS SSC (NRC 2012-TN3810) and SSAR Section 2.5.2.2.5 ("Post-CEUS SSC Studies") (TVA 2017-TN5387). The staff notes that the ETSZ earthquakes are located below the Alleghanian décollement, and Paleozoic thrust faults mapped in the site vicinity do not penetrate through the regional décollement. Because the ETSZ earthquakes are located below the Paleozoic thrust faults and are based on the discussion and characterization of the seismicity of the ETSZ in SSAR Section 2.5.2.2.5 (TVA 2017-TN5387), the staff agrees with the applicant's conclusion that there is no evidence linking seismicity in the ETSZ to faults at the ground surface.

Based on actions performed by the staff associated with the review of SSAR Section 2.5.3.3 (TVA 2017-TN5387), as outlined in the above section, the staff finds that the applicant provided a thorough and accurate description of the correlation of earthquakes with capable tectonic sources in support of the CRN Site ESPA.

2.5.3.3.4 Ages of Most Recent Deformation

In SSAR Section 2.5.3.4, the applicant discussed the timing of deformation due to the bedrock thrust faults, the formation of the shear-fracture zone, and karst collapse (TVA 2017-TN5387). SSAR Sections 2.5.1.1.2, 2.5.1.1.4, 2.5.1.2.4, and 2.5.3.2.1 summarize multiple lines of evidence suggesting bedrock thrust faults in the Valley and Ridge province were active during the Late Paleozoic Alleghanian orogeny (TVA 2017-TN5387). The applicant also cited the geochronologic analyses of fault gouge (ages of 280 to 290 and 279.5 ± 11.3 Ma) from the Copper Creek fault and the lack of evidence for later reactivation, and concluded that the bedrock thrust faults were not active more recently than the Late Paleozoic. In addition, the applicant observed that several undeformed Mesozoic diabase dikes cross-cut Valley and Ridge structures in the central Appalachians in central Virginia and Pennsylvania, suggesting that thrusting and folding on these structures occurred prior to approximately 200 Ma.

The staff examined the figures the applicant developed from high-resolution LiDAR and noted that there is no apparent deformation of Pleistocene and Holocene river terraces that overlie the projected surface trace of the shear-fracture zone, indicating that deformation within the shear-fracture zone has not been active since at least the deposition of the terraces. The staff also viewed the shear-fracture zone in rock core during the 2017 and 2018 site visits. The staff observed that stylolites show two distinct orientations, one subparallel to bedding and the other at higher angles. In FSER Section 2.5.3.3.2.1, the staff interpreted the subparallel stylolites as being non-tectonic diagenetic pressure solution features related to overburden pressures, while the higher angle stylolites are likely the result of tectonic overprinting associated with Late Paleozoic thrust faulting. The staff concluded that the field relationships support this interpretation of pressure solution resulting from both non-tectonic diagenetic effects and tectonic effects during the Alleghanian thrust faulting.

Based on the available data, the staff concludes that the most recent deformation of Valley and Ridge thrust faults within the site region occurred during the Late Paleozoic era. Accordingly, based on all available data derived from field examination of the shear-fracture zones, the staff agrees with the applicant that the shear-fracture zones have a history defined by both diagenetic non-tectonic pressure solution features and post-diagenetic tectonic overprint pressure solution features and are not characterized by the extensive cataclasis exhibited by the thrust faults. The staff further concludes that the formation of the shear-fracture zones likely coincided with deformation associated with the Alleghanian orogeny.

The staff based this conclusion on observations of stylolites in rock core that show two orientations interpreted as non-tectonic subparallel stylolites with a tectonic overprint of high-angle stylolites. The staff's field observations also support the applicant's conclusion that the abundance of pressure solution features and paucity of evidence for mechanical grain-size reduction (i.e., cataclasis) in the shear-fracture zones suggest the zones accommodated strain mainly by pressure solution resulting from both non-tectonic diagenetic and later tectonic effects, but with limited cataclastic deformation of the shear-fracture zones during the tectonic event (i.e., Alleghanian thrust faulting).

Regarding the timing or age of limestone dissolution and karst collapse, SSAR Section 2.5.3.4.3 states that carbonate dissolution and the development of karst features is ongoing (TVA 2017-TN5387). During the May 2017 site audit (NRC 2017-TN5908) and January 2018 site visit (NRC 2018-TN5941), the staff observed karst features, such as sinkholes, caves, and pinnacle and cutter exposures, at the CRN Site location and in the CRN Site area. Based on field observations, the staff agrees with the applicant that it is likely that limestone dissolution was

active through the Holocene and is still active. Therefore, the staff concludes that the development of karst features in the CRN Site area remains an ongoing process that has the potential for future surface deformation. The staff's review and evaluation of the potential for surface deformation at the site is in FSER Section 2.5.3.3.8. Furthermore, because carbonate dissolution and the development of karst are ongoing processes in the CRN Site area, in FSER Section 2.5.3.4 the staff proposes a geologic mapping permit condition to assess this potential hazard during excavation and construction activities.

Based on actions performed by staff associated with the review of SSAR Section 2.5.3.4 (TVA 2017-TN5387), as outlined in the above section, the staff finds that the applicant provided a thorough and accurate description of the ages of the most recent deformation in support of the CRN Site ESPA.

2.5.3.3.5 Relationship of Geologic Features in the Site Area to Regional Geologic Features

In SSAR Section 2.5.3.5, the applicant reported that Alleghanian Copper Creek and Whiteoak Mountain bedrock faults that occur within the CRN Site area are part of the regional Valley and Ridge foreland fold-thrust belt system (TVA 2017-TN5387). The applicant mapped the northeast-striking, southeast-dipping thrust faults along orogenic strike from northeastern Alabama to eastern Pennsylvania in the Valley and Ridge province distinct from the adjacent terrane/province subdivisions.

The staff reviewed the information provided by the applicant, including regional maps and aerial photography and agrees with the applicant that the strike and dip of the Copper Creek and Whiteoak Mountain bedrock faults are consistent with the thrust faults of the Valley and Ridge province. The staff concludes that the applicant adequately described the relationship of the Whiteoak Mountain and the Copper Creek faults with respect to the regional geologic features of the Valley and Ridge thrust faults formed during the Alleghanian orogeny.

The staff noted that, in addition to the Whiteoak Mountain and Copper Creek faults, the Chestnut Ridge fault and shear-fracture zones are also within the CRN Site area. The staff noted that the applicant did not discuss these faults with respect to their relationship to regional tectonic structures. The need to address the interrelationship between these structures and the tectonic setting of the CRN Site are included in eRAI-8991 (RAI No. 5), Question 02.05.01-04(d). The applicant provided a response to eRAI-8991 (RAI No. 5), Question 02.05.01-04(d) in Response Letter CNL-17-114 dated October 19, 2017 (TVA 2017-TN5927), which included revisions to SSAR Sections 2.5.1.2.4.4, 2.5.3.2.2, and 2.5.3.4.2 (TVA 2017-TN5387). The applicant discussed the Valley and Ridge thrust faults and shear-fracture zones in terms of the three primary deformation mechanisms: brittle cataclasis, diffusive mass transfer, and intracrystalline plasticity. The applicant concluded that the thrust faults and shear-fracture zones accommodated strain during the Alleghanian orogeny with varying contributions from the primary deformation mechanisms. The staff determined that the applicant adequately discussed the relationship of the Chestnut Ridge fault and shear-fracture zones. The staff makes this conclusion based on the applicant's discussion of the relationship between the deformation mechanisms and how the Chestnut Ridge fault and shear-fracture zone accommodated strain during the Alleghanian orogeny. FSER Section 2.5.1.3.2.4 also documents the staff's evaluation of the information provided in response to this RAI. The staff concluded that the response is sufficient and the RAI is resolved.

Based on actions performed by staff associated with the review of SSAR Section 2.5.3.5 (TVA 2017-TN5387), as outlined in the above section, the staff finds that the applicant provided a

thorough and accurate description of the relationship of tectonic structures in the site area to regional tectonic sources in support of the CRN Site ESPA.

2.5.3.3.6 Characterization of Capable Tectonic Sources

In SSAR Section 2.5.3.6, the applicant stated that there are no significant neotectonic features within the 200 mi CRN Site region but noted the elevated seismicity in the site region that is associated with the ETSZ (TVA 2017-TN5387). Vaughn et al. (2010-TN6125) provided the basis for their conclusions regarding Quaternary tectonic structures and paleoliquefaction features. Subsequent field work and associated publications, theses, and abstracts provide further support for the original hypothesis (e.g., Hatcher et al. 2013-TN6118; Warrell et al. 2012-TN6115). The applicant provided additional characterization and analysis to demonstrate that the ETSZ does not represent a potentially significant seismic hazard for the site. The work completed and in progress in the ETSZ would clarify whether there is possible secondary faulting at the surface associated with true paleoliquefaction features that are "off fault", which could potentially refine the current understanding of earthquake magnitude, frequency, and distribution. The applicant also provided alternative non-tectonic interpretations based on field observations and concluded that pedogenic processes can also explain the origin of these potential paleoliquefaction features.

The staff considered the published evidence and interpretations, as well as field observations and new research presented at the annual meeting of the Southeastern Section of the Geological Society of America in April 2018 (GSA 2018-TN6153). The staff reviewed the results of the field work, including trenches that the applicant re-excavated in the ETSZ; alternate hypotheses regarding Quaternary tectonic deformation in the ETSZ; and documentation provided by the SSHAC Level 2 study and sensitivity analysis, as described in SSAR Section 2.5.2.2.2 ("Post-CEUS SSC Studies" [TVA 2017-TN5387]) and discussed in FSER Sections 2.5.2.1.6, 2.5.2.3.2.3, and 2.5.2.3.5.2. In FSER Section 2.5.2.3.2.3, the staff reviewed the sensitivity studies and determined that no modifications are needed to the CEUS SSC model (NRC 2012-TN3810) to account for seismicity in the ETSZ. The staff also observed potential tectonic features in the field and notes that although they are interpreted to be paleoseismic in origin, an alternate interpretation of these features could suggest a non-seismic origin. The staff concluded that although the interpretations and hypotheses regarding Quaternary surface deformation continue to evolve, there is no new information that would alter the current characterization of geologic hazards and surface deformation in the CRN Site area related to the ETSZ.

The staff reviewed the information provided in the SSAR (TVA 2017-TN5387) including the alternate interpretation that paleoseismic features observed in the CRN Site area could be the result of non-tectonic processes. Based on its review of currently available information, the staff identified no evidence that the ETSZ earthquakes are structurally linked to the Alleghanian thrust faults. Therefore, the staff concludes there is no evidence that recent seismicity in the ETSZ is due to the reactivation of Paleozoic thrust faults. FSER Section 2.5.2 discusses the sensitivity calculations, including the possibility that the paleoseismic features are tectonic in origin. Based on available information, the staff concludes that there is no known correlation of a tectonic feature with earthquakes associated with the ETSZ.

Based on actions performed by the staff associated with the review of SSAR Section 2.5.3.6 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of the characterization of capable tectonic sources in support of the CRN Site ESPA.

2.5.3.3.7 Designation of Zones of Quaternary Deformation in the Site Region

In SSAR Section 2.5.3.7, the applicant stated that there are no zones of Quaternary deformation in the site vicinity or site area (TVA 2017-TN5387). However the applicant identified three possible fault systems showing potential evidence of Quaternary deformation within the site region—the Kentucky River fault system, Rough Creek-Shawneetown fault system, and the unnamed Quaternary faults in western North Carolina. The applicant also noted that alternate, non-seismic interpretations could explain the potential Quaternary deformation observed within the Kentucky River fault system (Crone and Wheeler 2000-TN6117). The staff reviewed the information provided by the applicant in the SSAR (TVA 2017-TN5387) and noted that the three possible zones of Quaternary deformation are each over 177 km (110 mi) from the CRN Site. The staff further noted that Crone and Wheeler (Crone and Wheeler 2000-TN6117) concluded that there is insufficient research to definitively conclude whether the observed Quaternary deformation is seismic in origin.

Based on actions performed by staff associated with the review of SSAR Section 2.5.3.7 (TVA 2017-TN5387), as outlined in the above paragraph, the staff finds that the applicant provided a thorough and accurate description of the designation of zones of Quaternary deformation in the site region in support of the CRN Site ESPA.

2.5.3.3.8 Potential for Tectonic and Non-tectonic Deformation at the Site

SSAR Section 2.5.3.8.1 states that, although the CRN Site lies within the boundary of the ETSZ, earthquakes within the ETSZ occur below the Paleozoic foreland fold-thrust belt (TVA 2017-TN5387). The applicant noted that there are no Quaternary tectonic faults exposed within the CRN Site area or site vicinity. Therefore, the applicant stated that the potential for tectonic surface deformation at the CRN Site is negligible. The applicant also stated that the potential for non-tectonic surface deformation as a result of karst features is possible and represents the most significant geologic hazard to the CRN Site.

SSAR Section 2.5.3.8.2.1 (TVA 2017-TN5387) states that the planned site construction will bear on carbonate rocks of the middle Chickamauga to upper Knox Group bedrock units in which both the staff and applicant observed cavities and karst conditions in boreholes. The staff noted that although the applicant would remove overburden soils and cavities associated with limestone dissolution near the top of rock during the excavation process, thereby mitigating the hazard of a cover-collapse or subsidence sinkhole, the remaining cavities and karst conditions might compromise the structural stability of the foundation. However, SSAR Section 2.5.4.13 states that the anticipated foundation rocks are the Fleanor Member of the Lincolnshire Formation and the Benbolt and Rockdell Formations, all of which the applicant characterized as intact or massive rock in SSAR Section 2.5.1.2.6.2 (TVA 2017-TN5387). The staff also noted that the applicant would perform detailed geologic mapping of the excavation to confirm the staff's conclusions with respect to the potential for tectonic and non-tectonic deformation at the CRN Site.

For tectonic surface deformation, the staff observed that there is no known or defined Quaternary age surface faulting in the CRN Site vicinity. The staff considered the impact of the ETSZ seismicity and evaluated that zone using sensitivity studies in FSER Section 2.5.2. The staff also noted that earthquakes in the ETSZ generally occur beneath the décollement in crystalline basement rocks. Furthermore, the staff noted that thrust faults in the site area are overlain by undeformed Quaternary river terraces in multiple locations. Accordingly, the staff

concludes that the potential for tectonic surface deformation in the CRN Site vicinity is negligible because all existing data strongly support that interpretation.

For non-tectonic surface deformation related to karst, the staff noted that although the potential for non-tectonic surface deformation as a result of karst features represents the most significant geologic hazard to the CRN Site, the CRN Site plant structures would likely be placed in deep excavations that would decrease the likelihood of a cover-collapse or subsidence sinkholes. The staff also noted that the presence of cavities below the base of the foundation might compromise the structural stability of the foundation. FSER Section 2.5.4.1.13 describes the staff's evaluation of the foundation assessment model to analyze the impact of subsurface cavities on foundation stability, which refers to COL Action Item 2.5-2 in FSER Section 2.5.4.3.1.4. Accordingly, the staff concludes that the final evaluation of potential surface deformation associated with karst at the CRN Site should be based on detailed geologic mapping of the excavations for safety-related engineered structures and geophysical surveys at the foundation level to determine the presence or absence of voids beneath the sub-foundation elevation. Therefore, in FSER Section 2.5.3.4, the staff proposes a permit condition requiring detailed geologic mapping of the excavations.

Based on actions performed by the staff associated with the review of SSAR Section 2.5.3.8 (TVA 2017-TN5387), as outlined in the above section, the staff finds that the applicant provided a thorough and accurate description of the potential for tectonic and non-tectonic deformation at the site in support of the CRN Site ESPA.

2.5.3.4 *Geologic Mapping Permit Condition*

For the evaluation of the suitability of a proposed site, requirements in 10 CFR 100.23 (TN282), specifically 100.23(c), provide that geologic data on tectonic and non-tectonic surface deformation must be obtained through review of pertinent literature and field investigations. The regulation in 10 CFR 100.23(d)(2) (TN282) explicitly states that geologic and seismic siting factors considered for design must include determination of the potential for tectonic and non-tectonic surface deformation at the proposed site. RG 1.208 specifically states that faults exposed in site excavations should be mapped and assessed with regard to rupture potential, while walls and floors of the excavations are exposed, the assessment should consider non-tectonic surface deformation (NRC 2007-TN5858). In SSAR Section 2.5.1.2.6.10, the applicant acknowledged the need to perform geologic mapping for documenting the presence or absence of karst features, faults, or shear-fracture zones in plant foundation materials (TVA 2017-TN5387). In supplemental information letter CNL-16-184, submitted on December 15, 2016 (TVA 2016-TN5909), as incorporated in SSAR Section 2.5.1.2.6.10, Revision 1, the applicant described plans to perform detailed geologic mapping of excavation walls during excavation and construction; document characteristics of dissolution features in the near-surface carbonate rock units; and verify a decrease in cavity size and abundance with depth (TVA 2017-TN5387). The applicant also stated that it would design and conduct surface geophysical surveys, develop a grouting program, and perform confirmatory drilling, among other activities, during the excavation and construction phase at the CRN Site. These confirmatory activities, and the development of a grouting program and associated Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) are included as part of COL Action 2.5-3, as discussed in FSER Section 2.5.4.3.1.4. Therefore, the staff considers it the responsibility of the COL or CP applicant, who would reference the ESP for the CRN Site, if granted, to perform geologic mapping of future excavations for safety-related engineered structures at the CRN Site. This activity is Permit Condition 2.5-1 (Permit Condition 3), for which the required actions are as follows:

- Permit Condition 2.5-1 (Permit Condition 3): 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.

2.5.3.5 *Conclusions*

As documented in FSER Sections 2.5.3.1 through 2.5.3.4 above, the staff reviewed and evaluated information related to surface tectonic and non-tectonic deformation submitted by the applicant in SSAR Section 2.5.3 of the CRN Site ESPA (TVA 2017-TN5387). The review and evaluation allowed the staff to confirm that this information provides an adequate basis for concluding that there is negligible potential for tectonic surface deformation in the site vicinity, area, or location that could adversely affect the suitability of the CRN Site. Based on the review and evaluation, the staff recognize karst as a potential hazard and cause of non-tectonic surface deformation at the CRN Site. Completion of geologic mapping and geophysical testing and boring programs as outlined in Permit Condition 2.5-1 (Permit Condition 3) and COL Action Item 2.5.3 would allow the staff to verify, and the applicant to confirm, determinations made during the ESPA review related to surface deformation and, if necessary, mitigate this hazard through appropriate means.

The staff also concludes there is no potential for the effects of anthropogenic activities, such as surface or subsurface mining or road construction, to cause surface deformation that would compromise the safety of the CRN Site.

Finally, based on the results of the review and evaluation of SSAR Section 2.5.3 (TVA 2017-TN5387), the staff concludes that the applicant provided a thorough and accurate description of the potential for tectonic and non-tectonic surface deformation in the site vicinity, site area, and at the site location in full compliance with applicable regulatory requirements in 10 CFR 52.17(a)(1)(vi) (TN251), 10 CFR 100.23(c) (TN282), and 10 CFR 100.23(d) (TN282) and in accordance with guidance in RG 1.208 (NRC 2007-TN5858) and SRP Section 2.5.3 (NRC 2007/2018-TN5898).

2.5.4 Stability of Subsurface Materials and Foundations

Revision 1 of the TVA ESP SSAR (TVA 2017-TN5387), in Section 2.5.4, "Stability of Subsurface Materials and Foundations," presents an evaluation of the stability of subsurface materials and foundations that relate to the CRN Site. The properties and stability of the soil and rock underlying the site are important to the safe design and siting of the plant. The information provided by the applicant in SSAR Section 2.5.4 addresses the following:

- geologic features in the site vicinity;
- static and dynamic engineering properties of soil and rock strata underlying the site;
- relationship of the foundations for safety-related facilities and the engineering properties of underlying materials;
- results of geophysical surveys, including in-hole and cross-hole explorations;
- safety-related excavation and backfill plans and engineered earthwork analysis and criteria;

- groundwater conditions and piezometric pressure in all critical strata as they affect the loading and stability of foundation materials;
- responses of site soils or rocks to dynamic loading;
- liquefaction potential and consequences of liquefaction of all subsurface soils, including the settlement of foundations;
- earthquake design bases;
- evaluation of static and dynamic stability of safety-related structure foundations including bearing capacity, heave, settlement, and lateral earth;
- criteria, references, and design methods used in static and seismic analyses of foundation materials;
- techniques and specifications to improve subsurface conditions, which are to be used at the CRN Site to provide suitable foundation conditions; and
- any additional information provided by the applicant in accordance with 10 CFR Part 52 (TN251), "Licenses, Certifications; and Approvals for Nuclear Power Plants."

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 ESPA. However, additional site investigation activities need to be performed by a future COL or CP applicant after selection of a specific reactor technology and location. The staff has identified 16 COL Action Items to document these additional activities. The COL Action Items would be resolved in a future COL or CP application.

2.5.4.1 *Summary of Application*

In SSAR Section 2.5.4 (TVA 2017-TN5387), the applicant presented information about the stability of subsurface materials and foundations at the CRN Site based on the results of site geological, geophysical, and geotechnical investigations. The applicant has not selected a reactor technology to be constructed at the CRN Site. The applicant identified a set of bounding parameters using available information from four light-water-cooled, SMR designs to develop the PPE. SSAR Table 2.0-1 (TVA 2017-TN5387) provides a summary of the site characteristics at the CRN Site, and Table 2.0-2 provides site-related design parameters from the PPE.

The applicant originally planned the CRN Site to support a CP application and identified two locations for the units considered at that time. Those locations are identified in the CRN Site ESPA as Location A and Location B. The applicant performed the subsurface investigations over a substantial portion of the CRN Site but predominantly within the footprint of the power block area. Figure 2.5.4-1, shows a cross section through the power block area that illustrates the approximate ground surface and site stratigraphy including Locations A and B.

The applicant stated that additional site-specific exploration and testing required to support the COLA would be performed when a reactor technology is selected.

2.5.4.1.1 Geologic Features

SSAR Section 2.5.4.1 refers to SSAR Section 2.5.1 for a detailed description of the geologic features at the CRN Site (TVA 2017-TN5387). The applicant described the existing site elevations in the power block area as ranging from approximately 260.6 to 237.7 m (855 to 780 ft) with an average elevation of 246.9 m (810 ft) NAVD88. The applicant stated that the

finished plant grade elevation would be at 250.2 m (821 ft) and the foundation embedment is not expected to exceed elevation 208.2 m (683 ft) NAVD88. All references to elevations specified in this report are to NAVD88, with the exception of elevations pertaining to the CRBRP, which are with respect to the National Geodetic Vertical Datum of 1929 (NGVD29).

2.5.4.1.1.1 *Stratigraphy*

SSAR Section 2.5.4.1.1 refers to SSAR Sections 2.5.1.2.3.2 and 2.5.1.1.3.1 for a complete description of the stratigraphy of the site (TVA 2017-TN5387). The applicant stated that the stratigraphic units at the site strike northeast and dip relatively steeply to the southeast. Figure 2.5.4-1 (SSAR Figure 2.5.4-2) shows a cross section of the stratigraphic units at the site underneath the power block area. The applicant identified the stratigraphic units underlying the power block area as predominantly the Newala Formation belonging to the Knox Group, the Blackford Formation, the Lincolnshire Formation (Eidson and Fleanor Members), and Rockdell and Benbolt Formations belonging to the Chickamauga Group. The applicant stated that the contact between the Knox and the Chickamauga groups is an unconformity.

The applicant used acoustic televiewer (ATV) logging and outcrop mapping to estimate the average strike and dip of the bedding planes for the units. The applicant stated that the average strike and dip of the bedding planes is N63°E and 33°SE and that it does not change considerably between stratigraphic units. The applicant used a dip angle of 33 degrees to project the contacts between the stratigraphic units at depth in the power block area, and to estimate the vertical thickness of each stratigraphic unit. The applicant noted that, due to the dipping beds found at the site, various units may be exposed at the foundation elevation (El. 208.2 m [683 ft]) when the future excavation of geologic material is completed.

2.5.4.1.1.2 *Previous Loading History*

In SSAR Section 2.5.4.1.2, the applicant indicated that the CRN Site area has undergone extensive periods of excavation, backfilling, grading and redressing associated with the CRBRP (TVA 2017-TN5387). The applicant noted that toward the center of the CRN Site, two hills were removed using blasting techniques and approximately 30.5 m (100 ft) below the ground surface was excavated for the reactor buildings of the now abandoned CRBRP. The applicant stated that up to about 6.1 m (20 ft) of fill was placed in the southern portion of the power block area and up to about 21.3 m (70 ft) of material was removed from the central and northern portions.

2.5.4.1.1.3 *Discontinuities, Shear-Fracture Zones, Weathered/Fracture Zones*

SSAR Section 2.5.4.1.3.1 summarizes discontinuities encountered at the CRN Site and refers to SSAR Section 2.5.1.2.4 for more details about bedding planes and joints (TVA 2017-TN5387). The applicant identified two primary joint sets—Joint Set 1 and Joint Set 2. Joint Set 1 has an average strike and dip of N60°E and 59°NW, and Joint Set 2 has an average strike and dip of N60°E and 38°SE. The applicant stated that these joint sets strike parallel to the strike of the bedding planes, which have an average strike and dip of N63°E and 33°SE. Additionally, the applicant identified three near-vertical secondary joint sets, one striking parallel to the strike of the bedding and the other two striking parallel to the bedding. The applicant stated that the highest frequency of joints occurs within the upper 30.5 m (100 ft) of bedrock. In addition, the applicant indicated that the two primary joints sets are prevalent in all stratigraphic units, whereas the secondary joints are found predominantly in the Newala Formation. The applicant described the condition of the joints as undulating to planar, rough to smooth to slickensided, very tight to open with tightly healed to slightly altered joint walls, and partially or wholly filled with calcite.

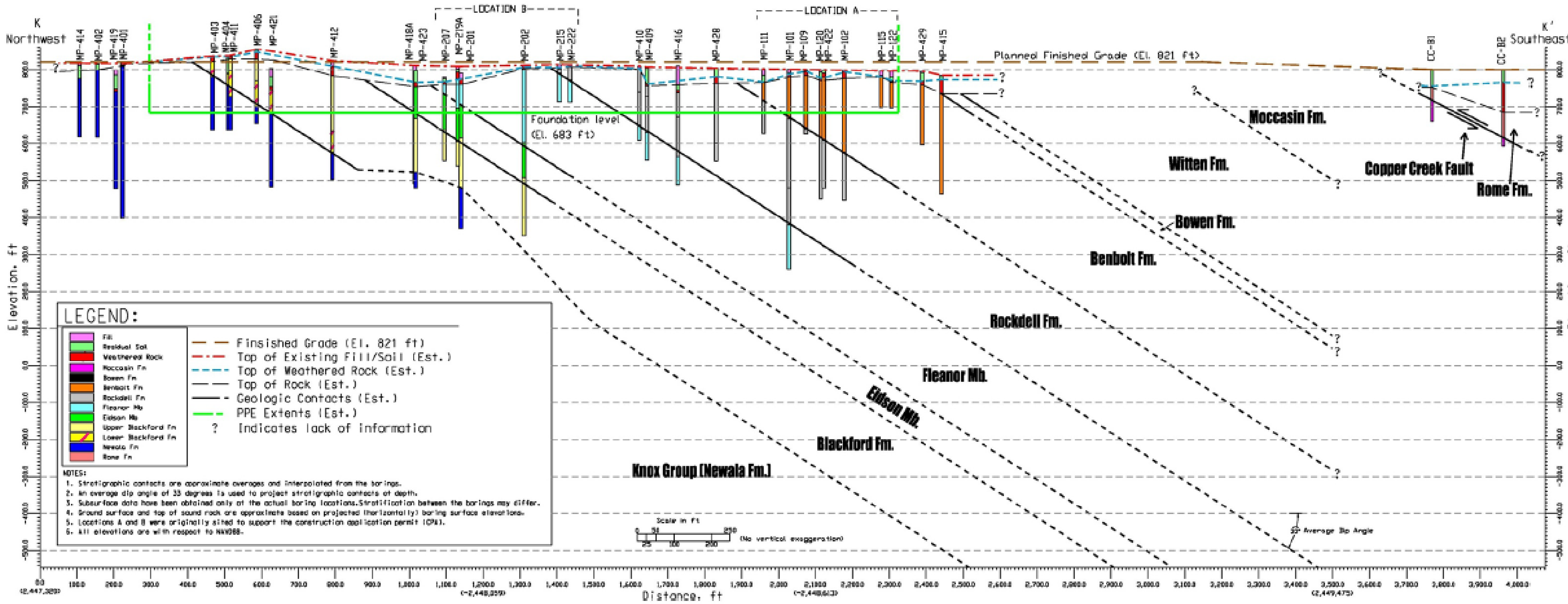


Figure 2.5.4-1 Geotechnical Cross Section of the Stratigraphy of the Power Block Area (reproduced from SSAR Figure 2.5.4-2 [TVA 2017-TN5387])

SSAR Section 2.5.4.1.3.2 summarizes shear-fracture zones encountered at the CRN Site and refers to SSAR Sections 2.5.1.2.4 and 2.5.1.2.6.4 for more details (TVA 2017-TN5387). The applicant stated that shear-fracture zones were encountered in the Rockdell and Benbolt Formations, and the Eidson Member between elevations of about 228.6 and 137.2 m (750 and 450 ft). The applicant described them as typically zones of multiple, closely spaced, tightly healed, calcite-filled fractures with apparent thicknesses ranging from 0.3 to 6.7 m (1 to 22 ft) with an average of 1.2 m (4 ft). The applicant indicated that these shear fractures zones are likely to be found at or below foundation level and that it incorporated them in the GSI rating for each stratigraphic unit for rock mass characterization. The applicant stated that during excavation for the power block area, detailed geologic mapping would provide further characterization of any shear-fracture zones encountered and that additional evaluation of shear-fracture zones would be performed for the COLA, once the reactor technology is selected.

SSAR Section 2.5.4.1.3.3 summarizes weathered and fracture zones encountered at the CRN Site and refers to SSAR Section 2.5.1.2.6.3 for more details (TVA 2017-TN5387). The applicant stated that fracture zones typically occur along bedding planes or fractures and likely represent early dissolution of the limestone. In addition, the applicant characterized them as zones of poor to fair quality rock with slightly to highly weathered fractures or bedding planes. The applicant stated that these zones are mostly located within the first 15.2 m (50 ft) of the current ground surface (between elevation 243.8 and 228.6 m [800 and 750 ft]) with thicknesses ranging from 0.3 to 3.7 m (1 to 12 ft) with an average of about 0.9 m (3 ft). The applicant stated that further evaluation of weathered and fracture zones would be performed for the COLA, once the reactor technology is selected.

2.5.4.1.1.4 _Karst Features_

SSAR Section 2.5.4.1.4 summarizes karst features encountered at the CRN Site and refers to SSAR Sections 2.5.1.2.5 for more details (TVA 2017-TN5387). The applicant stated that cavities are present in all of the stratigraphic units at the site but are more predominant in the Rockdell Formation and Eidson Member. The applicant stated that these cavities range from 0.3 to about 5.2 m (1 to about 17 ft) in height, include open and clay-filled voids and are predominantly found within the first 30.5 m (100 ft) of the current ground surface. The applicant noted that approximately four voids were encountered within 1.5 to 6.1 m (5 to 20 ft) below the deepest foundation embedment elevation of 208.2 m (683 ft) with a range of heights from 0.2 to 1.3 m (0.7 to 4.3 ft). The applicant referred to SSAR Section 2.5.1.2.6.10 for a discussion of a mitigation plan to address possible cavities encountered at and below the foundation levels for safety-related structures during excavation (TVA 2017-TN5387). The applicant indicated that details of this plan would be developed further to support a future COLA.

2.5.4.1.1.5 _Unrelieved Stresses in Bedrock_

SSAR Section 2.5.4.1.5 summarizes unrelieved stresses in bedrock at the CRN Site and refers to SSAR Section 2.5.1.2.6 for more details (TVA 2017-TN5387). The applicant stated that high residual stresses are not expected or considered to be a hazard during construction or for the bearing capacity of the foundation rock mass. The applicant noted that the use of blasting techniques is expected at the site in order to remove overburden, thus creating a disturbed zone of rock adjacent to the foundation. The applicant stated that this disturbance is accounted for in the rock mass strength properties.

2.5.4.1.2 Properties of Subsurface Materials

In SSAR Section 2.5.4.2, the applicant described the static and dynamic engineering properties of the CRN Site subsurface materials, including field investigations, laboratory tests, and engineering properties determined from subsurface exploration activities (TVA 2017-TN5387).

2.5.4.1.2.1 *Description of Subsurface Materials*

SSAR Section 2.5.4.2.1.1 briefly describes the existing fill and residual soils at the CRN Site (TVA 2017-TN5387). The applicant stated that both the existing fill and residual soils are classified as high plasticity (CH) clays according to the Unified Soil Classification System (USCS) and having median Standard Penetration Test (SPT) N_{60} values of 14 and 19 blows per foot (bpf), respectively. The thickest deposits for both soils that the applicant encountered is 15.5 m (51 ft).

SSAR Section 2.5.4.2.1.2 briefly describes the new backfill to be placed at the CRN Site and refers to SSAR Section 2.5.4.5 for more details (TVA 2017-TN5387). The applicant stated that both lean concrete and granular backfill would surround the safety-related structures at the CRN Site. The applicant indicated that lean concrete would extend from the foundation level to the top of the rock. Granular backfill would be used from the top of the rock to the finished grade.

SSAR Section 2.5.4.2.1.3 describes the weathered rock found at the CRN Site (TVA 2017-TN5387). The applicant initially defined weathered rock as material having a SPT blow count of 50 bpf, which results in less than 0.2 m (6 in.) of penetration. The applicant indicated that weathered rock is encountered in most of the borings drilled at the site. The applicant used different methods to define the thickness of the weathered rock and subsequent depth to bedrock throughout the site, including Rock Quality Designation (RQD) values, shear wave velocity (V_S) values, drill rates, and rock core photographs. The applicant stated that the maximum thickness of the weathered rock at the site is approximately 11.9 m (39 ft) and that the weathered rock would be excavated from the power block area prior to construction of foundations.

In SSAR Sections 2.5.4.2.1.4 through 2.5.4.2.1.10, the applicant described the stratigraphic units encountered at the site (TVA 2017-TN5387). Table 2.5.4-1 below, summarizes some of the properties of the rock stratigraphic units at the CRN Site.

2.5.4.1.2.2 *Field Investigations*

SSAR Section 2.5.4.2.2 refers to SSAR Sections 2.5.4.3 and 2.5.4.4 for a description of the field investigation program and geophysical surveys performed for the CRBRP and the CRN Site (TVA 2017-TN5387). The applicant stated that the field investigation at the CRN Site was performed in accordance with guidance in RG 1.132, “Site Investigations for Foundations of Nuclear Power Plants, Revision 2” (NRC 2003-TN5902).

Table 2.5.4-1 Summary of Properties of CRN Rock Stratigraphy

Rock Strata	Description	Vertical Thickness m (ft)	Average RQD (%)
Bowen Formation	Reddish brown to olive brown, laminated to very thinly bedded calcareous siltstone.	9.1 (30)	26
Benbolt Formation	Gray limestone (micrite/wackestone), strong, very thinly to thinly bedded, locally moderately bedded, and nodular limestone interbedded with little to some laminated to thinly bedded calcareous siltstone.	100.6 (330)	88
Rockdell Formation	Gray and brownish-gray, strong, laminated to moderately bedded limestone (micrite/wackestone/grainstone), interbedded with few to little, laminated to very thinly bedded calcareous siltstone.	87.5 (287)	88
Fleanor Member (Lincolnshire Formation)	Red, medium strong, laminated to medium bedded, calcareous siltstone with few to little gray micritic limestone layers.	78.3 (257)	89
Eidson Member (Lincolnshire Formation)	Gray, medium strong and strong, laminated to thinly bedded, fresh, argillaceous micritic limestone.	31.1 (102)	80
Blackford Formation	The Lower Blackford is generally described as a gray, locally mottled, strong, laminated to thickly bedded, micritic limestone. The Upper Blackford is generally described as a gray, calcareous siltstone, laminated to moderately bedded, interbedded with little to some limestone with few to little chert beds, lenses and nodules.	77.4 (254)	81
Newala Formation	Fresh, fine to medium grained, gray, locally mottled red, strong to very strong, moderately to thickly bedded crystalline dolomite, with few irregular chert nodules and chert beds.	–[(a)]	93

(a) Dash means unknown; none of the borings at the site penetrated the full thickness of the strata.

2.5.4.1.2.3 _Laboratory Testing_

SSAR Section 2.5.4.2.3 provides a brief description of the applicant's laboratory testing (TVA 2017-TN5387). The applicant stated that the laboratory testing was performed in accordance with RG 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants, Revision 3" (NRC 2014-TN5903) and under an approved QA program. The applicant stated that the soil and rock samples were shipped under chain of custody protection from the storage area to the testing laboratory. The applicant indicated that the laboratory tests performed on the soil samples focused on obtaining the basic characteristics of the soils and the shear strength and compaction characteristics. The applicant stated that the tests performed on the rock core samples focused on obtaining the basic characteristics of the rock and the compressive strength, shear and elastic moduli, Poisson's ratio, slake durability,

and calcium carbonate content. The applicant stated that details and results of the laboratory testing are included in Appendices F through H of the Geotechnical and Exploration and Testing report (AMEC 2014-TN6105).

2.5.4.1.2.4 *Engineering Properties*

The applicant derived the engineering properties for the existing fill and residual soil, granular backfill, weathered rock, and the bedrock around the power block area from the CRN Site subsurface investigation and the laboratory testing program. SSAR Table 2.5.4-21 summarizes the selected values of the engineering properties for the materials beneath the power block area (TVA 2017-TN5387). The applicant developed the engineering properties to evaluate the stability of the foundation materials.

2.5.4.1.2.5 *Soil Properties*

The applicant recommended SPT N_{60} values based on corrected field-measured N values. The applicant adjusted the field-measured N values using an energy correction factor, adjustment for field procedures, borehole diameter, and a sampler correction factor and rod length correction. The applicant performed sieve analyses of 34 existing fill and residual soil samples. The applicant estimated the unconfined compressive strength based on SPT N_{60} values. The applicant classified the existing and residual soils as CH based on the USCS, ASTM International D2487 (ASTM 2000-TN6085). The applicant determined the undrained shear strength from unconsolidated undrained triaxial testing, and also estimated it from the unconfined compressive strength of the soil using the relationship that the undrained shear strength is approximately one-half the unconfined compressive strength. The applicant determined the drained shear strength, effective cohesion, and angle of internal friction from consolidated undrained (CU) triaxial tests. The applicant used the suspension P-S velocity method to record the shear (V_S) and compression (V_P) wave velocity measurements. The applicant calculated the Poisson's ratio based on wave velocity measurements. The applicant derived the low strain shear modulus and low strain elastic modulus using the following relationships:

$$G_L = \left(\frac{\gamma}{g}\right) * {V_s}^2$$

$$E = 2\,(1 + \mu) * G$$

where

G = shear modulus,
E = elastic modulus,
γ = total unit weight,
μ = Poisson's ratio,
g = acceleration due to gravity, and
V_s = shear wave velocity.

The applicant used the following relationship with the undrained shear strength to derive the high strain or static modulus:

$$E_H = 600 * S_U$$

where E_H is the high strain elastic modulus and S_u is the undrained shear strength.

The applicant determined the maximum dry density and optimum moisture content as part of the laboratory testing program. SSAR Table 2.5.4-21 contains all recommended values for soil properties (TVA 2017-TN5387).

2.5.4.1.2.6 *Weathered Rock Properties*

The applicant stated that the weathered rock would be excavated during construction. The applicant considered the weathered rock in site response analyses and selected engineering properties from in situ testing and material correlations.

2.5.4.1.2.7 *Intact Rock Properties*

In SSAR Section 2.5.4.2.4.3, the applicant described the properties of the intact rock underneath the power block area, including the Benbolt, Rockdell, Blackford and Newala Formations and the Fleanor and Eidson Members (TVA 2017-TN5387). The applicant determined the total unit weight and specific gravity from the laboratory test results. The applicant conducted moisture content testing on rock core samples from the Fleanor Member and conducted unconfined compressive strength tests as part of the laboratory testing program. SSAR Table 2.5.4-16 presents a summary of the V_S and V_P measurements for each stratigraphic unit (TVA 2017-TN5387). The applicant calculated the Poisson's ratio based on wave velocity measurements. The applicant derived the low strain shear modulus and low strain elastic modulus and high strain shear modulus using the same relationships it used for soils. The applicant stated that, for sound rock, the shear and elastic moduli typically remain constant at both small and large strains as indicated by the similar results for the low strain and high strain shear and elastic moduli of the stratigraphic units. The applicant stated that results from the pressuremeter testing indicate a strain-hardening behavior. This suggests that the use of a low strain value is conservative. The applicant derived the coefficient of sliding from the tangent of the friction angle between foundation material and the bedrock. The applicant performed slake durability and calcium carbonate content tests as part of the laboratory testing program. SSAR Table 2.5.4-21 contains all recommended values for the rock properties (TVA 2017-TN5387).

2.5.4.1.2.8 *Rock Mass Properties*

SSAR Section 2.5.4.2.4.4 describes the rock mass strength and deformation properties developed for the stratigraphic units encountered within the power block area (TVA 2017-TN5387). The applicant developed the rock mass properties using the GSI classification and the Hoek-Brown failure criterion, which assumes that the rock mass contains several sets of discontinuities that are closely spaced relative to the proposed structure, such that it behaves as a homogeneous and isotropic mass and that a predetermined failure plane does not exist. The applicant indicated that the size of the power block area excavation is expected to be much larger than the rock blocks that make up the rock mass at the site. The applicant stated that rock core and geophysical data regarding discontinuities and fracture zones were reviewed and that the data indicate that weathered and fractures zones are, for the most part, encountered in the uppermost 30.5 m (100 ft). The applicant stated, based on the observation from the grouting program and the excavation for the CRBRP, that the rock mass below this zone typically is tighter and contains less frequent and less persistent discontinuities.

SSAR Section 2.5.1.2.6 includes a detailed description of the GSI for each stratigraphic unit (TVA 2017-TN5387). The applicant stated that the rock mass at the CRN Site contains five distinct joint sets that define the blockiness of the rock mass, making the GSI classification

system applicable to the site. SSAR Table 2.5.1-15 summarizes the GSI results for each stratigraphic unit (TVA 2017-TN5387). The applicant used the GSI to estimate rock mass strength and deformation properties. The applicant developed the rock mass strength and deformation properties for the stratigraphic units within the disturbed zone adjacent to the foundation to account for stress relief and blast damage of the rock mass immediately adjacent to the foundation and the undisturbed zone. The applicant used the RocData computer program to determine the rock mass strength using the generalized Hoek-Brown criterion. The applicant used a disturbance factor of 0.7 for damage from controlled blasting. The applicant stated that when comparing rock mass compressive strength with intact compressive strength for the stratigraphic units with GSI values greater than or equal to 80, the rock mass compressive strength between 10.3 and 45.5 MPa (1,500 and 6,600 psi) are approximately one-third of the intact compressive strength of 31 to 137.9 MPa (4,500 to 20,000 psi).

The applicant developed the deformation modulus of the rock mass using methods available in the RocData computer program and using empirical equations. SSAR Table 2.5.4-25 summarizes the rock mass deformation moduli estimated using empirical equations and the modulus obtained from in situ pressuremeter tests, and developed from the low strain V_S data for comparison purposes (TVA 2017-TN5387). The applicant indicated that rock mass deformation moduli for low strain are frequently overestimated using V_S data and frequently underestimated using the in situ pressuremeter test method. The applicant indicated that the deformation moduli, derived from the V_S, range from approximately 34,473 to 78,600 MPa (5,000 to 11,400 kip per square inch [ksi]). Deformation moduli derived from in situ pressuremeter testing range from about 6,205 to 16,547 MPa (900 to 2,400 ksi). The applicant stated that the estimated moduli from the empirical equations generally occur between these ranges.

2.5.4.1.3 Foundation Interfaces

In SSAR Section 2.5.4.3, the applicant described the foundation interface conditions at the CRN Site and described geotechnical exploration and testing activities(TVA 2017-TN5387). The applicant summarized the subsurface investigation programs performed for the CRBRP and for the CRN Site. The applicant stated that the field investigations for determining the engineering properties of soil materials follow the guidance of RG 1.132 (NRC 2003-TN5902).

The CRN Site subsurface investigation included 82 exploratory borings, 3 test pits, 44 observation wells, 2 surface geophysical tests (reflection and refraction), downhole geophysical tests in 28 borings, field permeability and pumping tests, and groundwater level monitoring in the observation wells.

Figure 2.5.4-1 (SSAR Figure 2.5.4-2) in FSER Section 2.5.4.1 presents a cross section illustrating the position of subsurface stratigraphy with the assumed foundation elevation for safety-related structures within the PPE (TVA 2017-TN5387).

2.5.4.1.3.1 <u>Borings and Soil Samples/Rock Cores</u>

The applicant drilled 82 borings at the CRN Site from depths of about 6.1 to 164.6 m (20 to 540 ft). The deep boreholes were at least 61.0 m (200 ft) deeper than the deepest foundation embedment depth in the PPE. Seven of the borings were drilled at inclinations of between 25 and 29 degrees from vertical. All borings were advanced until SPT refusal. The applicant followed the guidance in RG 1.132 (NRC 2003-TN5902) for the sampling interval, and ASTM standards when conducting SPTs and collecting samples. Figure 2.5.4-2 (SSAR Figure 2.5.4-1) shows the boreholes at the CRN Site within or near the power block area (TVA 2017-TN5387).

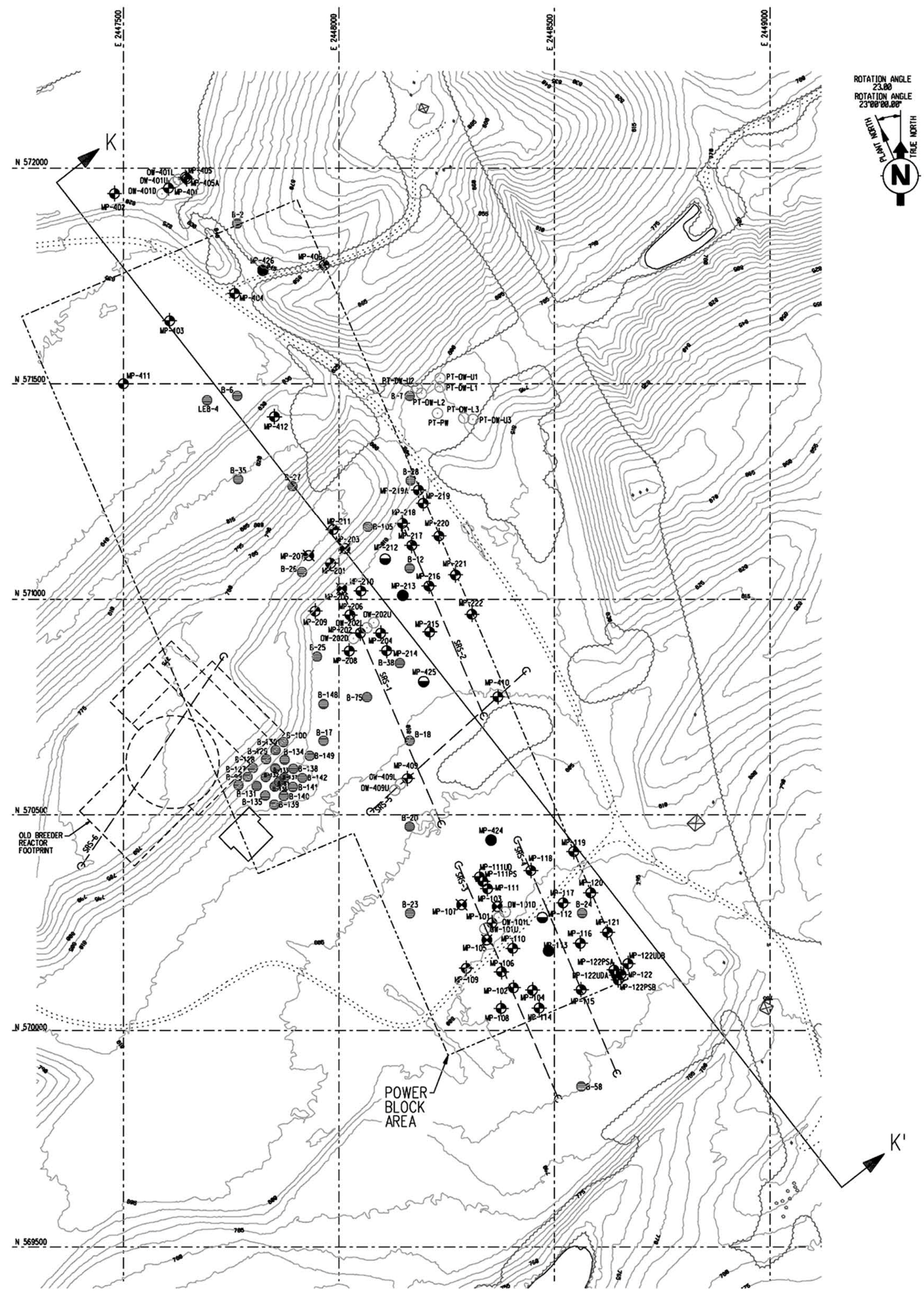


Figure 2.5.4-2 Boring Location Plan at the CRN Site (reproduced from SSAR Figure 2.5.4-1 [TVA 2017-TN5387])

2.5.4.1.3.2 *Groundwater Observation Wells and Associated Tests*

In SSAR Sections 2.5.4.3.2.2 and 2.5.4.3.2.3, the applicant described the groundwater wells installed at the CRN Site, along with associated tests (TVA 2017-TN5387). The applicant stated that 44 groundwater wells were installed at the CRN Site, 34 of which were used as groundwater observation wells for monitoring of groundwater levels and for water-quality sampling in select wells. The additional wells were for aquifer performance testing, and consisted of one pumping test well and six adjacent pumping-test-specific observation wells.

The applicant placed the observation wells in the weathered rock and/or bedrock between elevations of about 242.6 and 150.0 m (796 and 492 ft), and each well was developed by pumping and surging. Field permeability slug tests were performed in most of the observation wells to obtain estimates of transmissivity, storage coefficient, and hydraulic conductivity in accordance with ASTM D4044 (ASTM 1996-TN6086). Both rising and falling head tests were performed when possible.

The applicant stated that water level measurements were initially taken in the completed observations wells on a weekly basis for three months. Measurements were then collected on a monthly basis for the remainder of the 12-month period, followed by collection on a quarterly basis for the second year of monitoring. Pressure transducers were installed in 13 of the observation wells for continuous groundwater level monitoring. Groundwater samples were obtained from selected observation wells for geochemical characterization including pH, specific conductance, turbidity, dissolved oxygen, temperature, redox potential, and for major anions and cations.

2.5.4.1.3.3 *Test Pits*

The applicant excavated three test pits at the CRN Site, two of which were located in the footprint of the power block. The test pits were used to visually describe and classify soil in the field and to obtain bulk samples of representative soil types. The test pits were then backfilled with the excavated soil after test completion.

2.5.4.1.3.4 *Rock Tests*

The applicant performed rock pressuremeter and direct shear tests. The pressuremeter tests were performed in two borings for rocks within the Benbolt and Rockdell Formations, and the Fleanor and Eidson Members. Direct shear strength tests were performed on nine rock core samples in accordance with ASTM D5607 (ASTM 2008-TN6087), which included intact shear strength tests on five rock core samples and sliding friction tests on four rock core samples.

The applicant stated that Goodman Jack in situ tests (borehole tests to determine the in situ modulus of deformation of rock) were conducted for the CRBRP. The range of elastic moduli values derived from these tests for the Fleanor and Eidson Members is larger than those determined from the pressuremeter test results at the CRN Site.

2.5.4.1.4 Geophysical Surveys

SSAR Section 2.5.4.4 describes the geophysical surveys that the applicant conducted in its site investigation at the CRN Site (TVA 2017-TN5387). These surveys consist of surface and downhole geophysical testing that includes seismic refraction and reflection surveys. The surveys also consist of a suite of downhole tests including suspension P-S velocity logging to

obtain V_P and V_S measurements; other borehole loggings; ATV, conductivity, and natural-gamma data for soil, rock, and fluid; and fluid temperature data, along with borehole deviation measurement. The applicant also provided a summary of geophysical surveys for the CRBRP site and compared those results with the data obtained from the geophysical surveys conducted at the CRN Site.

2.5.4.1.4.1 *Surface Geophysical Testing*

The surface geophysical testing at the CRN Site included seismic refraction and reflection surveys. The seismic refraction survey was conducted to map the depth to bedrock beneath six seismic refraction profiles using the P-wave seismic refraction technique. The survey showed that the interpreted depth to bedrock is between approximately 2.7 and 12.8 m (9 and 42 ft) at the central portion of the power block area. In the southern portion of the power block area, the interpreted depth to bedrock is between approximately 4.9 and 13.1 m (16 and 43 ft), which is reasonably consistent with that observed in the boring logs. The applicant considered that any differences in the depth to bedrock between the interpreted seismic-bedrock interface and the observations from the boring logs reflect the degree of weathering of the bedrock and/or the presence of saturated soil. The tomographic model for the former excavation for the CRBRP shows that the interpreted depth to bedrock is about 16.5 m (54 ft), with shallower depths of about 0.9 and 9.1 m (3 and 30 ft) beneath the westernmost and easternmost portions of the refraction profile lines, respectively.

The applicant conducted a seismic reflection survey to interpret the contact (disconformity) between the stratigraphic units of the Chickamauga Group and underlying Knox Group; the general inclination of the bedding planes in the stratigraphic units between the borings; and the presence of any anomalies, such as faults or cavities. Two survey lines were placed during the reflection survey: one located in the power block area, and the other located west of the power block area. The applicant stated that the seismic reflection survey was conducted using the P-wave seismic reflection technique based on the procedure outlined in ASTM D7128 (ASTM 2005-TN6088). The applicant stated that the seismic reflection survey data showed generally continuous, moderately steeply dipping rock beds. The applicant identified three anomalous zones on the section in the power block area and two anomalous zones on the section west of the power block area. The applicant interpreted these anomalous areas as either being artifacts associated with out-of-plane reflectors or special aliasing, or as representing the effects of tuning or the interference from events outside of the plane of the seismic profile. The survey data identified no fault-like features.

2.5.4.1.4.2 *Downhole Geophysical Testing*

The applicant performed downhole geophysical testing in 27 uncased and 3 cased borings to measure V_P and V_S, deviation data, conductivity and natural-gamma data, caliper and natural-gamma data, fluid temperature, and fluid conductivity and natural-gamma data. Only downhole P-S logging and deviation testing were performed in the overburden in a select number of borings because the upper portions of those borings collapsed.

2.5.4.1.4.2.1 Suspension P-S Velocity Logging

Suspension P-S velocity logging was used to obtain in situ measurements of vertically propagating horizontally polarized shear and compressional wave velocities at 0.5 m (1.64 ft) intervals. The applicant processed the data and grouped the velocity measurements according to the stratigraphic unit based on their recorded mid-point depth in the boring and the

stratigraphic contacts identified for each unit. The applicant stated that the compilation of the profiles did not include velocity measurements from the inclined borings or from boring MP-420 that was considered too far from the power block area, and measurements within the weathered rock were also not included.

The suspension P-S velocity logging data showed that the Newala Formation exhibits the highest average V_S and V_P values of 3,292 m/s (10,800 fps) and 6,066 m/s (19,900 fps), respectively. The Rockdell Formation and Eidson Member exhibit similar velocities with an average V_s of 2,743 m/s (9,000 fps) and average V_P of about 5,182 m/s (17,000 fps). The Benbolt and Blackford Formations also exhibit similar V_S and V_P with an average V_S of 2,438 and 2,499 m/s (8,000 and 8,200 fps) and average V_P of 4,694 and 4,785 m/s (15,400 and 15,700 fps), respectively. The Fleanor Member exhibits the lowest average V_S and V_P of 2,195 and 4,420 m/s (7,200 fps and 14,500 fps), respectively.

The applicant also presented the minimum, maximum, and average V_S and V_P obtained for the CRBRP, for the Fleanor and Eidson Members, and for the Blackford Formation. The CRBRP data showed seismic velocity values similar to those for the CRN Site. The applicant stated that the velocity profiles, as presented in SSAR Figure 2.5.4-5 and SSAR Figure 2.5.4-6, show that the V_S and V_P do not vary significantly with depth for each rock formation (TVA 2017-TN5387).

2.5.4.1.4.2.2 Acoustic Televiewer Logging

The applicant used a High-Resolution Acoustic Televiewer (HiRAT) probe to obtain boring deviation/inclination data, and to collect images of the borings walls in accordance with ASTM D5753 (ASTM 2005-TN6089). The processed data in three-dimensional plots present the true dip and azimuth of the borehole. The dip and dip azimuths of the discontinuities collected from ATV logging are used to analyze the discontinuity orientations, prepare scatter and contour plots of the discontinuity poles, and determine discontinuity sets and their average orientations. The oriented images of borehole cores generated by the HiRAT probe provide visual information about subsurface material.

The applicant stated that the deviation data show that all of the vertical borings were inclined 3 degrees or less from vertical (with a mean dip of 1.3 degrees) and that the greatest error in depth due to this deviation was 2.4 cm in 1,768 cm (0.08 ft in 58 ft), or about 0.15 percent of depth.

2.5.4.1.4.2.3 Induction/Natural-Gamma; Caliper/Natural-Gamma; Fluid Temperature/Fluid Conductivity/Natural-Gamma Logging

The applicant conducted induction/natural-gamma (gamma) logging to identify the lithostratigraphic units at the CRN Site. The logging was performed in accordance with ASTM D5753 (ASTM 2005-TN6089), ASTM D6274 (ASTM 1998-TN6090), and ASTM D6726 (ASTM 2001-TN6091) using a DUIN model dual induction probe. Gamma logs provide a record of natural-gamma radiation emitted from the boring walls. Induction logs measure conductivity and high-resolution information about lithology when combined with gamma logs. The applicant stated that the processed data were measured along the boring axis for the inclined borings. However, mechanical caliper data in the inclined borings are not used because the weight of the probe prevented the opening of the caliper arms against the boring wall.

The applicant used caliper/natural-gamma (gamma) logging to measure the diameter of the boreholes and to identify anomalous structures in the walls of the borings such as cavities,

fissures, etc. Caliper measurements were collected concurrently with natural-gamma emissions in accordance with ASTM D5753 (ASTM 2005-TN6089), ASTM D6167 (ASTM 1997-TN6092), and ASTM D6274 (ASTM 1998-TN6090), using a Model 3ACS three-leg caliper probe. The applicant stated that the multiple parameter logs show that changes in conductivity correspond with changes in natural-gamma emissions and that the natural-gamma data agree well with natural-gamma data collected with the caliper data. Gamma signatures are typically higher in mud-supported rocks such as mudstones and siltstones. The natural-gamma logs reveal that gamma signatures are highest in the Fleanor Member, followed by the Benbolt and Blackford Formations, and lowest in the Eidson Member and Rockdell and Newala Formations. Caliper logs show consistent gauge below the bedrock surface and also the presence of open and clay-filled fractures by an increase in boring diameter and corresponding increase in natural-gamma emissions. Caliper and natural-gamma plots correspond well with changes in velocity.

The applicant also performed fluid temperature/fluid conductivity/natural-gamma logging to identify the lithostratigraphic units and the presence of salty groundwater or fresh groundwater (for observation well siting). Fluid temperature and conductivity measurements were collected concurrently with the natural-gamma emissions in accordance with ASTM D5753 (ASTM 2005-TN6089) and ASTM D6274 (ASTM 1998-TN6090) using a temperature, conductivity, and gamma probe. The applicant stated that fluid temperature and conductivity changes generally correspond to fractures identified on the ATV logs.

2.5.4.1.5 Excavation and Backfill

SSAR Section 2.5.4.5 describes the extent of anticipated safety-related excavations; fills and slopes; excavation methods and stability; backfill sources; quality control; ITAAC (Inspections, Tests, Analyses, and Acceptance Criteria); construction dewatering impacts; and retaining walls at the CRN Site (TVA 2017-TN5387).

2.5.4.1.5.1 *Extent of Excavations, Fill, and Slopes*

Figure 2.5.4-1 in Section 2.5.4.1 of this chapter shows a cross section through the power block area that illustrates the approximate ground surface and site stratigraphy. At the center of Locations A and B, the top of bedrock is encountered approximately 6.1 and 9.1 m (20 and 30 ft) below the existing ground surface. The applicant stated that the finished plant grade elevation for the power block area is set at elevation 250.2 m (821 ft), and the bottom of the basemat of the most deeply embedded safety-related power block structures are expected to not exceed a depth of 42.1 m (138 ft) below finished grade.

The applicant stated that the construction of the basemat at these locations requires a substantial amount of excavation of both soil and rock. Excavation sidewalls are expected to be vertical or near vertical in part because of the depth of excavation, which will requires the use of surface-mounted cranes. The lateral extents of the excavation are expected to be limited—on the order of 4.6 m (15 ft) beyond the exterior face of the perimeters walls to provide working room for construction and backfilling of the exterior walls. The floor of the excavation is expected to be irregular because of the different stratigraphic units that are encountered. Concrete will be used to establish a level grade, and for the base of the basemat of safety-related power block structures. The deepest location of the foundation is expected to not exceed 42.1 m (138 ft) below finished grade.

The applicant stated that concrete backfill and compacted granular backfill are needed to backfill the excavation. The concrete backfill will be used underneath the basemat and around

the structure from the basemat to the top of rock, then compacted granular backfill will be used above the elevation of rock to the finished grade. Compacted granular backfill will also be used for general site grading in the power block to raise the grade to the finished plant grade elevation.

In accordance with the PPE, construction of the safety-related structures requires a temporary excavation on the order of approximately 36.6 m (120 ft) below the existing grade at Location A and 39.6 m (130 ft) below the existing grade at Location B. The excavation slopes will be made in existing fill/residual soil, weathered rock, and bedrock. Design of the excavation and backfill will be done for the COLA.

2.5.4.1.5.2 _Excavation Methods and Stability_

In SSAR Section 2.5.4.5.2, the applicant discussed excavation methods and associated slope stability issues (TVA 2017-TN5387). The applicant stated that excavation in existing fill/residual soil can be done with conventional earthmoving equipment. Excavation must adhere to the regulations of the Occupational Safety and Health Administration, 29 CFR Part 1926, "Safety and Health Regulations for Construction" (TN4455). Depending on the excavation depth, the excavations in soil may include vertical cuts supported by tied-back sheet piles or soldier pile and lagging walls. The side slopes of the ramp for construction access made in soil can be excavated at slope angles of 2 (horizontal) to 1 (vertical).

The applicant stated that conventional excavating equipment can be used to excavate weathered rock that is about 2.7 and 3.0 m (9 and 10 ft) beneath the existing fill/residual soil at Locations A and B within the power block area. Groundwater is generally encountered within the weathered rock. Therefore, groundwater control will be required during excavation and for excavation support.

The applicant stated that the excavation of rock likely requires the use of controlled blasting techniques, as it did for the CRBRP. For the CRBRP excavation, to minimize rock excavation and to provide crane access to the bottom of the excavation, 22.9 m (75 ft) high near-vertical rock slopes in the north, south, and east portions of the excavation were required. The applicant provided a more detailed description of the controlled blasting techniques that consist of production and perimeter blasting. For the stability of the near-vertical rock slopes, the applicant stated that rock bolts were needed and the design will be based on information derived from geologic mapping of exposed rock surfaces. Furthermore, the slope movement and foundation performance was monitored with an extensive instrumentation program during and after the excavation.

The applicant stated that the blasting program for the CRN Site varies depending on where the safety-related structure(s) are located and in which stratigraphic unit they are embedded. The applicant also stated that for COLAs, additional subsurface data may be required to further characterize the underlying stratigraphic bedrock units for the final plant layout. The specific design of the excavation support system, including rock bolting, would be developed during detailed design.

2.5.4.1.5.3 _Backfill Sources_

In SSAR Section 2.5.4.5.3, the applicant described general requirements for backfill materials (TVA 2017-TN5387). For granular backfill materials, the applicant suggested the use of a processed graded aggregate that meets the gradation requirements of Type A aggregate of the

Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction Section 303, Table A2.6 (TDOT 2015-TN5904). The applicant also suggested setting up a crushing and blending plant onsite to produce the crushed aggregate to the required gradation specification. Otherwise, the graded aggregate needs to be imported from nearby quarries. The ESPA defers a detailed field and laboratory test program to the COLA for evaluation of backfill sources and their engineering properties. However, the applicant specified that the test program should include gradation (grain size distribution), density, soundness, durability, strength, and the dynamic properties of the backfill. A test pad would be needed to establish placement and compaction methods. The applicant also specified that the granular backfill should be compacted to at least 95 percent of the maximum dry density, as determined by the modified Proctor test, and that the moisture content of the compacted fill should be within 3 percent of its optimum moisture content.

2.5.4.1.5.4 _Quality Control and ITAAC_

In SSAR Section 2.5.4.5.4 (TVA 2017-TN5387), the applicant provided general requirements for backfill and subgrade quality control (QC), but it leaves details to the COLA, including identification of quality requirements and industry standards for safety-related backfill material and placement specifications, as well as ITAAC related to backfill.

The applicant stated that a QA and QC program for the backfill needs to be established to verify that the granular backfill is constructed in accordance with the design requirements. The ESPA specifies that for limited earthwork, where fill is compacted using hand equipment, one density test is conducted for every 56.6 m^2/m (2,000 ft^2/ft) of fill placed. Otherwise, field density tests are performed at a minimum of one per 929.0 m^2 (10,000 ft^2) of fill placed, with at least one test per lift.

The applicant stated that the concrete fill mix design specification will be provided during the detailed design phase of the project. Field observations and tests need to be performed to verify that specified design parameters are reached.

The applicant stated that COL applicants need to visually inspect the final bedrock excavation surface to confirm that material is in general conformance with the expected foundation materials based on boring logs. COL applicants also need to visually inspect the exposed bedrock foundation subgrade to confirm that cleaning and surface preparations are completed in accordance with the specification. Geologic mapping of the final exposed excavated bedrock surface is required before placement of concrete (dental) backfill and foundation concrete, and would be conducted in accordance with the guidelines of NUREG/CR-5738 (Torres et al. 1999-TN5905).

2.5.4.1.6 Groundwater Conditions

SSAR Section 2.5.4.6 summarizes the groundwater conditions at the CRN Site (TVA 2017-TN5387). Additional details are described in SSAR Section 2.4.12.

2.5.4.1.6.1 _Groundwater Measurements and Elevations_

The applicant installed 44 observation wells in two- and three-well clusters with screened intervals of upper (between 4.6 to 32.0 m [15 to 105 ft]), lower (between 27.1 to 54.3 m [89 to 178 ft]) and deeper (between 53.6 to 90.5 m [176 to 297 ft]) zones. Three observation well clusters installed in the power block area exhibited groundwater level elevations ranging from approximately 243.8 to 224.9 m (800 to 738 ft) in the upper zone, 237.4 to 215.2 m (779 to

706 ft) in the lower zone, and 233.2 to 225.2 m (765 to 739 ft) in the deeper zone. The applicant generally observed groundwater at depths ranging from the near surface to approximately 7.6 m (25 ft) below ground in the observation wells.

The applicant stated that the weathered rock generally acts as a water table aquifer and that most of the groundwater flow occurs within this zone. Groundwater flow also occurs through discontinuities and openings in the underlying bedrock, predominantly in the upper 30.5 to 45.7 m (100 to 150 ft) of the bedrock. The groundwater movement at the site is generally to the southeast and southwest toward the Clinch River arm of the Watts Bar Reservoir. Horizontal hydraulic gradients range from 0.03 to 0.11 m/m (ft/ft) and average vertical hydraulic gradients range from -0.71 m/m (ft/ft) (upward) to 1.15 m/m (ft/ft) (downward) for the observation well clusters. The applicant summarized the hydraulic conductivity values for the bedrock stratigraphic units based on the results of the slug tests. The applicant referred to details provided in SSAR Section 2.4.12 (TVA 2017-TN5387).

2.5.4.1.6.2 _Construction Dewatering_

The applicant stated that, during construction, the groundwater levels at the site are likely to result in the need for temporary dewatering of the foundation excavations extending below the water table. The applicant suggested the use of gravity-type dewatering systems, the extraction of water using sump pumps in the lowest working levels of the excavation, and then transfer of the water to an impoundment facility. The applicant pointed out that dewatering should consider minimization of drawdown effects on the surrounding environment, and that appropriate methods should be used for open bedding planes and fractures to reduce groundwater inflow to the excavation and to reduce the extent of dewatering. Horizontal relief wells may be needed in the rock excavation walls to prevent hydrostatic pressure buildup behind the walls. The applicant also stated that the response to groundwater extraction needs to be assessed using a network of observation wells installed at the site, plus stream gauges when needed.

2.5.4.1.6.3 _Groundwater Chemical Properties_

SSAR Section 2.5.4.6.3 summarizes the groundwater chemical properties based on the geochemical test results for the CRN Site (TVA 2017-TN5387). The applicant stated that the pH of the groundwater ranges from 6.97 to 9.58 and has an average pH of 7.53. The sulfate concentration of the groundwater ranges from 6.9mg/L to 150 mg/L and has an average sulfate concentration of 42 mg/L. The chloride concentration ranges from 1.3 mg/L to 24 mg/L and has an average chloride concentration of 4.5 mg/L. The applicant stated that with a sulfate concentration of 42 mg/L, the water-soluble sulfate concentration in contact with concrete is low and injurious sulfate attack is not a concern.

The applicant stated that for concrete fill and foundations, an Exposure Category C1 is assigned because the foundations would be exposed to moisture but would not be in contact with external sources of chlorides. Therefore, the applicant stated that the protection requirement specified in American Concrete Institute (ACI) Standard 318-14 (ACI 2014-TN6093) should be followed.

2.5.4.1.7 Response of Soil and Rock to Dynamic Loading

SSAR Section 2.5.4.7 describes the response of soil and rock to dynamic loading and discusses the effects of past earthquakes, development of velocity profiles, dynamic laboratory tests, and variation of shear modulus and damping with strain (TVA 2017-TN5387). The applicant referred to SSAR Section 2.5.2.1 for details regarding the historical earthquake events for the CRN Site (TVA 2017-TN5387).

2.5.4.1.7.1 *Velocity Profiles*

The applicant conducted various geophysical surveys, including seismic refraction and reflection, and P-S suspension logging at the CRN Site to characterize the in situ dynamic properties of the subsurface materials. The P-S suspension logging method was used to collect V_S and V_P measurements for each stratigraphic unit and then these unit V_S and V_P profiles were assembled to provide unique V_S and V_P profiles for Locations A and B. The Figure 2.5.4-3 and Figure 2.5.4-4 present geologic and V_s profiles for Locations A and B.

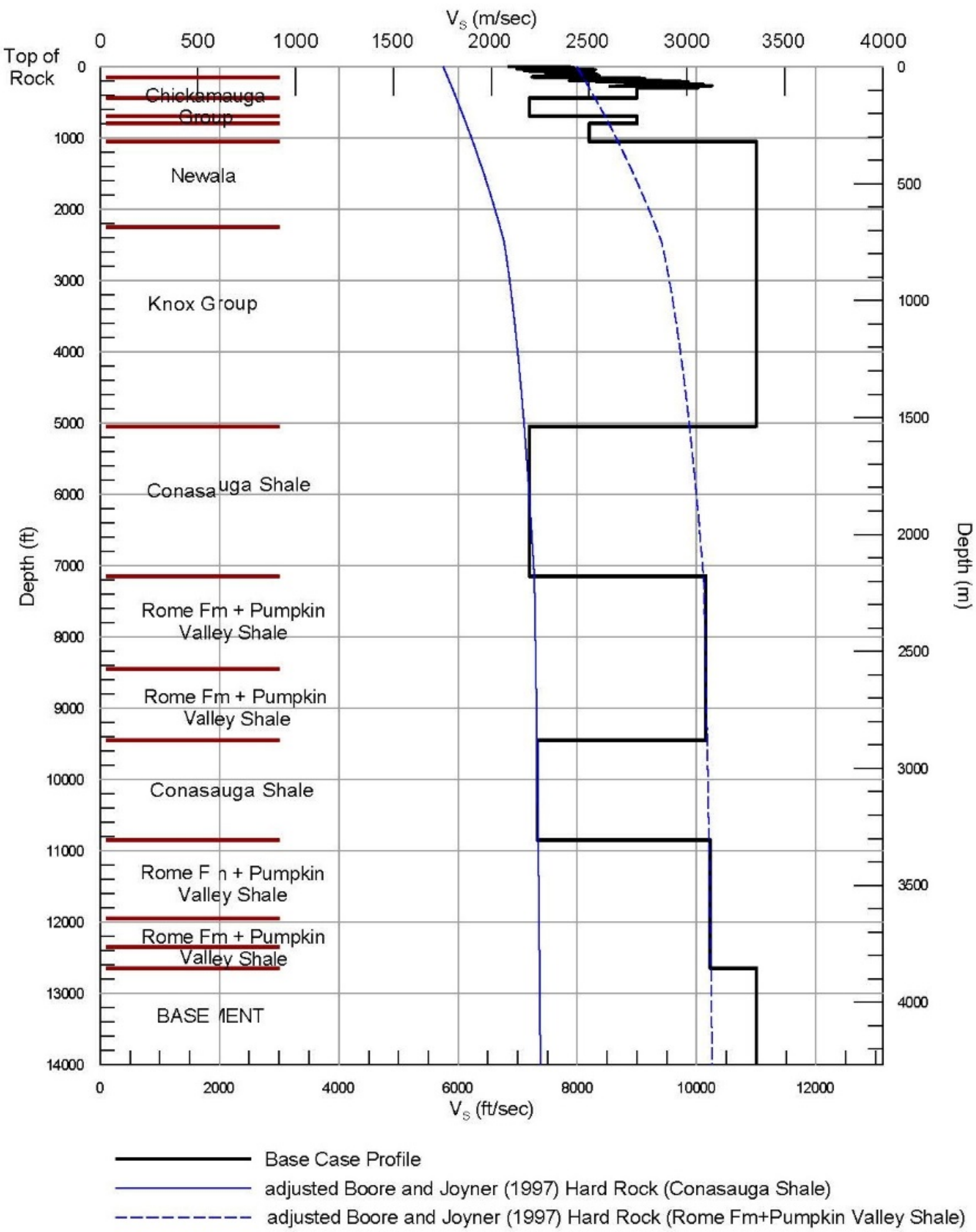


Figure 2.5.4-3 Geologic and Shear Wave Velocity Profile for Location A (reproduced from SSAR Figure 2.5.4-18 [TVA 2017-TN5387])

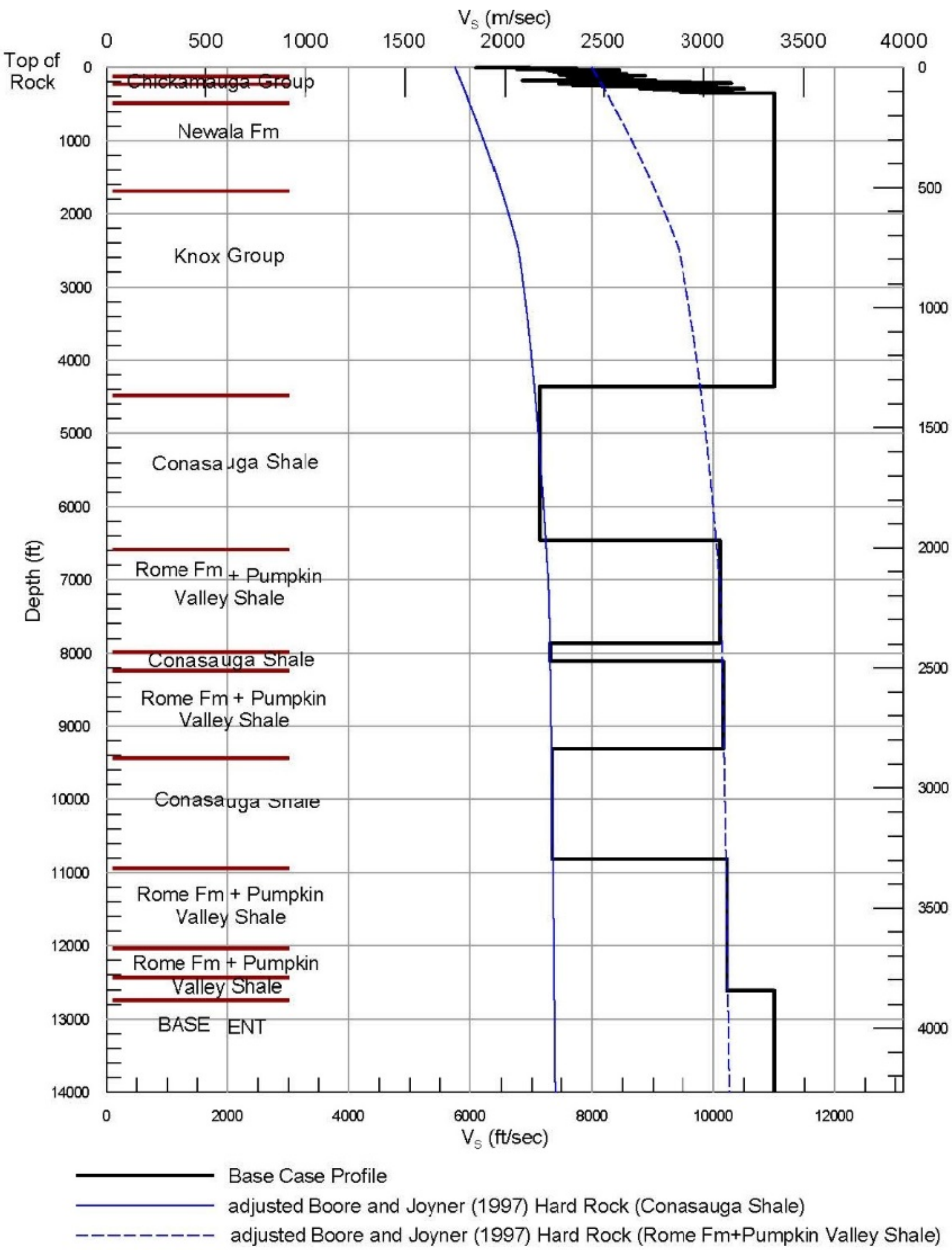


Figure 2.5.4-4 Geologic and Shear Wave Velocity Profile for Location B (reproduced from SSAR Figure 2.5.4-19 [TVA 2017-TN5387])

The applicant stated that the V_S profiles at Locations A and B were developed using site-measured V_S data. The applicant also used data measured in similar nearby geologic units combined with estimated V_S values from literature when no measurements were available. The best estimate (mean) base case V_S profile for the shallow geologic units was developed for each location by computing the lognormal mean profile for the measured V_S data from the boreholes taken within 30.5 m (100 ft) of the location.

Because limited V_S data are available for the deep geologic units at the CRN Site, the applicant used other available information in the development of its V_S profiles. That information included

measured data from spectral analysis of surface wave (SASW) surveys in the Conasauga shale, Pumpkin Valley shale, and Rome Formation at the nearby Watts Bar facility. These data were taken from depths of 152.4 and 457.2 m (500 and 1,500 ft) and were adjusted to the CRN Site. The applicant used generic CEUS hard rock V_S profiles for deeper geologic units of the CRN Site. The applicant assigned average V_S values for depths extending into the Newala Formation, below the measured data. Unless supported by measured data, the applicant assigned a V_S value of 3,353 m/s (11,000 fps) for the Newala Formation and for the remainder of the Knox Group.

The applicant took the epistemic uncertainty into consideration when developing the V_S profiles. For each location (A and B) the applicant first determined the mean base case (best estimate) V_S profile, and then developed upper- and lower-range base case profiles using a depth-independent scale factor of 1.25, or a plus or minus 25 percent variation about the mean base case profiles. The applicant capped the V_S values for the upper-range base case profiles at about 3,505 m/s (11,500 fps). The applicant stated that the uncertainty associated with a scale factor of 1.25 is considered sufficient to account for the potential complexity of seismic wave propagation associated with the dipping stratigraphy at the site. The applicant provided details of those profiles in SSAR Tables 2.5.4-30 and 2.5.4-31 and illustrated them in SSAR Figures 2.5.4-20 and 2.5.4-21 (TVA 2017-TN5387). Those figures are reproduced in Figure 2.5.4-5 and Figure 2.5.4-6.

The applicant developed the V_P profiles at Locations A and B in a manner similar to that for the V_S profiles, and illustrated the V_P profiles in SSAR Figure 2.5.4-6 (TVA 2017-TN5387).

2.5.4.1.7.2 *Dynamic Laboratory Tests*

The applicant conducted Resonant Column and Torsional Shear (RCTS) testing in two intact samples of the existing cohesive fill, and compared the test results with the EPRI curves (Plasticity Index [PI] = 30, 40 and 50 percent). The comparison shows that the shear modulus test data align reasonably well with the EPRI PI = 30 percent curve, which is supported by the measured PIs of 32 and 33 percent for the test samples. However, the applicant recommends using the EPRI PI = 40 percent curve for both shear modulus reduction and damping because the onsite soils have an overall average PI of 40 percent and the test data reasonably conform to the EPRI curves.

2.5.4.1.7.3 *Material Damping and Shear Modulus*

The applicant evaluated the dynamic performance of the firm rock material in the upper 152.4 m (500 ft) of the site under linear and nonlinear behavior by using two sets of hysteretic damping and shear modulus reduction curves. A subset of the EPRI rock curves is used to represent the upper-range nonlinearity (M1) in the materials and linear analyses (M2) to represent an equally plausible alternative rock response. The applicant stated that the original depth-dependent curves were provided over depths of 15.5 to 36.6 m (51 to 120 ft) and 609.9 to 1,524.0 m (2,001 to 5,000 ft). The curves are modified for the M1 profile to depths of 0 to 6.4 m (0 to 21 ft) and 6.4 to 152.2 m (21 to 500 ft). The applicant further revised the damping curves, reducing the original 3 percent low strain hysteretic damping to 2 percent damping. A damping value of 1.25 percent is used to represent a linear response. For rock layers at greater than 152 m (500 ft) depths, a linear response is used with damping adjusted such that the site attenuation (kappa) of the entire profile matches the target kappa. In SSAR Tables 2.5.4-30 and 2.5.4-31, the applicant presented the damping values for the nonlinear (M1) and linear (M2) analyses for each of the best estimate (P1), lower-range (P2), and upper-range (P3) profiles for Locations A and B.

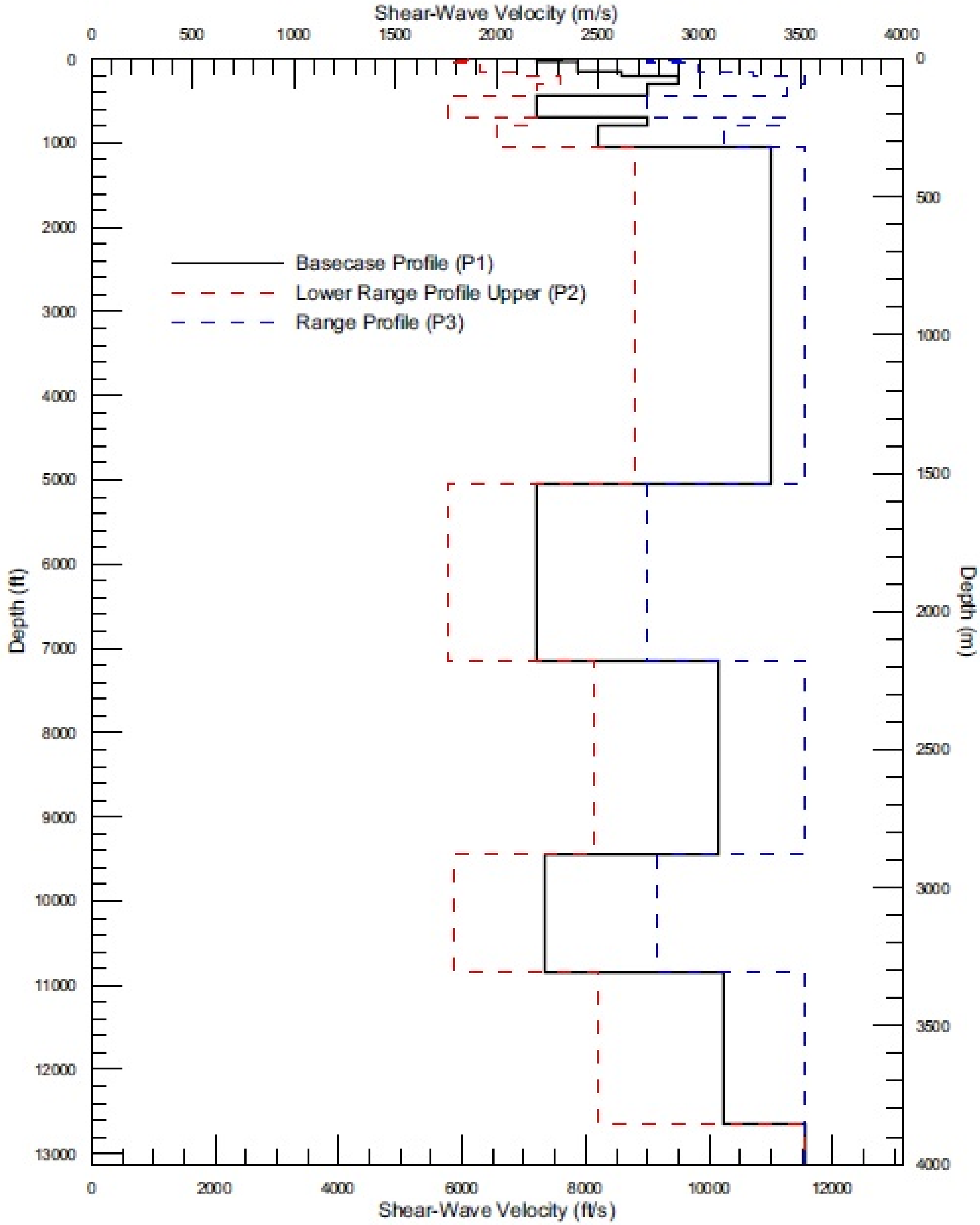


Figure 2.5.4-5 Base Case Shear Wave Velocity Profiles for Location A (reproduced from SSAR Figure 2.5.4-20 [TVA 2017-TN5387])

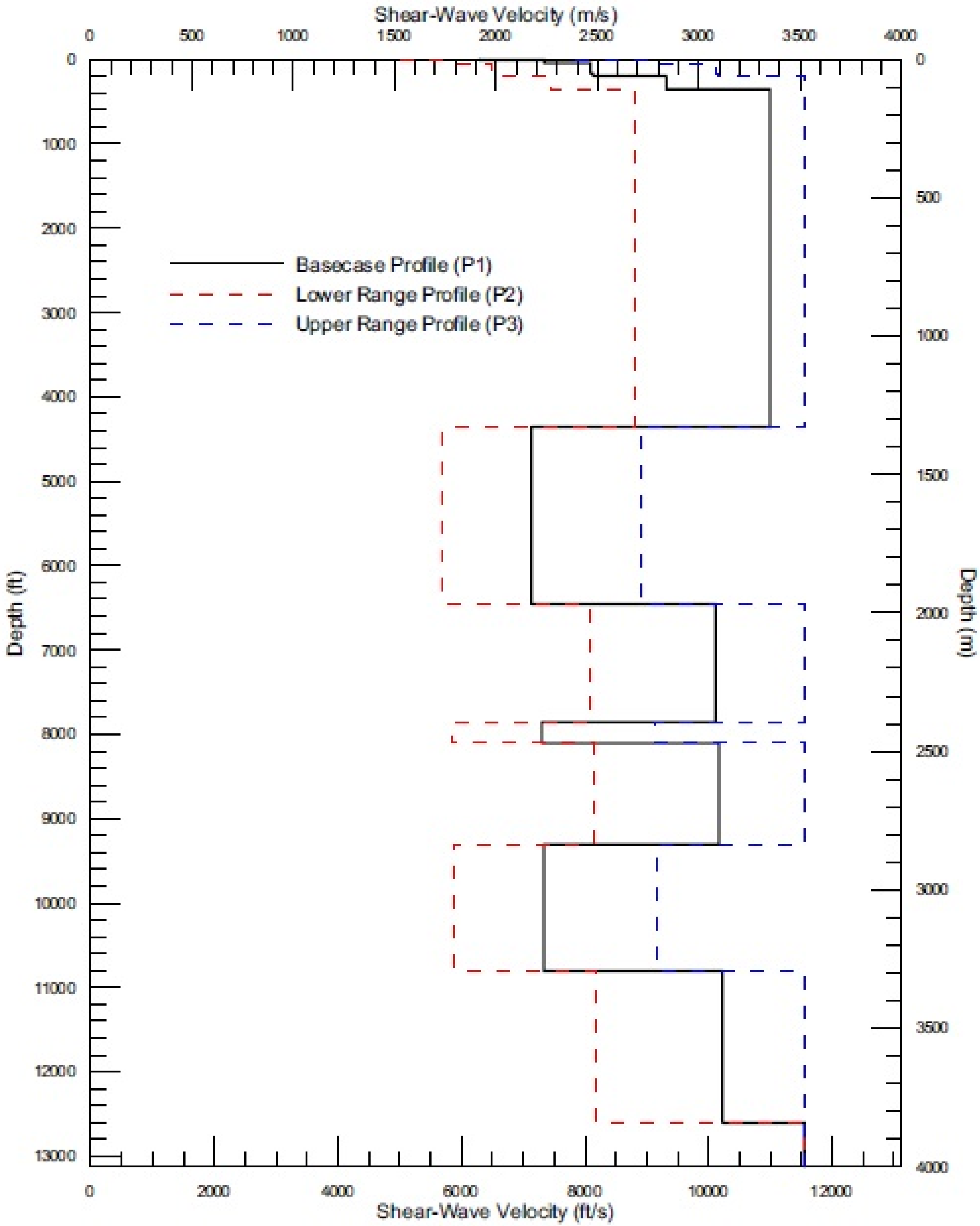


Figure 2.5.4-6 Base Case Shear Wave Velocity Profiles for Location B (reproduced from SSAR Figure 2.5.4-21 [TVA 2017-TN5387])

In SSAR Section 2.5.4.7.4.2, the applicant described the site attenuation (kappa) specified at the ground surface and zero epicentral distance from the seismic source (TVA 2017-TN5387). The applicant referred to SSAR Section 2.5.2.5.1 for additional discussion, and the staff's evaluation of the kappa value is presented in Section 2.5.2.3.5.1 of this chapter.

2.5.4.1.7.4 *Rock Column Amplification/Attenuation Analysis*

The rock column amplification/attenuation analysis considers a deep rock profile, from elevation 683 ft to the Precambrian basement rock. The applicant provided a detailed description in SSAR Section 2.5.2.5 (TVA 2017-TN5387). The applicant referenced SSAR Sections 2.5.4.7.4 or 2.5.2.5.1 for discussion of the V_S profiles, material damping, shear modulus, and kappa values used in this analysis.

For geologic units above and including the Newala Formation, the applicant used unit weights taken from SSAR Table 2.5.4-21 for its analyses (TVA 2017-TN5387). Unit weights of 26.7 kilonewtons per cubic meter (kN/m^3; [170 pound force per cubic foot [pcf]) for the Conasauga shale, and 27.5 kN/m^3 (175 pcf) for the Pumpkin Valley shale and Rome Formation are assigned to the rock units below the Newala Formation.

2.5.4.1.8 Liquefaction Potential

SSAR Section 2.5.4.8 describes the evaluation of liquefaction potential of the materials adjacent to and under safety-related structures at the CRN Site (TVA 2017-TN5387). The applicant performed geologically based screening and liquefaction potential analyses in accordance with RG 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plants” (NRC 2003-TN5906).

The applicant stated that the safety-related structures at the CRN Site are likely embedded at a depth not to exceed 42.1 m (138 ft) below final grade, and that the sound rock is located about 30.5 m (100 ft) above the foundation level at Locations A and B. If there is any need to repair the foundation surface, then concrete would be used, so there is no potential for liquefaction in the foundation materials. The granular backfill to be used around the structure from the top of the rock to the finished grade would also not be susceptible to liquefaction, because it would be compacted to at least 95 percent of the modified Proctor value.

The applicant assessed the liquefaction potential of existing fill/residual soil at the site. The applicant stated that both the existing fill and residual soils are classified as CH clay. Its liquefaction potential was evaluated in a qualitative manner using criteria for fine-grained soils proposed by Polito (1999-TN6108) and Seed et al. (2003-TN6109). Based on the Atterberg limit test results, all of the CRN Site soils fall outside of the proposed zone of liquefiable soils and are not susceptible to liquefaction.

2.5.4.1.9 Earthquake Design Basis

SSAR Section 2.5.4.9 referred to SSAR Section 2.5.2.5.8 for detailed information about the development of the site-specific GMRS (TVA 2017-TN5387).

2.5.4.1.10 Static and Dynamic Stability

SSAR Section 2.5.4.10 describes the evaluation of the static and dynamic stability of foundation subsurface materials under safety-related structures (TVA 2017-TN5387). The evaluation includes bearing capacity, heave, settlement, and lateral earth pressures in the power block area at the CRN Site.

The applicant noted that the site is underlain with a succession of stratigraphic units that generally strike N63°E with a dip angle of 33 degrees. The units contain discontinuities, shear-

fracture zones, and weathered/fracture zones encountered in the stratigraphic units. The applicant recognized that those discontinuities may affect the stability of foundations and considered the discontinuities when determining rock mass properties and performing foundation stability analyses.

The applicant stated that due to the dipping strata at the CRN Site, the stratigraphic units underlying the power block area vary depending on location. The applicant selected two specific locations in the power block area—Location A and Location B to evaluate static and dynamic stability of foundations with an embedment of 42.1 m (138 ft) below the finished grade (elevation 208.2 m [683 ft]).

The applicant used the Hoek-Brown failure criteria (Hoek et al. 2002-TN6110) and the GSI classification system to determine the rock mass strength. The applicant also used empirical equations and a combination of the intact elastic modulus, GSI, and a disturbance factor (D) in determining bearing capacity, heave, settlement, and lateral earth pressures. The applicant stated that the application of the GSI classification and the Hoek-Brown relationship was based on the observation that the rock mass contains several sets of discontinuities that are closely spaced relative to the dimensions of the proposed structure, and that a predetermined failure plane does not exist.

2.5.4.1.10.1 *Bearing Capacity*

In SSAR Section 2.5.4.10.1, the applicant described the methodologies used for its bearing capacity evaluation (TVA 2017-TN5387). In its evaluation, the applicant considered the limit of the influence zone of loadings under the foundation to be 134.1 m (440 ft). This value is two times the assumed width of the foundation of 67.1 m (220 ft). This depth of the influence zone is at elevation 116.1 m (381 ft).

At Location A, the Rockdell and Benbolt Formations are encountered at the foundation level and the underlying Fleanor Member is within the depth of the influence. This is because of the dipping strata at the CRN Site. At Location B, the Eidson and Fleanor Members are encountered at the foundation level and the underlying Blackford and Newala Formations are within the depth of the influence. In its bearing capacity analyses, the applicant separately considered each stratigraphic unit within the depth of influence and treated each unit as a single infinite rock layer below the foundation. The applicant stated that this approach provides a range of bearing capacity values and the most reasonably conservative value is considered.

The applicant examined several methods in its evaluation of rock-bearing capacity and noticed that each method generally considers intact rock properties and rock mass properties. The applicant discussed the intact rock properties based on laboratory testing in SSAR Section 2.5.4.2.4.3, and discussed the rock mass properties based on in situ testing in SSAR Section 2.5.4.2.4.4 (TVA 2017-TN5387).

2.5.4.1.10.2 *Ultimate Bearing Capacity*

The applicant used three empirical equations to estimate the ultimate bearing capacity (q_u). Two of these methods—the Wyllie (1999-TN6112) and Kulhawy and Carter (1992-TN6111) methods—use the Hoek-Brown (Hoek et al. 2002-TN6110) rock mass constants (m_i, m_b, s, a); and the other method, the USACE method (USACE 1994-TN6114), uses a bearing capacity factor based on the friction angle (Φ) of the rock mass.

2.5.4.1.10.3 *Allowable Bearing Capacity*

Allowable bearing capacity (q_a) is defined as the ultimate bearing capacity divided by a factor of safety (FS). The applicant applied an FS of three to determine the allowable bearing capacities. The q_a values were computed for the various stratigraphic units within the disturbed (D = 0.7) and undisturbed (D = 0) zones, and for the lower- and upper-bound GSI underlying Locations A and B. The applicant also used the Bowles method (Bowles 1988-TN6103) to estimate q_a of a rock mass by applying a large FS, ranging from 6 to 10 depending on the RQD of the rock. The applicant applied an FS of 6 to estimate q_a when the unconfined compressive strength, σ_{ci}, value is available. The applicant used an FS of 6 because all rock units considered in the bearing capacity evaluation have high RQD values, ranging from 80 to 93. SSAR Table 2.5.4-27 provides a summary of the calculated allowable bearing capacity values (TVA 2017-TN5387).

The applicant assumed 431 kPa (9 ksf) for the safety-related foundation load, which is less than the existing overburden pressure at the foundation level. Therefore, the net change in pressure at the foundation level, after construction, is expected to be negative. This results in an unloading condition. The applicant stated that the general shear failure, including sliding along a predetermined failure plane, such as a bedding plane, is not likely to occur due to a net decrease in the bearing pressure at the foundation level. Because of the non-general shear failure condition, the applicant stated that the material properties of the rock units (rock mass) are expected to control failure. The applicant also determined that the USACE and Bowles methods are better suited to conditions at the CRN Site. The applicant further stated that the Bowles method does not incorporate GSI or D values, thus there are no associated minimum values. The applicant indicated that the minimum allowable bearing capacity estimates are based on a uniformly disturbed rock mass, and considered the estimation overly conservative given the conditions at the CRN Site. Therefore, the applicant recommended that the allowable bearing capacities estimated using the Bowles method be used for design guidance. A rounded low-formation value of 5,266 kPa (110 ksf) is the recommended q_a for the PPE. For the allowable bearing capacity of concrete, the applicant used ACI Standard 318-14 (ACI 2014-TN6093) to obtain a q_a value of 7,852 kPa (164 ksf) for lean concrete with 17,237 kPa (2,500 psi) strength, which is greater than the recommended q_a for the PPE (5,266 kPa [110 ksf]).

For dynamic bearing capacity, the applicant recommends the same q_a values as that for allowable static bearing capacity, without considering the possible increases in the ultimate bearing capacity of rock and concrete fill under dynamic loads that have very short periods of loading time.

2.5.4.1.10.4 *Settlement and Heave Analysis*

In SSAR Section 2.5.4.10.2, the applicant provided analyses of the settlement and heave of the foundation at the CRN Site (TVA 2017-TN5387). The applicant used rock mass properties and two methods (Hoek and Diederichs, and Gokceoglu) in its analyses. Similar to the bearing capacity analyses, the applicant separately considered each stratigraphic unit within the depth of influence of a respective foundation as a single infinite rock layer below the foundation.

2.5.4.1.10.4.1 Settlement Analysis

The applicant stated that the safety-related structures at the CRN Site have an embedment depth not expected to exceed 42.1 m (138 ft) below the finished grade; thus, these structures

would sit directly on bedrock and settlement is expected to be small. Regardless, the applicant estimated settlement for each of the stratigraphic units being considered to have an assumed foundation contact pressure of 431 kPa (9 ksf).

The applicant estimated the total settlements to be less than 1.27 cm (0.5 in.) for all cases ranging from 0.03 to 0.71 cm (0.01 to 0.28 in.). The applicant provided a summary of the estimated settlements for each of the stratigraphic units in SSAR Table 2.5.4-28 (TVA 2017-TN5387).

2.5.4.1.10.4.2 Heave Analysis

The applicant estimated the total heave due to stress relief during the excavation by using an empirical method suggested by Christian and Carrier (1978-TN6107) for elastic deformation of an isotropic material. The equation assumes an infinite homogeneous material. The applicant assumed a single infinite rock layer for all involved stratigraphic units below the foundation.

The applicant estimated the total heave to range from 0.03 to 0.91 cm (0.01 to 0.36 in.) and the largest estimated total heave to be less than 1.27 cm (0.5 in.). The applicant provided the summary of the heave calculation in SSAR Table 2.5.4-29 (TVA 2017-TN5387).

The applicant concluded that the settlement is largely attributed to the recompression of the rock. The applicant also concluded that the estimated heave and settlement are expected to be instantaneous, occurring during and shortly after construction. Therefore, the applicant expected no long-term settlement after construction. The applicant pointed out that further analyses of settlement, including differential settlement and heave, need to be performed as part of the COLA. In addition, the analyses must take into account construction practices, the specific technology selected, foundation dimensions, foundation loads, embedment depth, and construction sequence when performing foundation settlement evaluations.

2.5.4.1.10.5 *Lateral Earth Pressure*

SSAR Section 2.5.4.10.3 discusses the methodology to be used in the evaluation of lateral earth pressure exerted on foundation/structure walls below ground (TVA 2017-TN5387).

The applicant suggested the use of Rankine's solution (Bowles 1988-TN6103) for determining the static lateral earth pressure based on the assumptions that the ground surface behind the top of the wall is flat and there is no friction between the wall and backfill. In addition, the assumptions include internal friction angles of 30 degrees for granular backfill and 20 degrees for in situ soil. The applicant pointed out the need for evaluation of lateral pressures, including hydrostatic pressure, surcharge-induced (equipment and adjacent structures) pressure, and seismic-induced pressure. The applicant stated that the evaluation of these components and a full assessment of lateral earth pressure will be performed for the COLA.

2.5.4.1.11 Design Criteria

SSAR Section 2.5.4.11 summarizes the geotechnical design criteria discussed throughout SSAR Section 2.5.4 (TVA 2017-TN5387). For evaluation of liquefaction potential, the applicant used the criteria provided in RG 1.198 (NRC 2003-TN5906). These criteria specify that cohesive soils, with fines contents greater than 30 percent that are either classified as clays or have a PI greater than 30 percent, should generally not be considered susceptible to liquefaction. For its bearing capacity and settlement evaluation, the applicant used settlement

limits generally accepted in engineering practices: 15.2 cm (6 in.) for total settlement and 7.6 cm (3 in.) for differential settlement for large mat foundations. For footings, the respective settlement limits are 2.5 cm (1 in.) and 1.3 cm (0.5 in.).

The applicant emphasized that the design criteria and other geotechnical-related criteria related to structural design would be reevaluated or addressed in the COLA and will be specific to the selected technology.

2.5.4.1.12 Techniques to Improve Subsurface Conditions

SSAR Section 2.5.4.12 discusses the soil improvement techniques for the foundation areas of the safety-related structures (TVA 2017-TN5387).

The applicant stated that the impact of karst features on safety-related structures must be evaluated once the locations of these structures have been finalized. The applicant suggested using geophysical subsurface investigation methods to evaluate the presence of karst once the floor of the excavation is reached. The goal of this investigation is to detect any potential voids below the foundation level within a certain zone of influence (void zone of influence). The applicant stated that remediation methods, such as grouting, may be used if anomalies are identified and validated.

The applicant pointed out that it will likely be difficult to obtain a smooth, flat excavation surface due to the dipping stratigraphic units and adjustment of the rock mass. Dental concrete needs to be used, following proper procedures, to create a smooth and level foundation surface.

The applicant stated that an instrumentation plan needs to be developed for the COLA to monitor lateral and vertical displacement during excavation and construction. The applicant suggested installing slope inclinometers and horizontal extensometers to monitor slope movement, extensometers to monitor heave in subsurface materials due to the excavation, a settlement monitor device to monitor the vertical movement of the foundation, and piezometers to monitor changes in pore pressures.

2.5.4.1.13 Foundation Assessment Model

SSAR Section 2.5.4.13 presents a finite element method (FEM) model that was developed to determine potential karstic cavity impacts on SMR foundations (TVA 2017-TN5387). The model can also be used to evaluate bearing capacity and settlement for Locations A and B at 24.4 and 42.1 m (80 and 138 ft) depths at the CRN Site. This FEM model was created using PLAXIS 2D commercial software that is widely used in geotechnical and structural engineering practices.

The FEM model considered Locations A and B with different cross sections to account for different rock formations due to the dip of the stratigraphic layers. The model included a disturbed zone around the simulated cavity with appropriate material properties used for cohesion and friction angle. The model also included initial conditions, dewatering assumptions, excavation assumptions, and loading, similar to currently approved new reactor designs.

The FEM simulations examined the foundation stability under various postulated cavity sizes and locations below foundations. The applicant considered the cavity diameters of 1.5 m (5 ft), 3.0 m (10 ft), and 4.6 m (15 ft) based on site investigation boring data. The applicant also assumed the cavity would have infinite length in the horizontal direction; cavity depths of 1.5 m (5 ft) and 9.1 m (30 ft) below foundation embedment depths; foundation embedment depths of

12.2 m (40 ft), 27.4 m (90 ft), and 42.7 m (140 ft); and cavity locations on the edge of the nuclear island, the center of the nuclear island, and on or along bedding planes that were conservatively assumed to feature significant discontinuities or fracture zones.

The results of the FEM model analyses show that the larger cavity has a bigger impact on foundation stability, deeper cavities produce increased relative shear around the cavity, embedment depth does not affect the relative shear force around the cavities but vertical deformation increases for shallower cavity locations, and cavities located on bedding plane discontinuities or in bedding plane fracture zones are most critical and result in the highest shear around the cavity.

Based on the site geologic conditions derived from site investigation data and FEM analysis results, the applicant stated that about 99 percent of the cavities observed in Location A and B borings are significantly less than 3.4 m (11 ft) in height. In addition, cavity development in the CRN Site areas is generally limited to the most markedly weathered zone immediately below ground surface to depths less than 30.5 m (100 ft) and cavity-related failure has a higher potential to occur at depths less than 9.1 m (30 ft) from the ground surface. Given that the foundation embedment depths for SMR designs are much deeper than 9.1 m (30 ft), and that the 4.6 m (15 ft) critical cavity diameter determined by PLAXIS 2D modeling is much greater than that for 99 percent of the cavities observed at the CRN Site, the applicant concluded that the proposed Locations A and B are generally suitable for an SMR foundation.

The bearing capacity analysis showed that for Location A, the PLAXIS bearing capacity is 7,037 kPa (147 ksf), compared with 7,133 kPa (149 ksf) using the Bowles method (Bowles 1988-TN6103). For Location B, the PLAXIS bearing capacity is 5,122 kPa (107 ksf) compared with 5,170 kPa (108 ksf) using the Bowles method. The results indicate that the site bearing capacity estimated from the PLAXIS model simulation and using the methods described in SSAR 2.5.4.10 (TVA 2017-TN5387) are in reasonable agreement.

The applicant stated that for the COLA, foundation performance will be reevaluated after final technology selection, taking into account specific plant design, specific plant loads, and any potential ground improvement or grouting plans. Final foundation locations will also be reevaluated using specific plant information, with consideration of specific site stratigraphy, subsurface layering orientation, and specific fracture or bedding plane discontinuity zonation.

2.5.4.2 *Regulatory Basis*

The applicable regulatory requirements for the stability of subsurface materials and foundations are as follows:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to the requirement for an ESP applicant to prepare an SSAR that contains information about geologic and seismic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 50, Appendix S, “Earthquake Engineering Criteria for Nuclear Power Plants” (TN249), as it relates to the design of NPP SSCs important to safety to withstand the effects of earthquakes or deformation.

- 10 CFR 100.23, "Geologic and seismic siting criteria" (TN282), as it relates to the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of NPPs.
- 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants" (TN249), as it relates to the requirements of the QA program to be applied to the design, fabrication, construction, and testing of the SSCs of the facility.

The related acceptance criteria from SRP Revision 5, dated July 2014, Section 2.5.4 (NRC 2007/2018-TN5898) are listed below. Many of these acceptance criteria are not evaluated for an ESP, and are deferred to the COLA, as indicated in the Technical Evaluation section of this report:

- Geologic Features. In meeting the requirements of 10 CFR Parts 50 (TN249), 52 (TN251), and 100 (TN282), the section defining geologic features is acceptable if the discussions, maps, and profiles of the site stratigraphy, lithology, structural geology, geologic history, and engineering geology are complete and are supported by site investigations that are sufficiently detailed to obtain an unambiguous representation of the geology.
- Properties of Subsurface Materials. In meeting the requirements of 10 CFR Parts 50 (TN249), 52 (TN251), and 100 (TN282), the description of properties of underlying materials is considered acceptable if state-of-the-art methods are used to determine the static and dynamic engineering properties of all foundation soils and rocks in the site area to sufficient depths that impact behavior during construction and over the life of the facility, including during postulated seismic events.
- Foundation Interfaces. In meeting the requirements of 10 CFR Parts 50 (TN249), 52 (TN251), and 100 (TN282), the discussion of the relationship of foundations and underlying materials is acceptable if it includes:
  - a plot plan or plans showing the locations of all site explorations, such as borings, trenches, seismic lines, piezometers, geologic profiles, and excavations with the locations of the safety-related facilities superimposed thereon;
  - profiles illustrating the detailed relationship of the foundations of all seismic Category I and other safety-related facilities to the subsurface materials;
  - logs of core borings and test pits; and
  - logs and maps of exploratory trenches in the COLA.
- Geophysical Surveys. In meeting the requirements of 10 CFR 100.23 (TN282), the presentation of the dynamic characteristics of soil or rock is acceptable if geophysical investigations have been performed at the site and the results obtained therefrom are presented in detail.
- Excavation and Backfill. In meeting the requirements of 10 CFR Part 50 (TN249), the presentation of the data concerning excavation, backfill, and earthwork analyses is acceptable under the following conditions:
  - The sources and quantities of backfill and borrow are identified and are shown to have been adequately investigated by borings, pits, and laboratory property and strength testing (dynamic and static); long-term solubility properties and dissolution behavior during the life of the facility have been determined; and these data are included, interpreted, and summarized.

- The extent (horizontally and vertically) of all seismic Category I excavations, fills, and slopes are clearly shown on plot plans and profiles.
- Compaction specifications and embankment and foundation designs are justified by field and laboratory tests and analyses to ensure stability and reliable performance throughout the life of the plant.
- The impacts of compaction methods are incorporated into the structural design of the plant facilities.
- QC methods are discussed and the QA program is described and referenced.
- Control of groundwater during excavation to preclude degradation of foundation materials and properties is described and referenced. If backfill is to be placed under safety-related structures, proper ITAAC should be specified in the applicant's technical submittal to ensure that the static and dynamic properties of in-place backfill material will be the same as, or better than, the design parameters. In case cementitious construction material is to be placed under safety-related structures, proper ITAAC should be specified in the applicant's technical submittal to ensure that the cementitious backfill placed underneath any seismic Category I structures to a thickness greater than 5 ft, meets the design, construction, and testing of applicable ACI standards. In addition, the long-term behavior of the backfill subjected to any aggressive groundwater characteristics is evaluated.
- For sites where deeply embedded structures are involved, deep excavation techniques will likely use wall-retaining systems rather than a sloped excavation of the soil. Also, a description of the planned excavation technique(s) and design of the wall-retention system with sufficient details is provided and it should be able to demonstrate that the excavation technique used will not significantly affect the surrounding soil properties that are relied upon in the analysis and design of the foundation and plant structures.

- Groundwater Conditions. In meeting the requirements of 10 CFR Parts 50 (TN249), 52 (TN251), and 100 (TN282), the analysis of groundwater conditions is acceptable if the following are included in this subsection or cross-referenced to the appropriate subsections in SRP Section 2.4 of the applicant's technical submittal:
  - discussion of critical cases of groundwater conditions relative to the foundation settlement and stability of the safety-related facilities of the NPP.
  - plans for dewatering during construction and the impact of the dewatering on temporary and permanent structures. This includes consideration of the potential for substantial head and volume of water due to the deep excavation for the plant structures.
  - analysis and interpretation of seepage and potential piping conditions during construction.
  - records of field and laboratory permeability tests as well as dewatering-induced settlements.
  - history of groundwater fluctuations as determined by periodic monitoring of an adequate number of local wells and piezometers (flood conditions should also be considered).
  - evaluation of the chemical properties of the groundwater that may impact long-term behavior of the rock/soil/fill materials as well as structural elements (concrete and steel materials).

- Response of Soil and Rock to Dynamic Loading In meeting the requirements of 10 CFR Parts 50 (TN249), 52 (TN251), and 100 (TN282), descriptions of the response of soil and rock to dynamic loading are acceptable under the following conditions:
  - An investigation has been conducted and discussed to determine the effects of prior earthquakes on the soils and rocks in the vicinity of the site (evidence of liquefaction and sand cone formation should be included).
  - Field seismic surveys (surface refraction and reflection and in-hole and cross-hole seismic explorations) have been accomplished and the data have been presented and interpreted to develop bounding P and S wave velocity profiles.
  - Dynamic tests have been performed in the laboratory on undisturbed samples of the foundation soil and rock sufficient to develop strain-dependent modulus reduction and hysteretic damping properties of the soils and the results included. If generic soil degradation properties are used in the related preliminary analyses (e.g., site seismic response and soil-structure interaction (SSI) analyses), then reconciliation of the generic properties and laboratory testing results should be performed. The section should be cross-referenced with SRP Section 2.5.2.5.
- Liquefaction Potential. In meeting the requirements of 10 CFR Parts 50 (TN249), 52 (TN251), and 100 (TN282), if the foundation materials at the site adjacent to and under seismic Category I structures and facilities are saturated soils and the water table is above bedrock, then an analysis of the liquefaction potential at the site is required.
- Static and Dynamic Stability. In meeting the requirements of 10 CFR Parts 50 (TN249), 52 (TN251), and 100 (TN282), the discussions of static and dynamic analyses are acceptable if the stability of all safety-related facilities has been analyzed from a static and dynamic stability standpoint, including bearing capacity, rebound, settlement, and differential settlements under deadloads of fills and plant facilities; dynamic loads including "live" and seismic loads with consideration of loading sequences and combinations; and lateral loading conditions.
- Design Criteria. In meeting the requirements of 10 CFR Part 50 (TN249), the discussion of criteria and design methods is acceptable if the criteria used for the design, the design methods employed, and the factors of safety obtained in the design analyses are described and a list of references is presented.
- Techniques to Improve Subsurface Conditions. In meeting the requirements of 10 CFR Part 50 (TN249), the discussion of techniques for improving subsurface conditions is acceptable if plans, summaries of specifications, and QC methods are described for all techniques to be used to improve foundation conditions (such as grouting, vibroflotation, bridging mats, dental work, rock bolting, or anchors).

In addition, the geologic characteristics should be consistent with the appropriate sections of RG 1.28, "Quality Assurance Program Requirements (Design and Construction)" (NRC 2010-TN5872); RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (NRC 2015-TN5907); and RG 1.132 (NRC 2003-TN5902), RG 1.138 (NRC 2014-TN5903), and RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites" (NRC 2003-TN5906).

2.5.4.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.5.4 to verify that the information contained in the ESPA adequately addresses the required information related to the stability of subsurface materials and foundations (TVA 2017-TN5387). This section of the FSER provides the staff's evaluation of that information. The staff examined the information obtained through geophysical and geotechnical site investigations, which were conducted by the applicant to characterize the geologic conditions and subsurface materials at the CRN Site. The staff examined the applicant's field and laboratory investigation data and the methodologies used to determine the geotechnical properties of the soil and rock underlying the proposed ESP site. The staff also determined whether the applicant conducted its site investigations at an appropriate level of detail in compliance with the applicable regulations. The staff evaluated whether the applicant adequately determined the engineering properties of the subsurface materials at the site with consideration of uncertainties and variability. The staff reviewed the subsurface materials and foundation stability analyses, including liquefaction potential assessment, bearing capacity, and settlement estimates under possible static and dynamic (seismic) loadings, and the associated assumptions and methods. The staff reviewed the applicant's responses to the staff's RAIs along with related supplemental information and calculation packages.

On May 8 and 9, 2017, the staff conducted a site audit (NRC 2017-TN5908) to examine selected borings, cores, and samples, and to review the geology, seismology and geotechnical modeling and calculation packages. The audit enabled the staff to better understand the actual site conditions including surface and subsurface characteristics of the site, methods and procedures used in determination of soil and rock properties, and evaluations of subsurface material and foundation stabilities. The staff also identified additional information needed to assist its review of the CRN ESPA during this site audit.

2.5.4.3.1 Description of Site Geologic Features

SSAR Section 2.5.4.1 refers to SSAR Section 2.5.1 for a description of the geologic features at the CRN Site (TVA 2017-TN5387). Section 2.5.1.3 of this report presents the staff's evaluation of the geologic features. The staff reviewed the summary of the description and characterization of the site geology provided in SSAR Section 2.5.4.1, including the site-specific stratigraphy, and foundation stability conditions such as (1) stratigraphy; (2) previous loading history; and (3) discontinuities, shear-fracture zones and weathered fracture zones (TVA 2017-TN5387).

2.5.4.3.1.1 <u>*Stratigraphy*</u>

The staff concentrated its review on the stability of the stratigraphic units within the expected zone of influence at the PPE proposed foundation level of elevation 208.2 m (683 ft). The staff focused its review on the impact of the 33-degree inclination of the stratigraphic units at the CRN Site. Due to this inclination, various units may be exposed at the foundation elevation when the excavation is surfaced, making it critical for the staff to ascertain the geometrical components of these units, including the apparent thicknesses of the layers and their true inclinations. The staff examined boring logs taken from these locations and was able to map the interface between layers as described in the applicant's submittal. In addition, the staff reviewed the applicant's supplemental letter dated December 15, 2016 (TVA 2016-TN5909), in which the applicant provided a relational analysis of the CRN Site and the former CRBRP site, which are co-located in close proximity, as shown in SSAR Figures 2.5.1-30 and 2.5.1-51. The information in the aforementioned letter shows that the geologic units mapped in the CRBRP excavation (Fleanor Member and Rockdell Formation) are the same units as those occurring in

Location B of the CRN Site and have a similar inclination. During the May 2017 site audit, the staff reviewed CRN Site deep borings, MP 101 and MP 102, obtained from Location A of the CRN Site. Based on visual inspections, the staff was able to correlate the actual boundaries between geologic layers with the applicant's descriptions. Based on the aforementioned data, the staff concludes that the applicant adequately described the stratigraphy at the CRN Site.

2.5.4.3.1.2 *Previous Loading History*

The staff reviewed the references related to previous loading history at the CRN Site provided in SSAR Section 2.5.4.1.2 (TVA 2017-TN5387). The staff reviewed SSAR Figure 2.5.4.-1 and SSAR Table 2.5.4-2 where the applicant presented differences between the historic ground surface elevations prior to site development for the CRBRP subsurface investigation. The staff agrees with the applicant's assessment of the loading history at the site, based on up to 6.1 m (20 ft) of fill placed in the southern portion of the power block area, and up to 21.3 m (70 ft) of material removed from the central and northern portions.

2.5.4.3.1.3 *Discontinuities, Shear-Fracture Zones, and Weathered Fracture Zones.*

The applicant referred to SSAR Section 2.5.1.2.4 for a detailed discussion of discontinuities, shear-fracture zones, and weathered fracture zones at the CRN Site (TVA 2017-TN5387). The applicant described the shear-fracture zones as closely spaced, tightly healed, calcite-filled shear fractures having an average apparent thickness of about 1.2 m (4 ft). The staff reviewed SSAR Figures 2.5.1-65 through 2.5.1-67, which show a set of cross sections through all shear-fracture zone features encountered in borings drilled for the CRBRP and CRN Site subsurface investigations (TVA 2017-TN5387). The staff noted that a shear zone was reported to have been encountered during the subsurface investigation for the CRBRP in the lower portion of the Eidson Member. Similarly, the staff noted that a shear-fracture zone was identified within the Eidson Member for the CRN Site investigation. In addition, the staff noted that the applicant identified, in SSAR Figure 2.5.1-67, a shear-fracture zone in the Rockdell and Benbolt Formations (TVA 2017-TN5387). The staff noted that both shear fractures zones range in elevation between 228.6 and 137.2 m (750 and 450 ft). These representations provide evidence of shear-fracture zones at or close to the expected deepest foundation level of 208.2 m (683 ft). The applicant stated that detailed geologic mapping will be performed during excavation for the power block area to further characterize any shear-fracture zones encountered. As documented in TVA letter dated December 15, 2016 (TVA 2016-TN5909), the applicant committed to performing a detailed geologic mapping of excavation walls during excavation and construction, allowing documentation of the characteristics of dissolution features in the near-surface carbonate rock units and verification of the decrease in cavity size and abundance with depth. Section 2.5.3.4, "Geologic Mapping Permit Condition," of this chapter identifies Permit Condition 2.5-1 (Permit Condition 3) as the COL or CP applicant's responsibility to perform detailed geologic mapping of excavations for safety-related engineered structures at the CRN Site.

The staff reviewed SSAR Table 2.5.1-16 and noted that 52 fracture zones were listed and 10 of those zones occur below the power block area at an elevation of about 208.2 m (683 ft) NAVD 88 (TVA 2017-TN5387). In SSAR Section 2.5.4.3, the applicant stated that further evaluation of the shear-fracture zones and weathered fracture zones will be performed in support of the COLA, when the reactor technology is selected. Given that the site investigation data indicate that bedding fractures have weathering or weakening below the power block foundation level, and consistent with the applicant's stated intentions, the staff identified the following COL Action Item:

- COL Action Item 2.5-1: An applicant for a COL or CP referencing this ESP, upon selection of a final technology and site location, should conduct further evaluation of the shear-fracture zones and weathered fracture zones at the CRN Site.

Similar to the shear-fracture zone review, the staff independently reviewed boring logs and information in SSAR Table 2.5.1-16 (TVA 2017-TN5387) to ascertain the applicant's descriptions of the weathered fracture zones. The staff reviewed Appendix B of the Geotechnical and Exploration and Testing Data Report (AMEC 2014-TN6105) and noted that most borings drilled at the CRN Site indicate the presence of weathered or fracture zones within the stratigraphic units. In accordance with the applicant's descriptions, these zones typically represent poor to fair quality rock consisting of multiple, healed to open, slightly to highly weathered fractures or bedding planes, some calcite or dolomite filled, with occasional core loss and loss of drilling fluid reported, and with an apparent thickness of 0.9 m (3 ft).

In SSAR Section 2.5.1.2.6.3, the applicant indicated that the uppermost weathered zone is at a depth of 30.5 m (100 ft) or less from the surface, and that rock mass discontinuities become tighter, less frequent, and shorter as depth increases (TVA 2017-TN5387). The applicant described the condition of the joints as undulating to planar, rough to smooth to slickensided, very tight to open with tightly healed to slightly altered joint walls, and partially or wholly filled with calcite. The staff reviewed actual cores from selected borings during the site audit and observed discontinuities within the rock units. The staff asked the applicant, in eRAI 9035 (RAI no. 6), Question 2.5.4-1, to discuss how the inclined rock formation interfaces were taken into account when determining the rock mass properties (NRC 2017-TN5911). The staff evaluated some of the information from the applicant's RAI response (TVA 2017-TN5910) as described in the following text, and some additional evaluation of this RAI response in FSER Section 2.5.4.3.2.

As part of the response to eRAI 9035 (RAI no. 6), Question 2.5.4-1, the applicant used geotechnical coring logs, rock core photographs, ATV logs, and information about shear-fracture zones to characterize rock mass discontinuities and fracture zones (TVA 2017-TN5910). The applicant performed an assessment for bedding fractures and joints in 15 borings and found a total of 1,997 bedding joints and associated fracture zones ranging in depth from 18.4 to 163.9 m (60.4 ft to 537.8 ft). The applicant indicated that for the bedding joints at drilled depths greater than 30.5 m (100 ft) only 57 bedding joints and associated fracture zones have non-softening clay coatings to softening clay fillings less than 5 mm (0.2 ft) in thickness. In addition, the applicant performed an assessment based on ATV logs on 14 borings and identified 2,438 bedding structures ranging in depth from 2.6 to 163.7 m (8.4 to 537.1 ft) and a total of 860 fractures ranging in depth from 1.9 to 163.5 m (6.2 to 536.4 ft). The applicant indicated that for fracture zones at drilled depths greater than 30.5 m (100 ft), only 1.7 percent of the fracture zones were identified as open, planar, and with similar orientation to the average bedding orientation.

The staff reviewed the applicant's response to eRAI 9035 (RAI no. 6), Question 2.5.4-1 (TVA 2017-TN5910), and noted that the applicant's assessment of discontinuities, and weathered and shear-fracture zones, was primarily focused on results below 30.5 m (100 ft). The staff noted that observations from the CRBRP excavations are consistent with the CRN Site investigation data regarding the depth of weathering and improvement in rock mass discontinuity conditions below a depth of 30.5 m (100 ft). While reviewing the CRBRP observations from construction excavation, the staff noted that the excavation for the CRBRP nuclear island was about 30.5 m (100 ft) deep. The staff reviewed the ATV data provided in Appendix C of the Geotechnical and Exploration and Testing Data Report (AMEC 2014-TN6105) and was able to confirm the

applicant's assertion that most discontinuities occur along bedding planes and within weathered rock in the upper 30.5 m (100 ft) of bedrock.

2.5.4.3.1.4 *Karst Features*

The applicant referred to SSAR Section 2.5.1.2.5 for a detailed analysis of karst features at the CRN Site (TVA 2017-TN5387). The staff focused its review on the applicant's PLAXIS 2D FEM model described in its supplemental letter dated July 3, 2017 (TVA 2017-TN5912), and the applicant's description of karst features. The staff reviewed Appendix D of the applicant's supplemental letter, which includes a table that summarizes all cavities observed in the CRN Site borings. The staff noted that a total of 233 cavities were reported by the applicant, 26 of which are below elevation 225.6 m (740 ft) (shallowest embedment structure foundation depth considered), and the biggest cavity, with a height of 2.9 m (9.5 ft), was found at a median elevation of 224.1 m (735.4 ft) in the Eidson Member.

The staff reviewed multiple boring logs within the power block area, including field notes and descriptions of these features. The staff paid particular attention to boring log MP-424, which shows the presence of considerably large cavities close to the deepest foundation level. Boring MP-424 shows four cavities within approximately 6.1 m (20 ft) of the ground at elevation 208.2 m (683 ft) and with a maximum height of 1.3 m (4.3 ft). In addition, the staff reviewed SSAR Table 2.5.1-11 (TVA 2017-TN5387), which shows all identified cavities in boreholes drilled at the site for the CRBRP investigation (1973–1978) and for the CRN investigation (2013). The staff noted that cavities are present in each of the stratigraphic units at the site and have heights ranging from less than 0.3 m (1 ft) to approximately 5.2 m (17 ft). The staff also reviewed SSAR Figures 2.5.1-51 and 2.5.1-52, which show the spatial distribution of the karst features at the site (TVA 2017-TN5387). The staff noted that most of the cavities occur within approximately 30.5 m (100 ft) of the ground surface, and are located mostly in the Rockdell Formation and the Eidson Member, which are the two strata located next to the foundation strata for CRN Locations A and B.

The applicant developed a FEM model using PLAXIS 2D to evaluate the potential impacts of karstic cavities on SMR foundations. The staff's review of this analysis focused on assessing the suitability of the site as it relates to the critical size of a cavity that can affect foundation stability. The applicant modeled a foundation using a typical NPP layout to determine the analysis input parameters, including foundation dimension, thickness, loading, and deformation limits. In addition, the applicant accounted for varying dip of the stratigraphic layers and included a disturbed zone around the simulated cavity with appropriate material properties. The applicant used, for the nuclear island basemat area, a final plant grade at elevation 250.2 m (821 ft) NAVD88 and considered multiple embedment depths (12.2 m [40 ft], 27.4 m [90 ft] and 42.7 m [140 ft]) below the ground surface. The applicant evaluated three cavity sizes—1.5 m (5 ft), 3.1 m (10 ft), and 4.6 m (15 ft)—and two different cavity depths below the foundation level—1.5 m (5 ft) and 9.1 m (30 ft)—at multiple cavity locations (edge of the nuclear island, center of the nuclear island, and along bedding planes) for site Locations A and B under static loading conditions. The staff noted that selected cavity sizes are similar to those observed during field investigations, and the postulated locations of cavities along bedding planes replicated the presence of shear-fracture zones. The applicant evaluated the potential collapse of cavities in terms of relative shear. The applicant selected a critical relative shear of 0.85 (85 percent of the material strength) to provide a margin of safety. The staff reviewed SSAR Table 2.5.4-34, which includes the model analysis results for Locations A and B (TVA 2017-TN5387). The staff noted that for all evaluated foundation depths, the analysis results indicate that the most critical condition is a postulated cavity having a diameter of 4.6 m (15 ft) located either on a bedding

plane discontinuity or in a bedding plane shear-fracture zone. Based on its review of the FEM model, the staff concludes that the applicant conducted an appropriate preliminary evaluation to determine potential karstic cavity impacts on SMR foundations. This analysis should be site and technology specific. Therefore, a COL or CP applicant referencing the CRN ESP, should consider, at a minimum, the following: specific plant design, loads, ground improvement, grouting plans, final foundation location, site stratigraphy, subsurface layering orientation, and specific shear failure or bedding plane discontinuity zones. The staff identified the following COL Action Item for the reevaluation of foundation performance upon selection of a final technology and site location:

- COL Action Item 2.5-2: Upon selection of a final technology and site location, an applicant for a COL or CP referencing this ESP, should reevaluate the potential for karstic cavity impacts, within the zone of influence of the foundation under all design loading conditions, and on foundation stabilities for safety-related structures. The evaluation should be performed using a method that can adequately model foundation performance under actual site geologic conditions and specific loading conditions. In the evaluation, detailed information should be provided to address the site subsurface geologic characteristics, foundation dimension and embedment depth, the lateral location of the foundation with respect to the bedding planes and shear-fracture zones, location and dimension of voids, the shear strength at the bedding planes and shear-fracture zones, the in situ stresses around the foundations, and proper subsurface material properties to be used. The analysis should also take into account undetected cavities that could adversely affect foundation performance and include details related to the expected size of such a potential cavity.

The staff reviewed supplemental information to the ESPA by letter dated December 15, 2016, (TVA 2016-TN5909), which presented a comparison of the CRN Site with the CRBRP site with respect to geologic formation, rock type, geologic structure, and character of karst and voids/cavities encountered at and below foundation depths. The staff also reviewed SSAR Figures 2.5.1-75 through 2.5.1-77, which depict the average elevation of cavity and cavity size from the CRN and CRBRP site investigations (TVA 2017-TN5387). The staff noted that for both site investigations, the majority of the cavities occur within approximately 30.5 m (100 ft) of the ground surface. The staff compared SSAR Figures 2.5.1-50 and 2.5.1-37 (TVA 2017-TN5387), which show the geologic mapping for the CRBRP and CRN Site investigations, respectively. The staff noted that karst-related features include large funnel-shaped and dish-shaped sinkholes, and that both site investigations identified small holes in the ground. The staff also noted that the applicant-mapped surface features for the CRN Site using high-resolution LiDAR topographic data, and identified the same two major sinkhole clusters, along with several additional sinkholes.

In the same supplemental information (TVA 2016-TN5909), and in SSAR Section 2.5.1.2.6.10 (TVA 2017-TN5387), the applicant provided a mitigation plan outlining additional actions to be detailed in the COLA. These actions will be completed as a part of the site excavation and construction to confirm the current understanding of karst features at the CRN Site; to ensure that the size, distribution, and extent of karst cavities are sufficiently understood; and to understand the potential impact of the cavities on safety-related structures. The applicant's mitigation plan includes detailed geologic mapping of the excavation floor, development of a grouting program; and additional geophysical surveys to detect and address possible cavities at and below the foundation levels. The staff agrees that this plan is needed to fully map and assess the presence of karst features, including open or filled cavities, at or below the expected foundation depths. FSER Section 2.5.3.4 identifies Permit Condition 2-5-1 (Permit Condition 3) as the COL or CP applicant's responsibility to perform detailed geologic mapping of excavations

for safety-related engineered structures at the CRN Site. Consistent with applicant's statements in SSAR Section 2.5.1.2.6.10 (TVA 2017-TN5387) and the applicant's supplemental information (TVA 2016-TN5909), the staff identified the following COL Action Item:

COL Action Item 2.5-3: An applicant for a COL or CP referencing this this ESP should conduct additional surface geophysical surveys during excavation to detect cavities below the foundation elevation that could adversely affect foundation performance. In addition, the applicant should perform confirmatory drilling or borehole testing during excavation to characterize any geophysical anomalies detected. Finally, if needed, the applicant should develop a grouting program based on the information obtained from the geologic mapping, geophysical surveys, and specific analyses, to mitigate the effect of voids or cavities on foundation performance at and below the foundation levels of safety-related structures. If a grouting program is needed, the associated ITAAC should be specified.

Based on its review, the staff concludes that the applicant provided sufficient information to characterize karst features at or below the expected foundation elevation at the CRN Site for the ESP. In addition, the staff finds that the applicant conducted an appropriate preliminary evaluation to determine potential karstic cavity impacts on SMR foundations. The staff acknowledges that more detailed information regarding the presence of karst features at or below the expected foundation level needs to be provided in a COL or CP application.

2.5.4.3.1.5 *Unrelieved Stresses in Bedrock*

The applicant refers to SSAR Section 2.5.1.2.6 for a complete discussion of unrelieved stresses in the bedrock at the CRN Site (TVA 2017-TN5387). The staff focused its review on the applicant's description of unrelieved stresses in the bedrock at close proximity to the expected foundation elevation of 208.2 m (683 ft). The staff noted that during the expected excavation process, removal of overburden may cause current discontinuities close to the surface of the excavation to open and may also create new discontinuities due to the release of overburden stress. The staff acknowledges that blasting techniques would likely be used during the excavation process that may also cause additional discontinuities within the bedrock especially adjacent to the foundation. The staff noted that the applicant considered this disturbed zone as part of the rock mass properties characterization. The staff evaluated the rock mass properties characterization in Section 2.5.4.3.2.8 of this report.

2.5.4.3.1.6 *Conclusions Regarding Site Geological Features*

Based on the review of SSAR Section 2.5.4.1 (TVA 2017-TN5387), the staff concludes that the applicant provided sufficient information to characterize geologic features at or below the expected foundation elevation for the current ESP, and meets the requirements of 10 CFR 100.23 (TN282). In addition, the staff proposed Permit Conditions 2.5-1 and 2.5-2 (Permit Conditions 3 and 4), as described in FSER Sections 2.5.3.4 and 2.5.4.4, respectively, to be imposed on the ESP for the CRN Site, if granted, to address geohazard-related safety matters; and as described in COL Action Items 2.5-1 through 2.5-3, the staff identified issues that shall be addressed by a COL or CP applicant referencing the ESP for the CRN Site, if granted.

2.5.4.3.2 Properties of Subsurface Materials

The staff focused its review of SSAR Section 2.5.4.2 (TVA 2017-TN5387) on the applicant's description of the static and dynamic engineering properties of the CRN Site subsurface materials, and the methods used to determine the engineering properties. The staff reviewed

the applicant's field investigation methods and the laboratory testing program as well as the assumptions used to determine the engineering properties. The staff performed its review in accordance with the guidance in RG 1.132 (NRC 2003-TN5902), RG 1.138 (NRC 2014-TN5903), RG 1.208 (NRC 2007-TN5858), and SRP Section 2.5.4 (NRC 2007/2018-TN5898).

2.5.4.3.2.1 *Description of Subsurface Materials*

The staff reviewed the information provided in SSAR Section 2.5.4.2.1.1 and SSAR Table 2.5.4-3, which shows depths and thicknesses of existing fill and residual soil encountered in the borings at the CRN Site (TVA 2017-TN5387). The staff reviewed boring logs obtained from the site subsurface investigation and noted consistency in the depths and thicknesses shown in the aforementioned table. The staff noted that the applicant used standard industry methods to describe the properties of the fill. The applicant classified the soil as a CH clay based on the USCS (ASTM D2487 [ASTM 2000-TN6085]). Based on its review, the staff agrees with the applicant's classification of existing fill and residual soils and the applicant's assessment of fill and soil thicknesses.

The applicant stated that the backfill surrounding the safety-related structures consists of both lean concrete and granular backfill; the lean concrete extends from the foundation level to the top of the rock, and granular backfill extends from the top of rock to the finished grade. The applicant provided a detailed description of the proposed backfill material in SSAR Section 2.5.4.5 (TVA 2017-TN5387). The staff's evaluation of backfill is provided in Section 2.5.4.3.5 of this report.

In SSAR Section 2.5.4.2.1.3, the applicant described the information related to weathered rock that was encountered in most of the borings drilled at the site (TVA 2017-TN5387). The staff reviewed information provided by the applicant to support its description of weathered rock at the CRN Site, including RQD values, V_S values, and rock core photographs. The applicant reviewed RQD values in accordance with ASTM D6032 Standard (ASTM 2002-TN6094) to further define the thickness of weathered rock and the corresponding depth to the bedrock. The applicant used RQD values equal to or less than 25 percent to represent very poor quality rock, and V_S values that are significantly lower than the average shear wave velocity value of the same rock formation to define the zone of the weathered rock. The applicant determined the maximum thickness of weathered rock at the CRN Site to be approximately 11.9 m (39 ft). The staff noted that the applicant used state-of-the-art methods to properly characterize the extent of weathered rock at the CRN Site. The applicant indicated that weathered rock would be excavated prior to the construction of foundation so that safety-related structures will be founded on competent subsurface materials. This will be ensured through Permit Condition 2.5-2 (Permit Condition 4), which is described in Section 2.5.4.4.

The staff reviewed the subsurface profiles and materials described in SSAR Sections 2.5.4.2.1.3 through 2.5.4.2.1.11 (TVA 2017-TN5387). The staff reviewed SSAR Figure 2.5.4-2, which shows the bedrock structure and succession of the stratigraphic units underneath the power block area. The stratigraphic units encountered at the site include the Benbolt Formation, Rockdell Formation, Fleanor Member (Lincolnshire Formation), Eidson Member (Lincolnshire Formation), Blackford Formation, and Newala Formation. FSER Table 2.5.4-1, summarizes the characteristics and properties of these formations (TVA 2017-TN5387). The staff focused its review on the Benbolt Formation and the Fleanor Member of the Lincolnshire Formation, which are the stratigraphic units on which the power block of the NPP is expected to be founded. The applicant described the Benbolt Formation as a gray limestone that is strong, very thinly bedded, and locally moderately bedded. The applicant also described the Benbolt

Formation as a nodular limestone with little to some laminated to thinly bedded calcareous siltstone. The staff noted that the average vertical thickness of the formation is approximately 100.6 m (330 ft) and that the RQD averages 88 percent, which is indicative of a good quality rock. The applicant described the Fleanor Member as a red bedrock that is medium strong, to strongly laminated, to medium bedded calcareous siltstone with few to little gray micritic limestone layers. The staff noted that the average vertical thickness of the formation is approximately 78.3 m (257 ft) and that the RQD averages 89 percent, which is indicative of a good quality rock. The staff noted that the applicant used standard industry methods and techniques to describe the stratigraphic units at the site. The staff reviewed boring logs, field notes, and photographs to verify the applicant's descriptions of the stratigraphic units at the site. Based on its review of the information provided, the staff concludes that the applicant appropriately described the stratigraphic units at the CRN Site.

2.5.4.3.2.2 *Field Investigations*

The applicant referred to SSAR Section 2.5.4.3 and 2.5.4.4 for details about field investigations and geophysical surveys performed at the CRN Site (TVA 2017-TN5387). The applicant indicated that the field investigation was performed in accordance with RG 1.132 (NRC 2003-TN5902). The staff's evaluation of the applicant's field investigations and geophysical surveys performed for the CRN Site is presented respectively in Sections 2.5.4.2 and 2.5.4.1.4 of this report.

2.5.4.3.2.3 *Laboratory Testing*

The staff reviewed SSAR Section 2.5.4.2.3 related to the laboratory testing program performed by the applicant to identify, classify, and evaluate the physical and engineering properties of the soil and rock at the CRN Site (TVA 2017-TN5387). The applicant conducted the laboratory testing program in accordance with an approved QA program following the guidance presented in RG 1.138 (NRC 2014-TN5903). The staff reviewed SSAR Table 2.5.4-7 (TVA 2017-TN5387), which lists the types and numbers of tests completed for the CRN Site subsurface investigation. The staff reviewed the test results for soil and rock core samples described in the SSAR. The staff noted that the applicant used soil samples to obtain basic characteristics such as grain size, natural moisture content and plasticity, and the shear strength and compaction characteristics. The applicant used rock samples to obtain the unit weight, specific gravity, compressive strength, shear and elastic moduli, Poisson's ratio, slake durability, and calcium carbonate content. The staff reviewed Appendices F through H of the Geotechnical and Exploration and Testing Data Report (AMEC 2014-TN6105), which contains details and references for the industry standards used for the testing. The staff concludes that the applicant used proper standard industry methods and performed a wide array of laboratory tests to determine soil and rock properties for the CRN Site in appropriate detail to satisfy its review of the CRN Site ESPA.

2.5.4.3.2.4 *Engineering Properties*

The staff reviewed SSAR Section 2.5.4.2.4, which presents the engineering properties of the soil, weathered rock, intact rock, and rock mass (TVA 2017-TN5387). The staff focused its evaluation on the methods used to develop the properties, which are derived from the subsurface investigation and laboratory testing program. The staff reviewed SSAR Table 2.5.4-21, which contains the selected engineering property values for the subsurface materials at the CRN Site.

2.5.4.3.2.5 *Soil Properties*

The applicant determined soil properties based on the results of its field and laboratory testing programs. The staff reviewed the summary of the field-measured N values presented in SSAR Table 2.5.4-8 and the recommended SPT N_{60} values presented in SSAR Table 2.5.4-21 (TVA 2017-TN5387). The staff noted that for the recommended SPT N_{60} values, the applicant corrected the field values for factors of energy, boring diameter, sampler type, and rod length. The staff reviewed a summary of the results of the sieve analyses, natural moisture contents, and Atterberg limits performed on fill and residual soil samples. The staff agrees with the applicant classification of both the existing fill and residual soils as high plastic clays. The applicant used methods such as unconsolidated triaxial testing and empirical relationships to characterize the undrained shear strength. The applicant determined the drained shear strength, effective cohesion, and internal friction angle from the CU triaxial testing. The applicant used P-S velocity methods for the shear and compression wave velocity measurements and calculated Poisson's ratio and shear modulus. The staff reviewed all information related to the characterization of the geotechnical engineering properties of the soils presented in SSAR Table 2.5.4-21 (TVA 2017-TN5387), and concludes that the applicant provided representative values for the soils at the CRN Site. The staff concludes that the applicant used appropriate standard industry methods and tests to characterize the soil properties at the CRN Site and to satisfy its review of the CRN Site ESPA.

2.5.4.3.2.6 *Weathered Rock Properties*

The staff reviewed SSAR Section 2.5.4.2.4.2, which describes the properties of weathered rock at the CRN Site (TVA 2017-TN5387). The applicant developed the engineering properties of the weathered rock for use in the site seismic response analysis. The staff noted that the applicant developed the properties from in situ testing and material correlations. The staff reviewed Appendix C of the Geotechnical and Exploration and Testing Data Report (AMEC 2014-TN6105) and noted that a limited number of V_S and V_P measurements were taken in the weathered rock as part of the field testing program. The staff acknowledge that the applicant will excavate all weathered rock during construction, if needed, and identified Permit Condition 2.5-2 (Permit Condition 4), which is described in Section 2.5.4.4 of this report as the responsibility of COL or CP applicant.

2.5.4.3.2.7 *Intact Rock Properties*

The staff reviewed SSAR Section 2.5.4.2.4.3, which contains the intact rock properties developed for the stratigraphic units encountered underneath the power block areas (TVA 2017-TN5387). The applicant determined the properties based on the results of the laboratory and field testing programs performed at the CRN Site. The staff reviewed SSAR Table 2.5.4-21 (TVA 2017-TN5387), which contains the selected values of the engineering properties that characterize the rock formations of the Bentbolt, Rockdell, Blackford and Newala Formations and the Fleanor and Eidson Members.

The staff reviewed the unconfined compressive strength for each formation, which is considered one of the most important intact rock properties for foundation design. The applicant presented a summary of the unconfined compression test results in SSAR Table 2.5.4-15 (TVA 2017-TN5387). The staff noted that the average unconfined compressive strength values of 31 to 137.9 MPa (4,500 to 20,000 psi) for all rock formations are reasonable, and indicative of intact rock behavior. The staff reviewed SSAR Figures 2.5.4-5 and 2.5.4-6 (TVA 2017-TN5387), which plot the V_S and V_P measurements for each stratigraphic unit against depth, and noted that

the test values are typical for the rock formations. The staff reviewed SSAR Table 2.5.4-19, which provides the slake durability index test results as a measure of the susceptibility of rock to disintegrate when exposed to moisture. The staff noted high durability indices, above 94 percent on average, for the Benbolt, Rockdell, Blackford Formations and for the Fleanor Member. The staff reviewed the applicant's calcium carbonate content test results presented in SSAR Table 2.5.4-20 (TVA 2017-TN5387). The staff noted that the Benbolt Formation had a 27 percent calcite equivalent but only one test was performed. The applicant performed five tests on the Fleanor Member resulting in an average of 34 percent of calcite equivalent. The Rockdell Formation and Eidson Member tests resulted in more than 53 percent of calcite equivalent, on average. For the Newala Formation, the staff noted 84 percent of calcite equivalent on average; only two tests were performed on this formation. The applicant performed one test on the Blackford Formation with a result of 39 percent of calcium equivalent. The applicant also performed pressuremeter testing and provided the shear moduli at various levels of strain. The staff noted that results are indicative of a strain-hardening behavior. The staff acknowledge that the applicant used appropriate standard industry methods and tests to characterize the intact rock properties at the CRN Site and to satisfy its review of the ESPA.

2.5.4.3.2.8 _Rock Mass Properties_

The staff reviewed SSAR Section 2.5.4.2.4.4 (TVA 2017-TN5387) and focused its review on the applicant's description of the rock mass properties. The applicant accounted for discontinuities and other features when characterizing the rock mass properties of the stratigraphic units. In SSAR Section 2.5.4.2.4.4, the applicant stated that the rock mass properties are determined using the GSI classifications of the stratigraphic units (TVA 2017-TN5387). The site investigation data indicate the presence of rock discontinuities and fractures in the stratigraphic units, and that the weathered or fracture zones typically occur along bedding planes at the CRN Site. The discontinuities and fracture zones may result in predetermined shear failure surfaces. Because the GSI chart may not be applicable when structural planes of inclined rock surfaces control the failure of a rock mass, the staff asked the applicant, in eRAI-9035 (RAI No. 6), Question 02.05.04-01 (NRC 2017-TN5911), to discuss how the inclined rock formation interfaces were taken into account when determining the rock mass properties.

The applicant provided a response to eRAI-9035 (RAI No. 6), Question 02.05.04-01, in Response Letter CNL-17-099 dated September 15, 2017 (TVA 2017-TN5910). In its response, the applicant stated that the use of the GSI classification system is applicable to rock masses featuring many joint sets that create interlocking blocks of rock and where the block sizes are small relative to the length of the potential failure surface. Therefore, the applicant concluded that use of the GSI classification system is applicable to the CRN Site. The applicant combined the inspection of rock cores, interpretation of downhole geophysical survey data, and observations made during field mapping for the CRBRP site to characterize the discontinuities of the rock units and rock mass properties of inclined rock units, and to determine whether the presence of continuous weathered or fracture zones could provide a predetermined failure plane. The applicant concluded that weathered and fracture zones are mostly encountered in the uppermost 30.5 m (100 ft), and that the rock mass below 30.5 m (100 ft) is typically tighter and contains less frequent and less persistent discontinuities, and therefore do not result in predetermined failure surfaces. In addition, the applicant stated that this conclusion is supported by its observation from the grouting program conducted at the CRBRP site.

The staff evaluated the applicant's response to eRAI-9035 (RAI No. 6), Question 02.05.04-01 (TVA 2017-TN5910). As documented in Section 2.5.4.3.1.3 of this report, the staff reviewed the applicant's evaluation of weathered and fracture zones. The staff reviewed boring logs and

SSAR Table 2.5.1-16 (TVA 2017-TN5387) to confirm the applicant's descriptions of the weathered fracture zones. The staff reviewed ATV data provided in Appendix C of the Geotechnical and Exploration and Testing Data Report (AMEC 2014-TN6105) and was able to confirm the applicant's assertion that most discontinuities occur along bedding planes and within weathered rock in the upper 30.5m (100 ft) of bedrock. Therefore, there is no sufficient evidence to support the existence of predetermined failure surfaces below the proposed CRN Site foundation level. The staff reviewed "Quantification of the Geological Strength Index Chart" (Hoek et al. 2013-TN6106) to evaluate the applicability of the GSI classification system used for estimating the mechanical properties of the rock masses at the CRN Site. This reference indicates that one important assumption for the GSI classification system is that if a site contains several discontinuity sets that are sufficiently closely spaced, relative to the size of the structure under consideration, then the rock mass can be considered homogeneous and isotropic. The staff acknowledged the presence of many joint sets and discontinuities at the CRN Site, and that the weathered and fracture zones are typically tighter and contain less frequent and less persistent discontinuities below 30.5 m (100 ft) from the ground surface. The staff also notes the applicant's assertion that the power block area excavation is expected to be much larger than the rock blocks that make up the rock mass at the site. Based on its review of the applicant's RAI response, the staff concludes that the GSI classification system is applicable for the estimation of the rock mass properties at the CRN Site. Accordingly, the staff considers Question 02.05.04-01 (TVA 2017-TN5910) resolved.

The applicant developed the rock mass strength using the generalized Hoek-Brown failure criterion available in the computer program RocData. The staff acknowledges that the GSI is a key input parameter in the Hoek-Brown failure criterion, and reviewed SSAR Table 2.5.1-15 (TVA 2017-TN5387), which contains the summary of the GSI parameter for each stratigraphic unit. The staff noted the applicant's recommended GSI range values of 70 to 80 percent for the Benbolt Formation and 65 to 85 percent for the Fleanor Member. Those rock formations are the proposed embedment foundation strata. The staff concludes that these GSI values are reasonable based on the applicant's subsurface investigation results and the staff's examination of rock cores during its May 2017 site audit. The staff reviewed the RocData input and output parameters for each stratigraphic unit to evaluate the rock mass strength and deformation modulus determination, as summarized in SSAR Table 2.5.4-22 and SSAR Table 2.5.4-23 (TVA 2017-TN5387). The applicant developed the deformation modulus using three empirical models available in RocData, and presented its results in SSAR Table 2.5.4-25. The staff reviewed the results and noted that for a GSI of 80 percent the rock mass compressive strength is approximately one-third of the intact compressive strength. However, the staff also noted that in several cases when using the lower range of the GSI, the rock mass compressive strength values are significantly lower than one-third of the intact compressive strength. Although the staff concludes that the applicant used appropriate methods to estimate the rock mass properties of the stratigraphic units at the CRN Site, it is known that the strength of fractured zones, discontinuities, and jointed rock is generally less than that of the individual units of the rock mass and that the empirical methods have a high degree of uncertainty. Therefore, the staff identified the following COL Action Item:

- COL Action Item 2.5-5: An applicant for a COL or CP referencing this ESP should perform additional testing to determine rock mass properties and to further characterize the rock shear strength along the bedding planes with discontinuities and fracture zones in areas where the safety-related structures will be located.

Based on its review of SSAR Section 2.5.4.2 (TVA 2017-TN5387) and the applicant's response to the RAI question discussed above (TVA 2017-TN5910), the staff concludes that the applicant

adequately determined the engineering properties of the soil and rock underlying the CRN ESP site following state-of-the-art methodologies for its field and laboratory investigations.

2.5.4.3.2.9 *Conclusions Regarding Properties of Subsurface Materials*

Based on the review of SSAR Section 2.5.4.2 (TVA 2017-TN5387), the staff concludes that the applicant adequately described the subsurface materials and properly determined the engineering properties of the subsurface materials at the CRN Site, and therefore meets the requirements of 10 CFR 100.23 (TN282). In addition, as described in COL Action Item 2.5-5, the staff identified issues that shall be addressed by a COL or CP applicant referencing the ESP for the CRN Site, if granted.

2.5.4.3.3 Foundation Interfaces

In SSAR Section 2.5.4.3, the applicant described the foundation interface conditions at the CRN Site based on a comprehensive geotechnical exploration and testing program (TVA 2017-TN5387). This program included borehole drilling and sampling, in situ geophysical testing, and observation well installation and testing, as well as laboratory testing.

In addition to the subsurface investigation programs performed for the CRBRP, the CRN Site subsurface investigation included 82 exploratory borings, three test pits, 44 observation wells, and two surface geophysical tests—reflection and refraction tests. The applicant performed downhole geophysical tests in 28 borings, rock pressuremeter tests in two borings, field permeability tests, and groundwater level monitoring in the observation wells.

The applicant chose two specific locations, Location A and Location B, as candidates for power block location that are illustrated in Figure 2.5.4-1. This non-unique power block area selection was based on the dipping strata at the CRN Site that result in the presence of varying stratigraphic units beneath the potential power block area, and the possibility that multiple reactor units will be built at the site.

The staff focused its review of SSAR Section 2.5.4.3 (TVA 2017-TN5387) on the relationship between the planned foundations for safety-related structures and the engineering properties of the underlying materials. The CRN Site consists of a succession of stratigraphic units with a dip angle of about 33 degrees. Discontinuities, shear-fracture zones, and weathered/fracture zones are all encountered in the stratigraphic units. This special geologic condition will affect the determination of rock engineering properties and the stability analyses of foundations and subsurface materials.

The staff reviewed the cross sections provided in SSAR Figures 2.5.4-2 and 2.5.4-12 in detail (TVA 2017-TN5387), and the results of all subsurface investigations conducted at the CRN Site. The staff finds that the applicant conducted sufficient site investigations and provided adequate descriptions of the subsurface material conditions for the ESPA.

2.5.4.3.3.1 *Conclusions Regarding Foundation Interfaces*

The staff concludes that the applicant provided an acceptable characterization of the relationship between foundations and underlying materials at the CRN Site, based on the results of geotechnical exploration. In addition, the applicant’s testing methods are consistent with industrial standards and common engineering practices. The staff concludes that the applicant’s evaluation of foundation interfaces is acceptable.

2.5.4.3.4 Geophysical Surveys

The staff focused its review of SSAR Section 2.5.4.4 (TVA 2017-TN5387) on the adequacy of the applicant's geophysical investigations to determine the soil and rock dynamic properties. The applicant provided a summary of geophysical surveys for the CRBRP site and compared these results with the measurements obtained from the CRN Site investigation. These surveys consisted of seismic refraction and reflection, electrical resistivity, spontaneous potential, and a suite of downhole geophysical tests, including suspension P-S velocity logging, ATV, and other downhole logging data.

The staff reviewed the applicant's use of the latest geophysical and geotechnical testing methods and equipment, as well as the applicant's results that detail the dynamic properties of the soil and rock underlying the site, in accordance with the requirements in 10 CFR 100.23 (TN282) and guidance outlined in RG 1.132 (NRC 2003-TN5902).

The staff examined the results of the applicant's geophysical surveys and paid special attention to the V_S and V_P profiles. The staff reviewed SSAR Figures 2.5.4-5 and 2.5.4-6 (TVA 2017-TN5387), which show the V_S and V_P profiles developed from the downhole geophysical testing and suspension velocity logging for each of the stratigraphic units. The staff also reviewed SSAR Figure 2.5.4-7, which shows the seismic tomography models for the CRN Site (TVA 2017-TN5387). The staff noted that the applicant conducted a series of geophysical surveys using different methods that provide sufficient and reliable data to determine the in situ dynamic properties of soil and rock at the CRN Site.

2.5.4.3.4.1 <u>*Conclusions Regarding Geophysical Surveys*</u>

Based on its review of SSAR Section 2.5.4.4 (TVA 2017-TN5387), the staff concludes that the applicant used acceptable geophysical survey methods that are up-to-date and commonly used in current engineering practices to determine seismic wave velocity for soil and for each of the rock formations at the CRN Site. The staff further concludes that the applicant adequately determined the dynamic properties of soil and rock based on the results of the geophysical surveys conducted at CRN Site and meets the requirements of 10 CFR 100.23 (TN282).

2.5.4.3.5 Excavation and Backfill

The staff focused its review of SSAR Section 2.5.4.5 (TVA 2017-TN5387) on the extent of anticipated excavations for safety-related structures, fills and slopes, excavation methods and stability, backfill sources, QC, and ITAAC.

2.5.4.3.5.1 <u>*Extent of Excavations, Fill and Slopes*</u>

The applicant proposed two locations, Location A and Location B, as the center of the planned reactors and a suggested finished plant grade at an elevation of 250.2 m (821 ft). The applicant anticipated that the bottom of the basemat of the most deeply embedded safety-related power block structures will not exceed a depth of 42.1m (138 ft) below the finished grade, will be founded on rock, and the lateral extent of the excavation will be on the order of 4.6 m (15 ft) beyond the exterior face of the perimeter walls to provide working room for construction and backfilling of the exterior walls.

The applicant stated that because excavation sidewalls are expected to be vertical or near vertical due to the depth of excavation, stability measures, such as the use of tied-back sheet piles and surface-mounted cranes, may be required.

Because the applicant specified that design of the excavation will be done for the detailed design and construction work, the staff identified the following COL Action Item:

- COL Action Item 2.5-6: An applicant for a COL or CP referencing this ESP should provide specific details regarding the lateral and vertical extent of the excavation consistent with the selected reactor technology.

2.5.4.3.5.2 *Excavation Methods and Stability*

The staff reviewed the applicant's description of excavation methods and associated stability issues in SSAR Section 2.5.4.5.2 (TVA 2017-TN5387).

The applicant stated that conventional earthmoving equipment can be used for excavation in existing fill/residual soil and weathered rock, and that controlled blasting techniques will be required for rock excavation. During the excavation, near-vertical slopes will be created and stabilization of the slopes will be needed.

Because both concrete and granular backfill are required after excavation, the applicant outlined the general requirements for concrete and compacted granular backfill material and included suggested sources of these materials.

The applicant specified items that need to be addressed in the COLA, including additional subsurface data that may be required to further characterize the underlying stratigraphic bedrock units for the final plant layout because the foundation backfill design will be based on information from geologic mapping of exposed rock surfaces; the specific design of the excavation support system, including rock bolting, will be developed during the detailed design; the slope movement and foundation performance will be monitored by an extensive instrumentation program during and after the excavation; and a detailed field and laboratory test program will be carried out for the evaluation of backfill sources and their engineering properties.

Based on the review of those construction related items, the staff identified the following COL Action Items:

- COL Action Item 2.5-7: An applicant for a COL or CP referencing this ESP should specify excavation procedures and methods that will not have adverse impacts on the integrity of the foundation subsurface materials. The applicant should design proper excavation support, and evaluate the stability of excavation slopes. The applicant should develop a monitoring plan that includes detailed instrumentation and data collection to monitor slope movement and heave of subsurface materials due to excavation, changes in pore pressures of soil underneath the foundation, and displacement of the foundation during and after construction.
- COL Action Item 2.5-8: An applicant for a COL or CP referencing this ESP should provide the detailed design of backfill materials including identification of sources and quantity requirements, backfill material property and placement specifications, applicable industry standards, and related ITAAC. The in-place backfill hydraulic characteristics, such as permeability and porosity, should be consistent with those specified in the SSAR. If

differences exist, then their effect on the site conceptual model and site characterization, as described in the SSAR, should be evaluated.

2.5.4.3.5.3 _Conclusions Regarding Excavation and Backfill_

Based on its review of SSAR Section 2.5.4.5 (TVA 2017-TN5387), the staff concludes that the applicant provided sufficient details related to the extent of anticipated excavations for safety-related structures, excavation methods and stability, backfill sources, and QC, consistent with commonly accepted engineering practices. Therefore, this section of the ESPA is acceptable and meets the relevant requirements of 10 CFR 100.23 (TN282). In addition, as described in COL Action Items 2.5-6 through 2.5-8, the staff identified issues that shall be addressed by a COL or CP applicant referencing the ESP for the CRN Site, if granted.

2.5.4.3.6 Groundwater Conditions

SSAR Section 2.4.12 presents the applicant's full descriptions and results of the groundwater flow models to be used during construction and subsequent plant operations (TVA 2017-TN5387). The staff's evaluation of these models is provided in FSER Section 2.4.12.4.

The staff reviewed SSAR Section 2.5.4.6 (TVA 2017-TN5387) focusing on site groundwater conditions, construction dewatering, and groundwater chemical properties.

The applicant evaluated the groundwater levels at the site based on groundwater observation well data. The applicant anticipates that temporary dewatering of the foundation excavations will be needed during construction, and discussed dewatering methods and associated monitoring requirements. The applicant also discussed the groundwater chemical test results and concluded that the water-soluble sulfate concentration in contact with concrete is low, and injurious sulfate attack is not a concern. In addition, the protection requirement specified in the ACI Standard 318-14 (ACI 2014-TN6093) should be followed.

The staff concludes that the applicant provided sufficient information about groundwater conditions, including adequate descriptions of construction dewatering and groundwater chemical properties for the current ESP. Because detailed design of dewatering and foundation protection will be done for the COLA, the staff identified the following COL Action Items:

- _COL Action Item 2.5-9_: An applicant for a COL or CP referencing this ESP should provide the detailed design of dewatering and groundwater control during excavation and construction, including a monitoring plan, and provide an evaluation of the impact of dewatering on the stability of foundations.
- _COL Action Item 2.5-10_: An applicant for a COL or CP referencing this ESP should provide the detailed design for foundation protection based on the chemical characteristics of the groundwater and foundation and fills materials at the site consistent with the applicable industrial standards.

2.5.4.3.6.1 _Conclusions Regarding Groundwater Conditions_

Based on its review of SSAR Section 2.5.4.6 (TVA 2017-TN5387), the staff concludes that the applicant conducted an appropriate preliminary evaluation of groundwater conditions at the CRN Site, and adequately discussed the anticipated dewatering method and requirements during excavation and construction. The applicant also provided the results of chemical test of groundwater and the possible effect of groundwater chemicals on foundation materials.

Because there is no specific reactor design selected, and a detailed dewatering plan will be developed for the COLA, the evaluation of the effect of groundwater conditions and dewatering on the stability of foundation materials, as well as groundwater control throughout the life of the plant, cannot be performed at this time. However, the applicant's discussion of dewatering methods and requirements, and the requirement for foundation and fills to be protected from exposure to groundwater chemicals, are in line with the common engineering practices and industrial standards, and therefore is acceptable. In addition, as described in COL Action Items 2.5-9 and 2.5-10, the staff identified issues that shall be addressed by a COL or CP applicant referencing the ESP for the CRN Site, if granted.

2.5.4.3.7 Response of Soil and Rock to Dynamic Loading

The staff reviewed SSAR Section 2.5.4.7 (TVA 2017-TN5387), focusing on the method and procedure used to develop seismic wave velocity profiles, soil shear modulus and damping degradation properties that are important for site seismic response, and other analyses. The applicant provided detailed information about the site amplification/attenuation analysis, the site seismic response analysis, and the development of the GMRS in SSAR Section 2.5.2.5 (TVA 2017-TN5387). The staff's evaluation of that information is presented in Section 2.5.2.3.5 of this report.

The applicant first developed seismic wave (both shear wave, V_S, and compression wave, V_P) velocity profiles for each rock unit based on geophysical surveys conducted for the CRN Site, including seismic refraction and reflection tests, and P-S suspension logging. The applicant then assembled the seismic wave profiles for Locations A and B in accordance with the stratigraphic conditions (Figure 2.5.4-3 and Figure 2.5.4-4). During the development of the seismic wave velocity profiles, the applicant used geophysical survey data taken within 30.5 m (100 ft) of the locations, and other data, such as SASW data, for depths where no measurement is available. The applicant assigned a shear wave velocity value of 3,353 m/s (11,000 fps) for bedrock when no measurement or other data were available. This assigned shear wave velocity value is within the normal range of similar rocks and reasonable for the bedrock presented at the CRN Site

The applicant took epistemic uncertainty into consideration when developing the V_S profiles. The applicant developed a best estimate base case V_S profile and upper- and lower-range profiles that use a plus and minus 25 percent variation about the base case, as illustrated in Figure 2.5.4-5 and Figure 2.5.4-6. The variation of 25 percent of the base case V_S profile is commonly used in site seismic response analysis and is acceptable.

The applicant used appropriate EPRI curves to describe the subsurface material damping and shear modulus reduction properties for soil and rock at the site. The applicant also compared the RCTS test data with the generic EPRI curves for existing fill soil to ensure that the EPRI curves used in the analyses closely represent the actual site conditions.

The actual locations of the safety-related structures may differ from the proposed locations, and additional site investigations need to be conducted for either a COL or CP application. Because seismic wave velocity profiles and other dynamic properties of the subsurface materials may need to be updated, the staff identified the following COL Action Item:

- COL Action Item 2.5-11: An applicant for a COL or CP referencing this ESP should develop seismic wave velocity profiles for the locations where the safety-related structures will be built, based on sufficient detailed site investigation data and with consideration of uncertainties and variability. The applicant should determine the appropriate damping and

shear modulus reduction properties for soil and rock for in situ subsurface materials at the CRN Site based on test data and/or justifiable generic curves.

2.5.4.3.7.1 *Conclusion Regarding Response of Soil and Rock to Dynamic Loading*

Based on its review of SSAR Section 2.5.4.7 (TVA 2017-TN5387), the staff concludes that the applicant provided adequate information about the development of the seismic wave velocity, especially the V_S profiles. The applicant also adequately described the modulus reduction and damping properties with proper justification and verification. The staff further concludes that the applicant adequately described the properties of soil and rock responding to seismic loading, and provided proper parameters for site seismic response analysis based on test data and generic EPRI curves that fit the CRN Site conditions. This is in line with common engineering practices and meets the requirements of 10 CFR 100.23 (TN282). In addition, as described in COL Action Item 2.5-11, the staff identified issues that shall be addressed by a COL or CP applicant referencing the ESP for the CRN Site, if granted.

2.5.4.3.8 Liquefaction Potential

The staff reviewed SSAR Section 2.5.4.8 (TVA 2017-TN5387), which includes the applicant's description of liquefaction potential at the CRN Site. The staff noted that sound rock is presented at shallow depth (less than 15 m [50 ft]) from ground surface, and the anticipated foundation levels considered by the applicant are about 24.4 m (80 ft) and 42.1 m (138 ft) below the final grade; therefore the foundation will be built on sound rock. In addition, the existing fill residual soils are classified as CH clay. 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.

2.5.4.3.8.1 *Conclusion Regarding Liquefaction Potential*

Based on its review of SSAR Section 2.5.4.8 (TVA 2017-TN5387), the staff concludes that the applicant performed an adequate evaluation of the liquefaction potential at the CRN Site. The applicant reached a no liquefaction potential conclusion, based on the geologic conditions of the site and the properties of the subsurface material, which meets the requirements of 10 CFR 100.23 (TN282).

2.5.4.3.9 Earthquake Design Basis

In SSAR Section 2.5.4.9 (TVA 2017-TN5387) the applicant referred to SSAR Section 2.5.2.5.8 for detailed information about the development of the site-specific GMRS. Section 2.5.2.3.6 of this report provides the staff's evaluation of the site-specific GMRS.

2.5.4.3.10 Static and Dynamic Stability

The staff reviewed SSAR Section 2.5.4.10 (TVA 2017-TN5387), focusing on the applicant's evaluation of bearing capacity, settlement, and lateral earth pressures in the two proposed power block areas at the CRN Site.

2.5.4.3.10.1 *Bearing Capacity*

The staff reviewed the methods and associated assumptions that the applicant used in its evaluation of foundation bearing capacity for the proposed power block areas. The staff noted

that the applicant considered each rock formation underlying the power block areas separately by treating each stratigraphic rock formation unit as a single infinite rock layer below the foundations. The applicant then evaluated the bearing capacity for each rock formation. The applicant compared the calculated bearing capacity values and then chose the lowest value as the recommended design bearing capacity for the CRN Site. However, this single rock formation layer assumption does not represent the specific site geologic condition because the actual subsurface of the CRN Site consists of multiple inclined layers of various rock formations with possible weakened interfaces between the formations. In addition, the methods used by the applicant to determine the site bearing capacity are based on a fundamental assumption that the structure is founded on a uniform half-space material, but this assumption may not be applicable for the CRN Site. The applicant also evaluated bearing capacity by using a 2D FEM model that takes the site-specific geologic characteristics into consideration. The applicant's results are summarized in SSAR Section 2.5.4.13 (TVA 2017-TN5387). It was not clear to the staff whether the applicant included the FEM results as part of its bearing capacity determination presented in SSAR Section 2.5.4.10.1 (TVA 2017-TN5387). Therefore, in eRAI-9035 (RAI No. 6), Question 02.05.04-02, the staff asked the applicant to (1) discuss all methods used in its determination of recommended allowable bearing capacity values, and (2) justify why the bearing capacity calculation methods, based on a uniform half-space subsurface materials assumption, can be used for the CRN Site (NRC 2017-TN5911).

The applicant provided a response to eRAI-9035 (RAI No. 6), Question 02.05.04-02 (1) and (2), in Response Letter CNL-17-099 dated September 15, 2017 (TVA 2017-TN5910). The applicant provided detailed explanations to justify the use of simplified site geologic conditions in its estimate of site bearing capacity. The applicant first provided more details about the four empirical methods used to evaluate bearing capacity with simplified site geologic condition assumptions. The applicant stated that (1) the Wyllie method is suitable for evaluating the bearing capacity of a closely fractured or very weak rock; (2) the Kulhawy and Carter method assumes a strip footing, incorporates the intact rock strength, and accounts for discontinuities in the rock; (3) the USACE methods can be used to estimate bearing capacity for four general rock mass conditions (intact, jointed, layered, and highly fractured); and (4) the Bowles method evaluates allowable bearing capacity based on geology, rock type, and rock quality measured by the RQD. The applicant then discussed the FEM modeling (presented in SSAR Section 2.5.4.13 [TVA 2017-TN5387]) that incorporates more realistic site-specific geologic conditions and strategic configurations in bearing capacity evaluation. The applicant stated that the FEM model incorporates the inclined rock units beneath foundations and conservatively includes a weakened interface between rock units. The failure mode exhibited by the FEM modeling results indicated the general shear failure mode of the rock, which is consistent with the assumptions of the empirical approaches. More importantly, the FEM modeling results provide good agreement with the results obtained by empirical models. Specifically, the FEM model resulted in a value of 7,037 kPa (147 ksf) compared to 7,133 kPa (149 ksf) using the Bowles method at Location A, and the FEM model resulted in a value of 5,122 kPa (107 ksf) compared to 5,170 kPa (108 ksf) using the Bowles method at Location B. The applicant concluded that the FEM modeling results validated the empirical methods used to evaluate bearing capacity, and confirmed that the assumptions used in the model calculations are appropriate for the CRN Site. The FEM modeling results also confirmed that the recommended allowable bearing pressure value of 5,266 kPa (110 ksf) is appropriate. The applicant then concluded that the similarity of the engineering properties of these rock units, in both strength and stiffness, suggests that, for evaluation purposes, the individual rock units may be considered separately to develop a range of results. In addition, the FEM model analysis results confirmed that the empirical relationships can be used to estimate the bearing capacity for this site.

The staff notes that the uniform half-space subsurface materials assumption used in the empirical methods to estimate the site bearing capacity does not represent the actual site subsurface geologic condition, because the actual site consists of multiple inclined layers of various rock formations with possible weaker interfaces between the formations. In addition, the empirical methods assume a uniform single rock unit condition. Even so, the staff determined that the selected calculation results are in good agreement with those obtained by the FEM modeling. Because the FEM model represented the actual CRN Site subsurface geologic conditions with inclined rock units beneath foundations, and conservatively includes a weakened interface between rock units, the recommended allowable bearing capacity values based on the results calculated by the selected empirical methods are acceptable because the lowest values with an adequate FS were chosen for the CRN Site. Because the applicant provided a detailed discussion of the empirical methods used to estimate the site bearing capacities, and adequately justified the use of those methods (TVA 2017-TN5910), the staff considers eRAI-9035 (RAI No. 6), Question 02.05.04-02 (1) and (2) resolved.

The locations and elevation of foundations for safety-related structures of a NPP at the CRN Site will be determined for the COL or CP application and the foundation bearing capacity will need to be reevaluated. Therefore, the staff identified the following COL Action Item:

- COL Action Item 2.5-12: An applicant for a COL or CP referencing this ESP should evaluate the foundation bearing capacity for safety-related structures, based on the selected plant structure and foundation designs and actual geologic conditions at the CRN Site under anticipated maximum static and dynamic loadings.

2.5.4.3.10.2 *Settlement and Heave*

The staff reviewed the methods and results of the applicant's analyses for settlement and heave of the subsurface materials at the proposed power block locations. Although the applicant used multiple methods to estimate the settlement and heave for the CRN Site, and considered the discontinuity of rock mass in its evaluation, the applicant used the same simplified site geologic condition assumptions as those used in its bearing capacity analysis, which does not represent the actual site condition. Therefore, in eRAI-9035 (RAI No. 6), Question 02.05.04-02 (3) (NRC 2017-TN5911) the staff asked the applicant to justify why the settlement and heave calculation methods, based on a uniform half-space subsurface materials assumption, are applicable for the CRN Site.

The applicant provided a response to eRAI-9035 (RAI No. 6), Question 02.05.04-02 (3), in Response Letter CNL-17-099 dated September 15, 2017 (TVA 2017-TN5910). The applicant stated that although the inclined layered stratigraphy beneath the foundation is not considered in the method applied, as demonstrated in its bearing capacity evaluation, these assumptions are appropriate because the stratigraphic units beneath the foundations contain similar lithologies, do not exhibit well-defined unit boundaries, and exhibit similar strength characteristics. The applicant stated that the rock mass elastic moduli were determined based on in situ V_S measurements and measured in laboratory unconfined compression tests using two different methods. The applicant pointed out that the analysis illustrates the relative similarity of modulus values between stratigraphic units, which is one basis for using a simplified geologic model to evaluate the settlement and heave. In addition, the applicant performed a FEM model that considered the inclined layered geology and associated rock mass properties, and conservatively included a weakened interface between rock units, to estimate the foundation settlement. A comparison of settlement results using the simplified geologic model to those obtained using the inclined layered geology, as presented in the FEM model, shows

good agreement, thus supporting the use of a simplified geologic model for the CRN Site. The applicant concluded that regardless of the methodology used, computed settlement and heave values are negligible; settlement values range from 0.25 to 7.11 mm (0.01 to 0.28 in.), and heave values range from 0.5 to 9.1 mm (0.02 to 0.36 in.).

Because the applicant adequately justified the use of a simplified site geologic model and empirical methods to estimate site settlement and heave, and used a more realistic FEM model that considered the actual site geologic conditions to confirm the analysis results obtained from the empirical methods, the staff considers eRAI-9035 (RAI No. 6),, Question 02.05.04-2 (3) (NRC 2017-TN5911) resolved.

The locations and elevation of foundations for safety-related structures of a NPP at the CRN Site will be determined for the COL or CP application and the settlement and heave of the foundations will need to be reevaluated. Therefore, the staff identified the following COL Action Item:

- COL Action Item 2.5-13: An applicant for a COL or CP referencing this ESP should evaluate the foundation settlement and heave for safety-related structures, based on the selected plant structure and foundation designs, and actual geologic conditions at the CRN Site under anticipated excavation depth and maximum static and dynamic loadings.

2.5.4.3.10.3 *Lateral Earth Pressures*

The staff reviewed the methodology that the applicant proposed for the evaluation of lateral earth pressure exerted on foundation/structure walls below ground. The staff concluded that the applicant's proposed methods for determining the static lateral earth pressure and associated assumptions, such as no friction between underground structure wall and backfill and an internal friction angle of 20 to 30 degrees for in situ and backfill soil, are reasonable. The staff made this determination because the assumed soil parameters are at the lower range of normal values for in situ soil and for engineering backfills, and the applicant's proposed method for determining lateral earth pressure is commonly used in engineering practices.

The applicant acknowledged that the COLA needs to be based on a full assessment of lateral earth pressures, including lateral pressures contributed from static soil pressure, hydrostatic pressure, surcharge-induced (equipment and adjacent structures) pressure, and seismic-induced pressure. Therefore, the staff identified the following COL Action Item:

- COL Action Item 2.5-14: An applicant for a COL or CP referencing this ESP should evaluate the maximum lateral earth pressure and its distribution along foundation and structure walls below ground. The total lateral earth pressure should include pressures contributed from static soil pressure, hydrostatic pressure, surcharge-induced (equipment and adjacent structures) pressure and seismic lateral earth pressure at the CRN Site under anticipated maximum static and dynamic loadings.

2.5.4.3.10.4 *Conclusions Regarding Static and Dynamic Stability*

Based on its review of SSAR Section 2.5.4.10 (TVA 2017-TN5387) and the applicant's responses to related RAIs, the staff concludes that the applicant provided an adequate preliminary assessment of the static stability of the CRN Site. In line with common engineering practices and the requirements of 10 CFR 100.23 (TN282), the applicant performed adequate evaluations of bearing capacity, settlement and heave, and provided adequate information about the evaluation of lateral earth pressure at the CRN Site. In addition, as described in COL

Action Items 2.5-12 to 2.5-14, the staff identified issues that shall be addressed by a COL or CP applicant referencing the ESP for the CRN Site, if granted.

2.5.4.3.11 Design Criteria

The staff reviewed the geotechnical design criteria used by the applicant for the CRN ESPA. The staff concludes that the design criteria, such as the soil liquefaction screening criteria, factors of safety for bearing capacity, acceptable settlement limits, and slope stability requirement are in line with the general engineering practices and guidelines provided in the relevant NRC guidance.

The applicant stated that the design criteria addressed in the CRN Site ESPA will be reevaluated in the COLA. In response, the staff identified the following COL Action Item:

- COL Action Item 2.5-15: An applicant for a COL or CP referencing this ESP should identify and reevaluate geotechnical engineering-related design criteria to meet applicable industrial standards and NRC regulations.

2.5.4.3.12 Techniques to Improve Subsurface Conditions

The staff reviewed the applicant's discussion of techniques to be used for subsurface condition improvement in areas where the safety-related structures might be built. The staff examined the proposed subsurface improvement methods, such as grouting to be used to remedy the voids/cavities located below the foundation level, and the anticipated concrete fill for creating a smooth and level foundation surface. The applicant also suggested implementing a monitoring plan, including proper installation of sensors and instruments, to monitor slope movement, heave due to the excavation, the vertical movement of the foundation, and changes in pore pressures. The staff concludes that the applicant's proposed subsurface improvement methods and monitoring plan are reasonable because the methods and equipment proposed are commonly used in engineering practices, and are adequate for the purpose of improving the stability of foundations at the CRN Site.

The actual locations of safety-related structures and the necessary subsurface condition improvement method and associated monitoring program will be determined for the COL or CP application. Therefore, the staff identified the following COL Action Item:

- COL Action Item 2.5-16: An applicant for a COL or CP referencing this ESP should evaluate subsurface conditions in the influence zone of foundations for safety-related structures when karst or other geologic hazard features are discovered. The applicant should determine remediation methods after evaluating the presence of geologic hazard features based on the results of adequate and more detailed geophysical testing at the site.

2.5.4.3.13 Foundation Assessment Model

The staff focused its review of SSAR Section 2.5.4.13 (TVA 2017-TN5387) on the elements used in the applicant's FEM model. In addition, the staff focused on the results of the model analysis for assessment of the impact of cavities on foundation stability, as well as foundation bearing capacity and settlement estimates at the CRN Site. To get details on the FEM model analysis, the staff also reviewed "Submittal of Supplemental Information Associated with Site Safety Analysis Report Section 2.5 in Support of the Clinch River Nuclear Site Early Site Permit Application," (TVA 2017-TN5912) provided by the applicant. The staff examined the model elements, including boundary and interface elements used in 2D FEM modeling, the

assumptions related to the size and locations of a hypothetical void within the influence zone of foundation loading, and assumptions regarding the embedment depth of the foundation. The 2D FEM model simulations were carried out using the commercial computer software, PLAXIS 2D—which is a commonly used software in geotechnical engineering-related design and analysis. Therefore, the staff determined that it is acceptable to use in assessing the impact of cavities on foundation stability. The applicant modeled the subsurface characteristics with multiple inclined rock formations with weaker contact interfaces. The applicant obtained the engineering properties of the subsurface materials using site investigation data, which closely represent the actual geologic conditions of the CRN Site. The applicant's assumption of a maximum void with a 4.6 m (15 ft) diameter and infinite length is consistent with the maximum vertical void discovered during site investigation, and the length of the void is conservatively assumed. Additionally, the applicant's assumption of the foundation embedment depth from 12.2 m to 42.7 m (40 ft to 140 ft) covers the embedment depth for known SMR designs. Also, the applicant considered the possible locations where voids may have the most impact on the foundation stability in its assumption of the void depth of 1.5 m to 9.1 m (5 ft to 30 ft) below the foundation and void locations at the edge and center of the nuclear island and at the interface of different rock formations. Therefore, the staff concludes that the 2D FEM model that the applicant developed to evaluate the effect of underground void on foundation stability is adequate and acceptable. The staff also concludes that the assumptions used in the model are reasonable.

Based on its review of the applicant's 2D FEM model and simulation results, the staff finds that the applicant realistically modeled the specific geologic conditions at the CRN Site, the size and location of possible voids at the site are conservatively assumed, and the results show that the proposed Locations A and B are generally suitable for an SMR foundation.

The applicant used the same 2D FEM model to estimate the site bearing capacity and settlement in order to confirm the validity of the simplified model used for bearing capacity and settlement assessments presented in SSAR Section 2.5.4.10. The applicant's analysis results showed that the estimated allowable bearing capacity and settlement values are in good agreement with those determined by simplified methods. For example, for Location A, the PLAXIS bearing capacity is 7,037 kPa (147 ksf) compared with 7,133 kPa (149 ksf) determined by simplified methods; and for Location B, the PLAXIS bearing capacity is 5,122 kPa (107 ksf) compared with 5,170 kPa (108 ksf) determined by the simplified methods.

The applicant specified that the foundation performance needs to be reevaluated in the COL or CP application, based on selection of a final technology and final foundation locations that will be determined based on additional detailed site-specific geologic conditions including stratigraphy, subsurface layering orientation, and specific fracture or bedding plane discontinuity zonation. In response, the staff identified COL Action Item 2.5-2, which is described in Section 2.5.4.3.1.4 of this report.

2.5.4.3.13.1 *Conclusions Regarding Foundation Assessment Model*

Based on its review of SSAR Section 2.5.4.13 (TVA 2017-TN5387) and the applicant's supplemental report, the staff concludes that the applicant used a realistic subsurface model based on the geologic characteristics of the site, and used a conservative approach for estimating a hypothetical void with respect to its size and locations. The staff determined that the applicant adequately evaluated the impact of voids on the foundation stability for the CRN Site. The analysis results showed that the CRN Site is generally suitable for a SMR NPP. The staff further concludes that the adequate foundation stability assessment meets the

requirements of 10 CFR 100.23 (TN282), and is therefore acceptable. In addition, as described in COL Action Items 2.5-15 and 2.5-16, the staff identified issues that shall be addressed by a COL or CP applicant referencing the ESP for the CRN Site, if granted.

2.5.4.4 *Permit Conditions*

In SSAR Section 2.5.4.5.4.3, the applicant acknowledged the need to perform geologic mapping to document the presence or absence of faults and shear zones in plant foundation materials before placement of concrete backfill and foundation concrete (TVA 2017-TN5387). Therefore, in Section 2.5.3.4 of this report, the staff identified Permit Condition 2.5-1 (Permit Condition 3) related to detailed geologic mapping of safety-related excavations at the CRN Site as the responsibility of the COL or CP applicant.

For evaluation of the suitability of a proposed site, requirements in 10 CFR 100.23 (TN282), specifically 10 CFR 100.23(c), provide that the engineering characteristics of a site and its environs must be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site. 10 CFR 100.23(d) discusses several siting factors and potential causes of failures that must be evaluated, including rock stability, the physical properties of the materials underlying the site, and ground disruption, in addition to several other geologic and seismic factors. The applicant identified discontinuities, shear fractures zones, and weathered fracture zones that typically exist in the uppermost 30.5 m (100 ft) at the CRN Site and are not suitable for safety-related structures to be built on; and the rock mass characterization presented in the ESPA mainly applies to bedrock stratigraphic units below 24.4 m (80 ft) (elevation 225.9 m [741 ft] NAVD88). Therefore, the staff identified Permit Condition 2.5-2 (Permit Condition 4) as follows:

- <u>Permit Condition 2.5-2 (Permit Condition 4)</u>: An applicant for a COL or CP that references this ESP shall remove the material above El. 225.9 m (741 ft) NAVD88 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 COL or CP applicant shall also perform additional geotechnical investigations, in accordance with RG 1.132, at the excavation level to identify any potential geologic features that may adversely impact the stability of subsurface materials and foundations.

In the event that adverse geologic features are identified through implementation of Permit Conditions 2.5-1 and 2.5-2 (Permit Conditions 3 and 4), the applicant should excavate or improve the subsurface materials to ensure the stability of safety-related structures in accordance with COL Action Item 2.5-3.

2.5.4.5 *Conclusions*

Based on its review of SSAR Section 2.5.4 (TVA 2017-TN5387) and pertinent supplemental information, and the applicant's responses to RAIs related to this section, the staff concludes that the applicant provided adequate information describing the geologic and engineering characteristics of the subsurface materials at the CRN Site based on data collected from site investigations. The applicant conducted adequate field and laboratory tests by using state-of-the-art methods, in accordance with applicable industrial standards and the guidance of RG 1.132 (NRC 2003-TN5902), RG 1.138 (NRC 2014-TN5903), and RG 1.198 (NRC 2003-TN5906). The staff also concludes that the applicant adequately evaluated the site suitability regarding the stability of subsurface materials and foundations with respect to the engineering properties of subsurface materials at the proposed site, the assessment of liquefaction potential,

bearing capacity, settlement, and lateral earth pressure, as well as the development of a shear wave velocity profiles for the proposed power block locations. The staff further concludes that the applicant adequately described requirements for a COL applicant referencing the ESP for the CRN Site, if granted, for topics where detailed stability evaluations could not be performed for the ESPA because no NPP design has been specified, and the actual location of the safety-related structures could not be determined. Based on the above, the staff concludes that the applicant meets the applicable requirements of 10 CFR Part 50 (TN249), Appendices B and S, 10 CFR 52.17(a)(1)(vi) (TN251), and 10 CFR 100.23 (TN282).

For evaluation of the suitability of a proposed site, 10 CFR 100.23(c) (TN282) requires that the geological, seismological, and engineering characteristics of a site and its environs be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site, to provide sufficient information to support evaluations performed to arrive at estimates of the Safe Shutdown Earthquake Ground Motion, and to permit adequate engineering solutions to address actual or potential geologic and seismic effects at the proposed site. Because more detailed site characterization for further siting evaluation and specific engineering analyses for foundation stability evaluations will be needed for a chosen NPP design in the COL or CP application, the staff identified issues specified in COL Action Items 2.5-1 through 2.5-16 in this FSER that a COL or CP applicant referencing the ESP for the CRN Site, if granted, must address in its application.

2.5.5 Stability of Slopes

In SSAR Section 2.5.5, “Stability of Slopes,” the applicant addresses the stability of both natural and manmade (cuts, fill, embankments, dams, etc.) earth slopes whose failure could adversely affect safety-related structures (TVA 2017-TN5387). The staff evaluated this section based on the data provided by the applicant in the SSAR. In SSAR Section 2.5.5, the applicant indicated that given the existing topography, the natural topography and the planned finished grade elevation of 250.2m (821 ft, NAVD88), a flat table-top site with no safety-related slope is anticipated (TVA 2017-TN5387). The applicant stated that the site grading plan and the stability of any safety-related slopes, including dams and dikes, are going to be evaluated as part of the COLA.

2.5.5.1 *Summary of Application*

In SSAR Section 2.5.5 the applicant discusses the stability of earth slopes whose failure could affect safety-related structures (TVA 2017-TN5387). The applicant deferred the specifics for slope stability design to the COL or CP application, which will include a selected reactor technology.

2.5.5.1.1 Slope Characteristics

The applicant stated that power block configuration and site grading have not been established, so the characteristics of any permanent slope will be established in the COLA. The applicant stated that temporary excavation will be made during the construction process and will include vertical faces and sloped ramp for access into the excavation. The applicant indicated that no slopes will remain after construction in the power block area.

2.5.5.1.2 Design Criteria and Analysis

The applicant stated that if permanent safety-related slopes are identified in the COLA, they will be analyzed relative to the potential slope failure impacting safety-related structures at that time.

2.5.5.1.3 Results of the Investigation

The applicant refers to SSAR Section 2.5.4 for details about subsurface investigation (TVA 2017-TN5387). The applicant stated that these data will be used in the design of any permanent safety-related slopes.

2.5.5.1.4 Properties of Borrow Material

The applicant refers to SSAR Section 2.5.4.5 for details related to backfill and borrow material for safety-related backfill (TVA 2017-TN5387). The applicant stated that if any permanent safety-related slope is identified once site grading has been established, the properties of borrow materials will be determined.

2.5.5.2 *Regulatory Basis*

The applicable regulatory requirements for the stability of slopes are as follows:

- 10 CFR 52.17(a)(1)(vi) (TN251), as it relates to the requirement for an ESP applicant to prepare an SSAR that contains information about the geologic and seismic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.
- 10 CFR Part 50 (TN249), Appendix S, as it relates to the design of NPP SSC important to safety to withstand the effects of earthquakes or surface deformation.
- 10 CFR 100.23 (TN282), as it relates to the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of NPPs.

The related acceptance criteria from SRP Section 2.5 (NRC 2007/2018-TN5898) are summarized as follows:

- Slope Characteristics. To meet the requirements of 10 CFR Part 50 (TN249), 10 CFR Part 52 (TN251), and 10 CFR Part 100 (TN282), the discussion of slope characteristics is acceptable if the discussion includes (1) cross sections and profiles of the slope in sufficient quantity and detail to represent the slope and foundation conditions; (2) a summary and description of static and dynamic properties of the soil and rock comprised by seismic Category I embankment dams and their foundations, natural and cut slopes, and all soil or rock slopes whose stability would directly or indirectly affect safety-related and seismic Category I facilities; and (3) a summary and description of groundwater, seepage, and high and low groundwater conditions.
- Design Criteria and Analyses. To meet the requirements of 10 CFR Part 50 (TN249), 10 CFR Part 52 (TN251), and 10 CFR Part 100 (TN282), the discussion of design criteria and analyses is acceptable if the criteria for the stability and design of all seismic Category I

slopes are described and valid static and dynamic analyses have been presented to demonstrate that there is an adequate margin of safety.

- Boring Logs. To meet the requirements of 10 CFR Part 50 (TN249), 10 CFR Part 52 (TN251), and 10 CFR Part 100 (TN282), the applicant should describe the borings and soil testing carried out for slope stability studies and dam and dike analyses.
- Compacted Fill. To meet the requirements of 10 CFR Part 50 (TN249) and 10 CFR Part 52 (TN251), the applicant should describe the excavation, backfill, and borrow material planned for any dams, dikes, and embankment slopes.

In addition, the geologic characteristics should be consistent with appropriate sections of RG 1.27 (NRC 2015-TN5907), RG 1.28 (NRC 2010-TN5872), RG 1.132 (NRC 2003-TN5902), RG 1.138 (NRC 2014-TN5903), and RG 1.198 (NRC 2003-TN5906).

2.5.5.3 *Technical Evaluation*

The staff reviewed SSAR Section 2.5.5 (TVA 2017-TN5387), which provides the applicant's general description of site-specific information related to slope stability, and concludes that the information provided by the applicant is adequate for this ESPA. The applicant deferred the slope stability analysis for the COLA because currently there is no safety-related slope at the CRN Site. As such, the staff identified the following COL Action Item to address the need for slope stability analyses:

- COL Action Item 2.5-17: An applicant for a COL or CP that references this ESP should perform a slope stability analysis of any safety-related slopes, including dams and dikes, consistent with the selected reactor technology.

2.5.5.4 *Conclusion*

In SSAR Section 2.5.5, the applicant stated that, for the COLA, it would evaluate the site grading plan and the stability of any safety-related slopes (TVA 2017-TN5387). Because there are no existing safety-related slopes currently at the CRN Site and the applicant provided necessary information about site topography and geologic conditions, the staff concludes that the SSAR Section 2.5.5 is adequate and acceptable because it meets applicable requirements of 10 CFR Part 50 (TN249, Appendix S), 10 CFR 52.17(a)(1)(vi) (TN251), and 10 CFR 100.23 (TN282). In addition, as described in COL Action Item 2.5-17, the staff identified issues that shall be addressed by a COL or CP applicant referencing the ESP for the CRN Site, if granted.

3.0 DESIGN OF STRUCTURES, COMPONENTS, EQUIPMENT, AND SYSTEMS

3.5.1.6 Aircraft Hazards

For the Clinch River Nuclear (CRN) Site early site permit application, the applicant provided evaluations of the potential hazards associated with aircraft. The U.S. Nuclear Regulatory Commission (NRC) staff reviewed the evaluations to ensure that the risks associated with potential aircraft hazards would be sufficiently low.

3.5.1.6.1 Summary of Application

In Site Safety Analysis Report (SSAR), Section 2.2.2.7, "Descriptions of Airports, Aircraft, and Airway Hazards," the applicant presented information concerning the airports, airways, and military training routes in the vicinity of the site to evaluate potential hazards with respect to nuclear units that might be constructed on the proposed CRN Site (TVA 2017-TN5387).

The applicant stated that five small privately owned airports—Big T, Wolf Creek, Cox Farm, Will A Hildreth Farm, and Riley Creek—are located between 8 to 16.1 km (5 and 10 statute mi) from the CRN Site. Two small privately owned airports, Oliver Springs and Fergusons Flying Circus, are within 16.1 to 24.1 km (10 to 15 mi) of the CRN Site. These airports and their estimated number of flight operations are listed in SSAR Table 2.2-7. Airports located beyond 24.1 km (15 mi) are also considered and listed in SSAR Table 2.2-7 (TVA 2017-TN5387).

There is one Federal airway route (V16) and one high altitude route (J46), whose nearest edge lies within 2 statute mi of the CRN Site. The closest military route is located approximately 31 km (19.2 mi) to the west-northwest of the site. The closest military operations area (MOA) is the Snowbird MOA located approximately 58 km (36 mi) from the CRN Site.

3.5.1.6.2 Regulatory Basis

The acceptance criteria for aircraft hazards are based on meeting the relevant requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) 52.17 (TN251), "Contents of Applications, Technical Information," and 10 CFR Part 100 (TN282), "Reactor Site Criteria." The staff considered the following regulatory requirements and guidance in reviewing the site location and area description:

- 10 CFR 52.17 (TN251), as it relates to the requirement that the applicant provides the location and description of any nearby military or transportation facilities and routes.
- 10 CFR Part 100 (TN282), as it relates to the following:
  - 10 CFR 100.20(b), which states that the nature and proximity of human-related hazards (e.g., airports, transportation routes, and military facilities) must be evaluated to establish site characteristics for use in determining whether a plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.
  - 10 CFR 100.21(e), which states that the potential hazards associated with nearby transportation routes, industrial, and military facilities must be evaluated and site characteristics established such that potential hazards from such routes and facilities will pose no undue risk to the type of facility proposed to be located at the site. Review Standard (RS)-002, Section 3.5.1.6, "Processing Applications for Early Site Permits"

(NRC 2004-TN2219), Regulatory Guide (RG) 1.206, “Regulatory Guide for Combined License Applications for Nuclear Power Plants” (NRC 2007-TN3035), and NUREG–0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants” (hereafter the SRP, NRC 2007/2018-TN5898), specify that the above regulatory requirements are met if the probability of aircraft accidents having the potential for radiological consequences greater than the 10 CFR Part 100 (TN282) exposure guidelines is less than about 10^{-7} per year. The probability is considered to be less than about 10^{-7} per year if the distance to an airport, or a to a military route, or to a Federal airway from the site meets the appropriate following criteria:

- The site-to-airport distance (D) is between 5 and 10 statute mi and the projected annual number of operations is less than 500 D^2, or the D is greater than 10 statute mi, and the projected annual number of operations is less than 1,000 D^2.
- The site is at least 5 statute mi from the edge of military training routes, including low-level training routes, except for those associated with usage greater than 1,000 flights per year, or where activities (such as practice bombing) may create an unusual stress situation.
- The site is at least 2 statute mi beyond the nearest edge of a Federal airway, holding pattern, or approach pattern.

If the above proximity criteria are not met, or if sufficiently hazardous military activities are identified, then a detailed review of aircraft hazards should be performed. The guidance on the performance of such reviews appears in RS-002, Section 3.5.1.6 (NRC 2004-TN2219), RG.1.206 (NRC 2007-TN3035), and the SRP (NRC 2007/2018-TN5898).

3.5.1.6.3 Technical Evaluation

In SSAR Section 3.5.1.6, the applicant addressed the aircraft hazards evaluations (TVA 2017-TN5387). Five airports are within 8 to 16.1 km (5 to 10 mi) of the CRN Site. The airports have small numbers of flight operations annually (less than the allowable number of flight operations based on 500 D^2, where D is the distance in miles from the site to the airport). The number of flights would not contribute to exceeding the acceptable aircraft hazards probability of 10^{-7} per year, and therefore, are not considered a safety hazard based on the guidance. Based on the review of the information provided by the applicant and the information obtained from sources available in the public domain, the staff considers the applicant’s conclusion acceptable.

Two airports within 16.1 to 24.1 km (10 to 15 mi) each have projected numbers of flights that are much less than the respective plant-to-distance criterion of 1,000 D^2, where D is the distance in miles from the site to the airport. Therefore, the aircraft crash probability is considered to be acceptable—less than about 10^{-7} per year. Based on the review of the flight data information, the staff considers the applicant’s approach and conclusion acceptable because it meets the acceptance criteria.

The applicant addressed a military training route and MOA, which were not evaluated further because they are much farther away (58 km [36 mi]) from the CRN Site and meet the above proximity screening criterion.

The applicant addressed and evaluated the airways for the aircraft hazards probability. The applicant identified two airways (V16 and J46) that are within 3.2 km (2 mi) of the site. The applicant performed aircraft hazard probability analysis using the U.S. Department of Energy’s (DOE’s) four-factor formula that uses crash rates for non-airport operations referenced in DOE-

STD-3014-96 (DOE 2006-TN5863), "Accident Analysis for Aircraft Crash into Hazardous Facilities." The staff considers the applicant's approach and methodology reasonable and acceptable in determining the aircraft hazard calculations because it conforms to the staff review guidance. The applicant used the calculated effective area based on an assumed maximum R (length of diagonal of the facility) value of 179.5 m (589 ft), a maximum length of 162.45 m (533 ft), a width of 75.9 m (249 ft), and a building height of 48.8 m (160 ft). The staff considers this reasonable and acceptable because the methodology meets the requirements and guidance. Using these data and assumptions, the applicant determined an aircraft crash probability of 7.53×10^{-7} per year.

The staff reviewed the applicant's assumptions and calculations and finds them reasonable, consistent, and acceptable, because they comply with the requirements of 10 CFR 52.17 (TN251), 10 CFR 100.20(b) (TN282), and conform to the guidance in RS-002 (NRC 2004-TN2219), RG 1.206 (NRC 2007-TN3035), and the SRP (NRC 2007/2018-TN5898). The staff performed independent confirmatory aircraft crash probability calculations, using the highest of the most recent 5-year (2011–2015) Federal Aviation Administration (FAA)-supplied flight operations data within 8 km and 16.1 km (5 mi and 10 mi) of the site. The potential aircraft crash probability of 1.5×10^{-8} per year is estimated by the staff, conservatively assuming that all the flights within 10 mi of the CRN Site based on FAA data follow these two airways. Therefore, the staff considers that the probability of aircraft accidents, resulting in radiological consequences greater than 10 CFR Part 100 (TN282) exposure guidelines, is approximately less than an order of magnitude of 10^{-7} per year for the CRN Site, and agrees with the applicant's conclusion.

3.5.1.6.4 Conclusion

The staff reviewed the applicant's aircraft hazard analysis using the guidelines in RS-002, Section 3.5.1.6, RG 1.206 (NRC 2007-TN3035), and the SRP (NRC 2007/2018-TN5898). As discussed above, the staff independently verified the applicant's assessment of aircraft hazards at the CRN Site and concludes that the estimated probability of an accident having the potential for radiological consequences in excess of the exposure criteria contained in 10 CFR Part 100 (TN282) is approximately less than an order of magnitude of 10^{-7} per year.

Based on these considerations, the staff concludes that aircraft hazards do not present an undue risk to the safe operation of nuclear units at the CRN Site, and finds the CRN Site acceptable. The staff also concludes that the CRN Site meets the relevant requirements related to aircraft hazards identified in 10 CFR Part 52 (TN251) and 10 CFR Part 100 (TN282) for compliance with respect to determining the acceptability of the site.

11.0 RADIOACTIVE WASTE MANAGEMENT

This chapter describes the U.S. Nuclear Regulatory Commission (NRC) staff's evaluation of the information provided in Chapter 11, "Radioactive Waste Management," of the Site Safety Analysis Report (SSAR) contained in Part 2 of the Tennessee Valley Authority (TVA) Clinch River Nuclear (CRN) Site Early Site Permit (ESP) Application, originally submitted on May 12, 2016, Revision 0 (TVA 2016-TN5018). TVA subsequently revised the SSAR to address staff audit information items and requests for additional information (RAIs) in SSAR Revision 1 (TVA 2017-TN5387) and SSAR Revision 2 (TVA, 2019-TN6195).

The information in SSAR Chapter 11 (TVA 2017-TN5387) describes the liquid and gaseous effluent releases (i.e., normal plant parameter envelope [PPE] liquid and gaseous effluent release source terms), exposure pathways, and projected offsite doses to demonstrate that reactor units could be sited at the proposed CRN Site without undue risk to the health and safety of the public, in compliance with the relevant requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 20 (TN283), "Standards for Protection Against Radiation;" 10 CFR Part 50 (TN249), "Domestic Licensing of Production and Utilization Facilities," Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As is Reasonably Achievable' [ALARA] for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents"; 10 CFR 52.17 (TN251), "Contents of Applications"; 10 CFR Part 100 (TN282), "Reactor Site Criteria"; and the U.S. Environmental Protection Agency's (EPA's) 40 CFR Part 190 (TN739), "Environmental Radiation Protection Standards for Nuclear Power Operations."

Liquid and gaseous effluent release source terms and exposure pathway doses provided in SSAR Chapter 11 (TVA 2017-TN5387) are developed using a PPE approach. A representative activity for each of the radionuclides derived from information about the four light-water-cooled small modular reactor (SMR) technologies—BWXT mPower (Generation mPower LLC design), NuScale (NuScale Power, LLC, design), SMR-160 (Holtec SMR, LLC, design), and Westinghouse SMR (Westinghouse Electric Company, LLC, design)—was considered in the development of the PPE for the CRN Site. These radionuclides and their associated activities are described in SSAR Chapter 2, "Site Characteristics," and in the TVA letter to the NRC, CNL-17-075, "Resubmittal of Supplemental Information Regarding Radiation Protection Accident Consequences in Support of Early Site Permit Application for Clinch River Nuclear Site," dated June 16, 2017 (TVA 2017-TN5884).

In support of the ESP application (ESPA) safety review, input, output, and modified computer code files in native formats were submitted with the TVA letter to the NRC, CNL-16-157, "Submittal of Groundwater Calculation Input and Output Files in Support of Early Site Permit Application for Clinch River Nuclear Site," dated September 30, 2016 (TVA 2016-TN5885).

Also, the NRC issued an audit plan (NRC 2017-TN5886) consisting of two phases: (1) a face-to-face meeting between the NRC staff, the applicant, and the applicant's contractor staff at Bechtel Power Corporation in Reston, Virginia, on April 14–17, 2017; and (2) an additional face-to-face meeting between the same parties at the TVA Knoxville Complex in Knoxville, Tennessee, on April 24–27, 2017, which included a visit to the proposed site location and surrounding area to become familiar with the site setting and layout on April 25, 2017. The NRC audit report documents the interactions between the parties and NRC staff audit observations (NRC 2018-TN5915).

11.1 Summary of Application

The applicant provided information about liquid and gaseous effluent releases (i.e., normal PPE liquid and gaseous effluent release source terms) and exposure pathway doses that would be generated as a normal byproduct of nuclear power operations. The applicant stated that these effluents will be collected, processed, stored, and released in a controlled manner. The applicant further stated that the proposed facility will have the ability to handle these effluents in a manner that minimizes effluent releases to the environment and maintains exposure to the public during normal plant operations including anticipated operational occurrences (AOOs), and maintenance at levels that are ALARA.

In the SSAR (TVA 2017-TN5387), the applicant considered the guidance in Nuclear Energy Institute (NEI) 10-01, Revision 1, "Industry Guidance for Developing a Plant Parameter Envelope in Support of an Early Site Permit" (NEI 2012-TN5237), for developing the normal PPE liquid and gaseous effluent release source terms in SSAR Section 11.2.3 (and SSAR Table 2.0-6) and SSAR Section 11.3.3 (and SSAR Table 2.0-4). These source terms are used to describe the types and quantities of liquid and gaseous effluents released annually from normal plant operations. The four SMR design technologies used to develop the normal PPE liquid and gaseous effluent release source terms in the surrogate plant for the PPE based on NEI 10-01 (NEI 2012-TN5237) are summarized in Table 11.1-1.

Table 11.1-1 SMR Design Technologies Considered in the PPE

SMR Design	No. Units	Per Unit MWt (MWe)	RCP Per Unit MWt	Total MWt (MWe)
BWXT mPower	4	530 (171)	2.1	2,120 (684)
NuScale	12	160 (50)	No RCP	1,920 (600)
Holtec SMR-160	4	525 (154)	No RCP	2,100 (616)
Westinghouse SMR	3	800 (240)[a]	4.0	2,420 (720)[b]

(a) Maximum megawatt thermal (MWt) and megawatt electric (MWe) core output considered for all SMR designs at CRN Site.
(b) Includes additional reactor coolant pump (RCP) thermal output (if applicable to SMR design) for margin.

The applicant used the guidance in Regulatory Guide (RG) 1.109, Revision 1, "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" (NRC 1977-TN90), and RG 1.111, Revision 1 (with Errata), "Methods for Estimating Atmospheric Transport and Dispersion of Strenge et al. 1986-TN82), to evaluate the exposure pathway doses for the normal PPE liquid and gaseous effluents released annually on a per unit and site basis in SSAR Sections 11.2.3.1 and 11.3.3.1, respectively (TVA 2017-TN5387).

Further, the applicant used analytical methods and the applicable guidance, including the NRC-endorsed LADTAP II (NUREG/CR-4013, "LADTAP II – Technical Reference and User Guide" [Strenge et al. 1986-TN82]), XOQDOQ (NUREG/CR-2919, "XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations" [Sagendorf et al. 1982-TN280]), and the GASPAR II (NUREG/CR-4653, "GASPAR II – Technical Reference and User Guide" [Strenge et al. 1987-TN83]), computer codes to evaluate the calculated doses from normal PPE liquid and gaseous effluent releases to members of the public as documented in SSAR Sections 11.2.3.2 and 11.3.3.2, respectively (TVA 2017-TN5387).

11.2 Regulatory Basis

The acceptance criteria for addressing doses to a member of the public from liquid and gaseous effluents due to normal plant operations are based on meeting the relevant requirements of the following:

- 10 CFR 20.1301, 10 CFR 20.1302, and Table 2, Columns 1 and 2 and Note 4 of Appendix B to 10 CFR Part 20 (TN283), as they relate to radioactivity in liquid and gaseous effluents released to unrestricted areas and doses to offsite receptors located in unrestricted areas;
- 10 CFR Part 50, Appendix I, Sections II.A, II.B, and II.C (TN249), as they relate to the numerical guides on ALARA design objectives and limiting conditions for operation;
- 10 CFR 52.17(a)(1)(ii) (TN251), as it relates to anticipated maximum levels of radiological and thermal effluents each facility will produce;
- 10 CFR 100.21(c)(1) (TN282), as it relates to the requirement that site atmospheric dispersion characteristics be evaluated and dispersion parameters established such 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; and
- 40 CFR Part 190 (TN739), (the EPA's generally applicable environmental radiation standards), as implemented under 10 CFR 20.1301(e) (TN283), as it relates to limits on annual doses from all sources of radioactivity contained in liquid and gaseous effluents and external radiation from site buildings and facilities (with single or multiple reactor units).

11.3 Liquid Effluent Releases

The following sections describe the normal PPE liquid effluent source term, evaluation of exposure pathways, and calculated public doses to the public surrounding the CRN Site. The staff's technical evaluation involving these aspects of liquid effluent releases is discussed in Section 11.4 of this final safety evaluation report (FSER).

11.3.1 Normal PPE Liquid Effluent Release Source Term

In the TVA letter to the NRC, CNL-17-075, dated June 16, 2017 (TVA 2017-TN5884), the applicant provided SSAR markups and the bases for the normal PPE liquid effluent release source terms to address the staff's audit observations described in the NRC audit report (NRC 2018-TN5915).

An overview of the input from the four SMR designs used to create a surrogate plant, as defined in NEI 10-01 (NEI 2012-TN5237), and for developing the normal PPE liquid and gaseous effluent release source terms, is provided in the enclosure to TVA letter CNL-17-075 (TVA 2017-TN5884). The four SMR designs are randomly represented as Vendors 1 through 4. This enclosure contains SSAR markups and updates in Attachment 1 (SSAR Sections 1.11, 2.4.13.1, 2.4.13.8, 11.2.3.1, 11.2.4, 11.3.3.1, and 11.3.4), Attachment 2 (tellurium [Te]-129 and Te-131 unit and site liquid effluent release rates), and Attachment 3 (asterisks on noted site gaseous effluent release rates for Vendors 2 and 4 in Table 7-B) (TVA 2017-TN5884). No other changes were identified for the additional attachments in the enclosure.

In the markup, the applicant revised SSAR Section 1.11 (TVA 2017-TN5387) to indicate a basis summary for each plant parameter is provided in the SSAR section indicated in SSAR Table 2.0-2 for that plant parameter. The staff found the markup acceptable because the basis

summary and SSAR section of each plant parameter were provided, and the staff confirmed that Revision 1 of SSAR (TVA 2017-TN5387) Section 1.11 and Table 2.0-2 included this information.

Additionally, the applicant revised SSAR Section 11.2.3.1 (TVA 2017-TN5387) to specify that the guidance in NEI 10-01 (NEI 2012-TN5237) was used for developing the surrogate plant source term for liquid effluent releases. The staff found the markup acceptable because NEI 10-01 was described and referenced, and the staff confirmed that Revision 1 of SSAR Section 11.2.3.1 (TVA 2017-TN5387) included this information.

In the TVA letter to the NRC, CNL-17-086, "Submittal of Supplemental Information Related to Plant Parameter Envelope Source Terms in Support of Early Site Permit Application for Clinch River Nuclear Site," dated June 26, 2017 (TVA 2017-TN5888), the applicant provided a markup correcting the Te-129 and Te-131 unit and site liquid effluent release rates in Composite Tables 10-A (unit) and 10-B (site) in Attachments 2 and 3 of TVA letter CNL-17-075 (TVA 2017-TN5884). The Te-129 and Te-131 unit and site liquid effluent release rates are also provided in the TVA ESPA Part 3, Environmental Report, Tables 3.5-1 and 3.5-2 (TVA 2017-TN4921). The staff found the markup acceptable because the Te-129 and Te-131 unit and site liquid effluent release rates were corrected, and the staff confirmed that Revision 1 of SSAR, Tables 2.0-6 and 11.2-4 (TVA 2017-TN5387) included this information.

11.3.2 Normal PPE Liquid Effluent Release Concentrations

The normal PPE liquid effluent release source term for the surrogate plant is evaluated for compliance with the water (liquid) effluent concentration limits (ECLs) in 10 CFR Part 20 (TN283), Appendix B, Table 2, Column 2, for release to the environment using the unity rule or sum of fractions calculation. SSAR Table 11.2-4 (Sheets 1 through 3 [TVA 2017-TN5387]) provides the projected annual liquid effluent concentrations in the Clinch River arm of the Watts Bar Reservoir. Liquid effluent release concentrations in SSAR Table 11.2-4 (Sheets 1 through 3) are taken from Composite Table 10-B (Site) in Attachment 2 of TVA letter CNL-17-075 (TVA 2017-TN5884), which contains the normal PPE liquid effluent release source term. SSAR Table 11.2-4 (Sheets 1 through 3) shows the normal PPE liquid effluent release source term projected into the Clinch River arm of the Watts Bar Reservoir results in a calculated sum of fractions value less than one (TVA 2017-TN5387).

11.3.2.1 Doses from Normal PPE Liquid Effluent Release Source Terms

The applicant's receptor locations are based on the CRN Site Land Use Survey conducted on January 7–10, 2014, and the guidance in Section 3/4.12.2, "Land Use Census," of NUREG-1302, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling Water Reactors" (NRC 1991-TN5757). Section 3/4.12.2 of NUREG-1302 states, "a Land Use Census shall be conducted and shall identify within a distance of 8 kilometers (5 miles) the location in each of the 16 meteorological sectors of the nearest milk animal, the nearest residence, and the nearest garden of greater than 50 m^2 (500 ft^2) producing broad leaf vegetation." This guidance for conducting a Land Use Census that complies with the regulations is the same as that found in Section 3/4.12.2 of NUREG-1301, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors" (NRC 1991-TN5758).

The guidance in NUREG-1301 (NRC 1991-TN5758) and NUREG-1302 (NRC 1991-TN5757) for developing an Offsite Dose Calculation Manual (ODCM), including controls and surveillance

requirements for instrumentation, effluents, radiological environmental monitoring, and technical and regulatory bases, are described in NEI 07-09A, Revision 0, “Generic FSAR Template Guidance for Offsite Dose Calculation Manual (ODCM) Program Description” (NEI 2009-TN5890). At the time of the combined license (COL) application, a COL applicant may commit to follow the NRC-endorsed guidance in NEI 07-09A, Revision 0, as an alternative to providing the full programs for the ODCM and Radiological Environmental Monitoring Program (REMP). As such, the ODCM and REMP are outside the review scope for an ESPA.

The applicant used the methodology described in RG 1.109 (NRC 1977-TN90) to determine the sensitive receptors for the maximally exposed individual (MEI) in the exposure pathway dose analyses. The guidance in RG 1.109 is an acceptable method for demonstrating compliance with the ALARA design objectives in 10 CFR Part 50, Appendix I (TN249), and for performing the exposure pathway dose analyses for licensed operations. When the ALARA design objectives in 10 CFR Part 50, Appendix I, on a per unit basis are met along with the EPA’s radiation standards in 40 CFR Part 190 (TN739) for the site, as implemented under 10 CFR 20.1301(e) (TN283), then the dose limit of 100 mrem total effective dose equivalent to a member of the public in 10 CFR 20.1302 (TN283) is satisfied.

The results of the CRN Site Land Use Survey identified the nearest beef cattle, nearest garden, and nearest residence, and did not show any dairy cows and goats within a 8 km (5 mi) radius around the CRN Site. For the purpose of calculating the population dose at the 80 km (50 mi) boundary, the applicant considered dairy cows and dairy goats within a 50 mi radius in the exposure pathway dose analyses. The applicant’s exposure pathway dose analyses using the NRC-endorsed LADTAP II (Strenge et al. 1986-TN82) and GASPAR II (Strenge et al. 1987-TN83) codes, the guidance in RG 1.109 (NRC 1977-TN90), its demonstration of compliance with the ALARA design objectives in Appendix I to 10 CFR Part 50 (TN249), the public dose limit in 10 CFR 20.1301 (TN283), and environmental dose limits in 40 CFR Part 190 (TN739), are discussed in Sections 11.3.3.1, 11.3.3.2, and 11.4 of this FSER.

Calculated doses for total body and various body organs are evaluated by the applicant with the normal PPE liquid effluent release source term and parameters specific to the CRN Site using the guidance in RG 1.109 (NRC 1977-TN90) and the NRC-endorsed LADTAP II code (Strenge et al. 1986-TN82). SSAR Section 11.2.3.1 (TVA 2017-TN5387) describes the exposure pathways considered in RG 1.109 (NRC 1977-TN90) and in the LADTAP II code (Strenge et al. 1986-TN82). The parameters, values, and bases for calculating doses to the MEI and to the general population are presented in SSAR Tables 11.2-1 (Sheets 1 and 2) and 11.2-3 (TVA 2017-TN5387). SSAR Section 11.2.3.2 describes the exposure pathway activities considered for calculating doses to the MEI surrounding the CRN Site and to the projected general population within 50 mi of the CRN Site in SSAR Table 11.2-2 (TVA 2017-TN5387).

The results of total body and organ doses to the MEI from the exposure pathways and normal PPE liquid effluent release source terms are presented in SSAR Tables 11.2-5 (unit) and 11.2-6 (site) (TVA 2017-TN5387). In SSAR Tables 11.2-7 and 11.2-8, the total body, organ, and gamma and beta air doses to the MEI are compared to the ALARA design objectives in Sections II.A, II.B, and II.C of Appendix I to 10 CFR Part 50 (TN249), and the calculated dose from all sources in 40 CFR Part 190 (TN739), as implemented under 10 CFR 20.1301(e) (TN283). SSAR Tables 11.2-7 and 11.2-8 (TVA 2017-TN5387) show all doses calculated using the LADTAP II code (Strenge et al. 1986-TN82) are within the ALARA design objectives in Appendix I to 10 CFR Part 50 (TN249), and the EPA’s radiation standards in 40 CFR Part 190 (TN739). Calculated doses per unit and for the projected general population within 50 mi of the CRN Site resulting from the normal PPE liquid effluent release source term are compared to the

dose from natural background in SSAR Table 11.2-9 (TVA 2017-TN5387). The staff's technical evaluation involving these aspects of exposure pathway doses from liquid effluent releases is discussed in Section 11.4 of this FSER.

11.3.3 Gaseous Effluent Releases

The following sections describe the normal PPE gaseous effluent release source term, evaluation of exposure pathways, and calculated public doses surrounding the CRN Site. The staff's technical evaluation involving these aspects of gaseous effluent releases is discussed in Section 11.4 of this FSER.

11.3.3.1 Normal PPE Gaseous Effluent Release Source Term

In the TVA letter to the NRC, CNL-17-075, dated June 16, 2017 (TVA 2017-TN5884), the applicant provided updates and the bases for unit and site normal PPE gaseous effluent release source terms to address the staff's audit observations described in the NRC audit report (NRC 2018-TN5915).

As discussed in Section 11.3.1 of this FSER, the enclosure associated with TVA letter CNL-17-075 (TVA 2017-TN5884) contains SSAR markups and updates. In particular, Attachment 1 (SSAR Sections 11.3.3.1 and 11.3.4 [TVA 2017-TN5387]) and Attachment 3 (asterisks on noted release rates for Vendors 2 and 4 in Table 7-B) are relevant to gaseous effluent releases.

In the markup, the applicant revised SSAR 11.3.3.1 (TVA 2017-TN5387) to specify that the guidance in NEI 10-01 (NEI 2012-TN5237) was used for developing the surrogate plant source term for gaseous effluent releases. The staff found the markup acceptable because NEI 10-01 was described and referenced, and the staff confirmed that Revision 1 of SSAR, Section 11.3.3.1 (TVA 2017-TN5387) included this information.

As discussed in the basis for normal gaseous effluent releases in Attachment 3, krypton (Kr)-85 and Kr-85m release rates were inadvertently reversed in Table 7-A (unit) of Attachment 3 for Vendor 2 (TVA 2016-TN5018). The correct release rates for Kr-85 and Kr-85m are 633 Ci/yr and 23.2 Ci/yr, respectively. The staff found the updated Attachment 3 (TVA 2017-5387) acceptable because these Kr release rates were corrected, and the staff confirmed that Table 7-A (unit) of Attachment 3 for Vendor 2 included this information.

11.3.3.2 Normal PPE Gaseous Effluent Release Concentrations

The normal PPE gaseous effluent release source term in the surrogate plant is evaluated for compliance with the air (gaseous) ECLs in 10 CFR Part 20, Appendix B, Table 2, Column 1 (TN283) for release to the environment using the unity rule or sum of fractions calculation. SSAR Table 11.3-3 (Sheets 1 and 2 [TVA 2017-TN5387]) provides the projected annual normal gaseous effluent concentrations at the CRN Site exclusion area boundary (EAB). Gaseous effluent release concentrations in SSAR Table 11.3-3 (Sheets 1 and 2 [TVA 2017-TN5387]) are taken from Composite Table 7-B (site) in Attachment 3 of TVA CNL-17-075 (TVA 2017-TN5884), which contains the normal PPE gaseous effluent release source term. SSAR Table 11.3-3 (Sheets 1 and 2 [TVA 2017-TN5387]) shows the normal PPE gaseous effluent release source term projected at the CRN Site EAB results in a calculated sum of fractions value less than one.

Maximum atmospheric dispersion (χ/Q) and relative (ground) deposition (D/Q) factors (also referred to as χ/Q and D/Q values) for receptor locations are shown in SSAR Table 11.3-2 (TVA 2017-TN5387). Meteorological information used for developing the χ/Q and D/Q factors is described in SSAR Section 2.3, "Meteorology" (TVA 2017-TN5387), which is evaluated by the staff in Section 2.3.5 of this FSER. Both χ/Q and D/Q factors are used to calculate the doses from the normal PPE gaseous effluent release source term for compliance with the public dose limit in 10 CFR 20.1301 (TN283), the ALARA design objectives in Appendix I to 10 CFR Part 50 (TN249), and the EPA's radiation standards in 40 CFR Part 190 (TN739), as implemented under 10 CFR 20.1301(e) (TN283).

The χ/Q factor is also used to calculate the projected normal gaseous effluent concentrations at the CRN Site EAB for compliance with the gaseous ECLs of 10 CFR Part 20 (TN283), Appendix B, Table 2, Column 1. The staff's evaluation of these projected normal gaseous effluent concentrations at the CRN Site EAB is discussed in Section 11.4 of this FSER.

From the meteorology review of SSAR Section 2.3 (TVA 2017-TN5387), the staff requested in Question 02.03.03-2 of RAI No. 9 (eRAI-8972) that the applicant confirm whether the processing of onsite wind direction measurements used as input for developing the χ/Q and D/Q factors represented vector- or scalar-averaged values (NRC 2017-TN5933). In the response to eRAI-8972 (TVA 2017-TN5891), the applicant provided proposed markups to SSAR Section 2.3. Based on a review of these markups, the staff shared observations in public meetings with the applicant about the potential effects of using this wind direction averaging methodology along with guidance cited in RG 1.23 (NRC 2007-TN278).

As a result, on April 9, 2018, the applicant voluntarily submitted a response (TVA 2018-TN5892) to address the staff's observations. To evaluate the applicant's voluntary submittal, the staff conducted an audit May 7–21, 2018 (NRC 2018-TN5893) to examine the applicant's calculation packages and supporting documents for developing the χ/Q and D/Q factors, including the calculated normal offsite gaseous effluent doses to members of the public. The NRC audit report documenting the staff's audit observations is located under Agencywide Documents Access and Management System (ADAMS) Accession No. ML18248A113 (NRC 2018-TN6152).

11.3.3.3 Doses from the Normal PPE Gaseous Effluent Release Source Term

According to the applicant, calculated doses for total body and various organ doses, and gamma and beta air doses are evaluated with the normal PPE gaseous effluent release source term and parameters specific to the CRN Site using the guidance in RG 1.109 (NRC 1977-TN90) and the GASPAR II code (Strenge et al. 1987-TN83). SSAR Section 11.3.3.1 (TVA 2017-TN5387) describes the exposure pathways considered. The parameters, values, and bases for calculating doses to the MEI and to the general population are presented in SSAR Tables 11.3-1 and 11.3-2. SSAR Section 11.3.3.2 (TVA 2017-TN5387) describes the receptor locations considered for calculating doses to the MEI surrounding the CRN Site and to the projected general population within 50 mi of the CRN Site in SSAR Table 11.2-2.

Results of total body and organ doses to the MEI per reactor and for the site from the exposure pathways and gaseous effluent release rates are presented in SSAR Tables 11.3-4 (Sheets 1 and 2) and 11.3-5 (Sheets 1 and 2), respectively (TVA 2017-TN5387). In SSAR Tables 11.2-7 and 11.2-8 (TVA 2017-TN5387), the total body, organ, and gamma and beta air doses for the MEI are compared to the ALARA design objectives in Sections II.A, II.B, and II.C of Appendix I to 10 CFR Part 50 (TN249), and the calculated dose from all sources in 40 CFR Part 190

(TN739), as implemented under 10 CFR 20.1301(e) (TN283). SSAR Tables 11.2-7 and 11.2-8 (TVA 2017-TN5387) show all doses calculated using the GASPAR II code (Strenge et al. 1987-TN83) are within the ALARA design objectives in Appendix I to 10 CFR Part 50 (TN249), and the EPA's radiation standards in 40 CFR Part 190 (TN739). Calculated doses per reactor and for the projected general population within 50 mi of the CRN Site from the projected annual release of the normal PPE gaseous effluent source term, compared to the dose from natural background, are shown in SSAR Table 11.2-9 (TVA 2017-TN5387). The staff's technical evaluation involving these aspects of exposure pathway doses from gaseous effluent releases is discussed in Section 11.4 of this FSER.

11.4 Technical Evaluation

11.4.1 Normal PPE Liquid and Gaseous Effluent Release Source Terms

The guidance in NEI 10-01 recommends that the applicant assemble a list of radionuclides released by liquid and gaseous effluent pathways in creating a surrogate plant to bound radionuclide release rates in the PPE (NEI 2012-TN5237). For each reactor technology considered, release rates from each reactor technology are compared and the highest value is selected. The resulting composite table represents the bounding release rates from normal operations for the surrogate plant. Dose calculations are then performed using computer codes to evaluate all exposure pathways to man as described in NUREG-0800, "Standard Review Plan [SRP] for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)" (NRC 2007/2018-TN5898, hereafter the SRP). The SRP describes the guidance in RGs 1.109 (NRC 1977-TN90) and 1.111 (NRC 1977-TN5887), and the XOQDOQ (Sagendorf et al. 1982-TN280), LADTAP II (Strenge et al. 1986-TN82), and GASPAR II (Strenge et al. 1987-TN83) codes as acceptable methods for evaluating exposure pathways and calculating doses for demonstrating compliance with NRC regulations.

The bases and list of normal liquid and gaseous effluents released annually for each SMR design (Vendors 1 through 4) are provided in Attachments 2 and 3, respectively, of TVA letter CNL-17-075 (TVA 2017-TN5884). For each vendor, liquid effluent release rates are listed in Tables 10-A (unit) and 10-B (site) of Attachment 2, and gaseous effluent release rates are listed in Tables 7-A (unit) and 7-B (site) of Attachment 3. Unit liquid and gaseous effluent release rates are multiplied by the maximum number of reactor units in the vendor's design to obtain the site liquid and gaseous effluent release rates. As a result, Composite Tables 10-A (unit), 10-B (site), 7-A (unit), and 7-B (site) represent the selected bounding effluent release rates from normal operations in the surrogate plant for the CRN Site. In Attachment 3, the applicant states that any variances (adjustments) in the values (release rates) considered will be evaluated during the development of the COLA.

As described in the bases for the tables in Attachments 2 and 3, adjustments are made on a case-by-case basis to exclude, reduce, or increase release rates for certain radionuclides based on the amount of conservatism and maturity of the source terms available from the vendors at the time. The applicant evaluated the adjusted release rates to ensure that the dose consequences are conservative compared to source terms for large light-water reactors (LWRs) scaled to a comparable thermal power output for the CRN Site. The staff reviewed the applicant's evaluation and agrees that the adjusted release rates are reasonable for representing the bounding effluent release rates from normal operations in the surrogate plant as summarized below.

For Vendor 1, the applicant increased liquid and gaseous effluent release rates by 10 percent for additional conservatism and margin in Composite Tables 10-A (unit) and 10-B (site) of Attachment 2 and Tables 7-A (site) and 7-B (unit) of Attachment 3, respectively, due to the preliminary nature of the source terms. The staff agrees that increasing the liquid and gaseous effluent release rates adds conservatism and margin for Vendor 1.

For Vendor 2, the applicant made no adjustments to liquid effluent release rates in Composite Tables 10-A (unit) and 10-B (site) of Attachment 2. As stated in Attachment 3, the gaseous effluent release rates for Kr-85m, Kr-89, xenon (Xe)-131m, Xe-133, Xe-135m, Xe-135, Xe-137, and Xe-138 in Table 7-A (unit); and carbon (C)-14 in Table 7-B (site) values were excluded because of excessive conservatism related to further evaluation in the surrogate plant. With respect to C-14, the applicant reduced its release rate in Composite Table 7-B (site) based on industry guidance from the Electric Power Research Institute (EPRI), "Estimation of Carbon-14 in Nuclear Power Plant Gaseous Effluents," Technical Report 1021106, Final Report 2010 (EPRI 2010-TN5894). Although this release rate is reduced, the selected C-14 value in Composite Table 7-B (site) is higher (more conservative) than the value determined by the EPRI method. The staff performed a confirmatory analysis and verified that the C-14 release rate used in the PPE was conservative for Vendor 2.

For Vendor 3, the applicant adjusted liquid effluent release rates for C-14 and Co-58 in Table 10-A (unit); and tritium (H-3), C-14, cobalt (Co)-58, and Co-60 in Table 10-B (site) of Attachment 2 on scaled unit and site power ratios from the Public Service Enterprise Group (PSEG) ESP (NRC 2016-TN6133) to the CRN Site ESPA (NRC 2019-TN6194). The PPE effluent release source terms approved by the NRC in the PSEG ESP considered four large LWR design technologies, including both pressurized and boiling-water reactor designs of various power levels: General Electric Nuclear Energy Advanced Boiling-Water Reactor; Westinghouse Electric Company Advanced Passive 1000 (AP1000); AREVA NP, Inc., U.S. Evolutionary Pressurized-Water Reactor (U.S. EPR); and Mitsubishi Heavy Industries, Ltd., U.S. Advanced Pressurized-Water Reactor (US-APWR). The staff agrees that scaling power levels from PSEG to the CRN Site is conservative because no single vendor should contain the highest source terms for all radionuclides. Also, the applicant adjusted the gaseous effluent release rate for argon (Ar)-41 in Table 7-A (unit) of Attachment 3. The liquid effluent release rates for C-14 and Co-58 in Table 10-A (unit), in addition to H-3 and Co-60 in Table 10-B (site) of Attachment 2, and the gaseous effluent release rate for Ar-41 in Table 7-A (unit) of Attachment 3 were identified by the applicant as values that were adjusted due to excessive conservatism. The applicant performed a sensitivity analysis on the reduced release rates to demonstrate that calculated doses are bounded by the doses in the surrogate plant and are within NRC regulatory limits. The staff performed a confirmatory analysis and verified that the doses in the surrogate plant are bounded for Vendor 3.

For Vendor 4, the applicant did not make adjustments to liquid effluent release rates in Tables 10-A (unit) and 10-B (site) of Attachment 2. As described in Attachment 3, radionuclide quantities (release rates) for Kr-85 in Table 7-A (unit), and Kr-85 and C-14 in Table 7-B (site) were considered overly conservative based on a scaled AP-1000 in Composite Tables 7-A (unit) and/or 7-B (site). As with Vendor 2, the applicant reduced the C-14 release rate in Composite Table 7-B (site) of Attachment 3 based on industry guidance from EPRI. Although this release rate is reduced, the selected C-14 value in Composite Table 7-B (site) is higher (more conservative) than the value determined by the EPRI method (EPRI 2010-TN5894). The applicant performed a sensitivity analysis on the reduced Kr-85 and C-14 release rates to demonstrate that calculated doses are bounded by the doses in the surrogate plant and are

within NRC regulatory limits. The staff performed a confirmatory analysis and verified that the doses in the surrogate plant are bounded for Vendor 4.

The staff reviewed the liquid and gaseous effluent concentrations in SSAR Tables 11.2-4 (Sheets 1 through 3) and 11.3-3 (Sheets 1 and 2) (TVA 2017-TN5387) for compliance with the liquid and gaseous ECLs in 10 CFR Part 20 (TN283), Appendix B, Table 2, Columns 1 and 2, respectively, for release to the unrestricted areas using the unity rule or sum of the fractions calculation. Based on the staff's confirmatory analysis, the projected normal liquid effluent release concentrations in the Clinch River arm of the Watts Bar Reservoir are within the liquid ECLs of 10 CFR Part 20 (TN283), Appendix B, Table 2, Column 2. The staff also confirmed that the projected normal gaseous effluent release concentrations at the EAB are within the gaseous ECLs of 10 CFR Part 20 (TN283), Appendix B, Table 2, Column 1, at the CRN Site.

11.4.2 Doses from Normal PPE Liquid and Gaseous Effluent Release Source Terms

As discussed in Section 11.3.3.2 of this FSER, the staff conducted an audit to examine the applicant's calculation packages and supporting documents for developing the χ/Q and D/Q values, including the calculated normal offsite gaseous effluent doses to members of the public. The staff's evaluation of these χ/Q and D/Q values is discussed in the NRC audit report documented under ADAMS Accession No. ML18248A113 (NRC 2018-TN6152), and in Section 2.3.5 of this FSER.

The staff reviewed the parameters, values, and bases for calculating doses from the normal PPE liquid and gaseous effluent release source terms in SSAR Tables 11.2-1 (Sheets 1 and 2), 11.2-2, 11.2-3, 11.3-1, and 11.3-2 (TVA 2017-TN5387). In addition, the staff reviewed the applicant's calculation package. The staff performed confirmatory analyses using the same parameters and values in Table 11.4-1 and Table 11.4-4 of this FSER in the NRCDose 2.3.20 code, which contains the NRC-endorsed XOQDOQ (Sagendorf et al. 1982-TN280), LADTAP II (Strenge et al. 1986-TN82), and GASPAR II (Strenge et al. 1987-TN83) codes.

Based on the staff's confirmatory analyses, the calculated total body and organ doses to the MEI in Table 11.4-2 and Table 11.4-3 of this FSER are within the ALARA design objectives in 10 CFR Part 50 (TN249), Appendix I, Sections II.A, II.B, and II.C, and within the EPA's radiation standards in 40 CFR Part 190 (TN739), as implemented under 10 CFR 20.1301(e) (TN283), at the CRN Site. Therefore, the staff finds these values acceptable.

Table 11.4-1 Liquid Effluent Dose Calculation Parameters (used by the staff for confirmatory analysis)

Parameter	Value	Basis
Radionuclide Release Rates	Ci/yr	SSAR[(a)] Table 2.0-6
Water Type	Freshwater	SSAR[(a)] Table 11.2-1
Reactor Effluent Discharge Rate	4,000 ft^3/s	SSAR[(a)] Table 11.2-1
Population Within 50 Miles	2,658,157	SSAR[(a)] Table 11.2-1
Impoundment Reconcentration Model	None	Does not apply to river discharge scenario
Shore-Width Factor	0.2	RG 1.109[(b)] Table A-2
Dilution Factor for Receptors	1	Does not apply to river discharge scenario

Parameter	Value	Basis
Transit Time to Receptors	0	No dilution assumed (Most conservative value)
Usage and Consumption Rates by Age Group	kg/yr, L/yr, hr/yr, m^3	RG 1.109[b] Tables E-4 and E-5
Sport Fishing Harvest	1.87E+08 kg/yr	SSAR[a] Table 11.2-1
Commercial Fishing Harvest	5.93E+06 kg/yr	SSAR[a] Table 11.2-1
Sport Invertebrate Harvest	2.71E+05 kg/yr	SSAR[a] Table 11.2-1
Commercial Invertebrate Harvest	8.61E+05 kg/yr	SSAR[a] Table 11.2-1
Population Supplied by Drinking Water	2.49E+05	SSAR[a] Table 11.2-1
Population Shoreline, Swimming, and Boating Usage	3.40E+07 hr/yr	SSAR[a] Table 11.2-1
Irrigation Rate	110 L/m^2/month	SSAR[a] Table 11.2-1
Vegetable Production	7.00E+08 kg/yr	SSAR[a] Table 11.2-3
Milk Production	1.91E+08 kg/yr	SSAR[a] Table 11.2-3
Meat Production	1.63E+08 kg/yr	SSAR[a] Table 11.2-3

(a) Source: TVA 2017-TN5387.
(b) Source: NRC 1977-TN90.

Table 11.4-2 Comparison of Doses to the MEI from Liquid and Gaseous Effluents for Compliance with 10 CFR Part 50 (TN249), Appendix I

		Annual Dose per Unit	
Type of Dose	Location	Site	Limit
Liquid Effluents			
Total Body (mrem)	Watts Bar Reservoir	0.020	3
Maximum Organ = GI-LLI (mrem)	Watts Bar Reservoir	0.097	10
Gaseous Effluents			
Gamma Air (mrad)	Site Boundary	9.5	10
Beta Air (mrad)	Site Boundary	12	20
Total Body (mrem)	Residence	0.9	5
Skin (mrem)	Residence	1.9	15
Iodines and Particulates			
Maximum Organ = Thyroid (mrem)	Residence/ Vegetable Garden/ Beef Animal	4.5	15

GI-LLI = gastrointestinal-lower large intestine.

Table 11.4-3 Comparison of Doses to the MEI for Compliance with 40 CFR Part 190 (TN739)

	Site Dose (mrem)				
Type of Dose	Liquid[(a)]	Gaseous[(b)]	Direct [(c)]	Total [(d)]	Limit [(e)]
Total Body	0.17	10	1.0	11	25
Thyroid	0.66	24	0.0	25	75
Other Organ (Bone)	0.54	23	0.0	24	25

(a) Source: SSAR Tables 11.2-6 and 11.2-8 note (a) (TVA 2017-TN5387).
(b) Source: SSAR Tables 11.3-5 and 11.2-8 note (b) (TVA 2017-TN5387).
(c) Source: SSAR Table 11.2-8 note (c) (TVA 2017-TN5387).
(d) Total site dose (mrem) is the sum of the liquid, gaseous, and direct radiation site doses.
(e) Source: 40 CFR Part 190 (TN739) as implemented under 10 CFR 20.1301(e) (TN283).

Table 11.4-4 Gaseous Effluent Dose Calculation Parameters (used by the staff for confirmatory analysis)

Parameter	Value	Basis
Radionuclide Release Rates	Ci/yr	SSAR[(a)] Table 2.0-4
Atmospheric Dispersion and Deposition Factors	s/m^3, $1/m^2$	SSAR[(a)] Table 11.3-2
Fraction of Year Leafy Vegetables Grown	1	RG 1.109[(b)] Table E-15 (Most conservative value)
Fraction of Year Milk Cows on Pasture	1	RG 1.109[(b)] default value (Most conservative value)
Fraction of Maximum Individual's Vegetable Intake from own Garden	0.76	RG 1.109[(b)] Table E-15 (Most conservative value)
Fraction of Milk-Cow Feed from Pasture	1	Most conservative value
Average Absolute Humidity for Growing Season	8 g/m^3	NUREG/CR-4653[(c)] Table 2.2
Average Temperature over Growing Season	0	Not used if absolute humidity is specified
Fraction of Year Goats at Pasture	1	Most conservative value
Fraction of Goat Feed from Pasture	1	Most conservative value
Fraction of Year Beef Cattle at Pasture	1	Most conservative value
Fraction of Beef Cattle Feed from Pasture	1	Most conservative value
Population Within 50 Miles	number	SSAR[(a)] Table 11.2-2
Milk Production Within 50 Miles	1.91E+08 L/yr	SSAR Table 11.2-3
Meat Production Within 50 Miles	1.63E+08 kg/yr	SSAR Table 11.2-3
Vegetable Production Within 50 Miles	7.00E+08 kg/yr	SSAR Table 11.2-3

(a) Source: TVA 2017-TN5387
(b) Source: NRC 1977-TN90
(c) Source: Strenge et al. 1987-TN83

As described above, the staff confirmed the adequacy of the applicant's dose calculations from normal operations including AOOs using the normal PPE liquid and gaseous effluent release source terms. The staff determined that because specific details about how the new facility will control, monitor, and maintain liquid and gaseous effluent releases are not known at the ESP

stage, a COL applicant or a construction permit (CP) applicant that references the ESP for the CRN Site, if granted, will need to verify that the calculated doses to members of the public from liquid and gaseous effluent releases for reactor units, which may be constructed at the CRN Site, are bounded by the doses evaluated by the staff in this FSER. A COL or CP applicant referencing the ESP, if granted, should address and justify any discrepancies. This includes justifying any changes made to address differences in the reactor design used to calculate doses (e.g., basis of the normal PPE liquid and gaseous effluent release source terms, liquid effluent discharge flow rates, and site-specific dilution flow rates). In addition, a COL or CP application referencing the ESP, if granted should include detailed information about the solid waste management system used to process liquid and gaseous effluents to reflect plant- and site-specific COL design considerations. The staff identified these items collectively as COL Action Item 11-1.

- COL Action Item 11-1: An applicant for a COL or CP referencing this ESP should verify that the calculated doses to members of the public from normal gaseous and liquid effluent releases for a chosen reactor design at the CRN Site are bounded by the doses evaluated in this ESPA as reviewed by the NRC staff. The applicant should evaluate discrepancies and justify any changes made to address differences in the source term for the reactor design used to calculate the doses for a COL or CP application.

11.5 Conclusion

As set forth above, the staff determined that the applicant provided information adequate to provide reasonable assurance that the normal PPE liquid and gaseous effluent releases from the CRN Site are within the ECLs in 10 CFR Part 20 (TN283), Appendix B, Table 2, Columns 1 and 2; the public dose limit in 10 CFR 20.1301 (TN283); and the ALARA design objectives in Sections II.A, II.B, and II.C of Appendix I of 10 CFR Part 50 (TN249). Under the requirements of 10 CFR 20.1301(e) (TN283), the applicant also demonstrated compliance with the EPA's radiation standards of 40 CFR Part 190 (TN739).

Based upon the above findings and considerations, including implementation of COL Action Item 11-1, at the COL or CP application stage, the staff concludes that calculated doses to members of the public from normal operation of the surrogate plant including AOOs represented with the normal PPE liquid and gaseous effluent release source terms for the proposed CRN Site do not present an undue risk to the health and safety of the public. In addition, the staff concludes that the normal PPE liquid and gaseous effluent release source terms are acceptable for constructing reactor units within the applicant's bounding site-specific PPE, and that the proposed CRN Site meets the relevant requirements of 10 CFR Part 52 (TN251), "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants," and 10 CFR Part 100 (TN282), "Reactor Site Criteria."

13.0 CONDUCT OF OPERATIONS

13.3 Emergency Planning

This section addresses the plans, design features, facilities, functions, and equipment necessary for radiological emergency planning (EP) that must be considered in an early site permit (ESP) application (hereinafter referred to as "ESPA" or "application") that includes proposed major features of the emergency plans, in accordance with the pertinent standards of Section 50.47 of Title 10 to the *Code of Federal Regulations* (10 CFR), and the requirements of Appendix E to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" (TN249). As defined in 10 CFR 52.1 (TN251), a "major feature of the emergency plans means an aspect of those plans necessary to: (i) address in whole or part one or more of the 16 standards in 10 CFR 50.47(b), or (ii) describe the emergency planning zones as required in 10 CFR 50.33(g)" (TN249). The emergency plans are an expression of the overall concept of operation and describe the essential elements of advanced planning that have been considered, as well as the provisions that have been made to cope with radiological emergency situations.

As addressed in 10 CFR 52.17(b)(1) (TN251), an ESPA must identify the physical characteristics of the proposed new reactor site that could pose a significant impediment to the development of emergency plans. 10 CFR 100.21(g) (TN282) includes the same requirement, with regard to non-seismic siting criteria associated with stationary power reactor site applications. In addition, as stated in 10 CFR 52.17(b)(4) (TN251), the application must include a description of contacts and arrangements made with Federal, State, and local governmental agencies that have EP responsibilities, and it must contain any certifications that have been obtained. Pursuant to 10 CFR 52.17(b)(2)(i) (TN251), the U.S. Nuclear Regulatory Commission (NRC) reviews and approves the major features of the emergency plans in consultation with the Federal Emergency Management Agency (FEMA) of the Department of Homeland Security (DHS).

The Tennessee Valley Authority (TVA) is the applicant for the ESP (hereinafter referred to as "TVA" or "applicant"). On May 12, 2016, TVA submitted its ESPA for approval of a site for construction of two or more small modular reactors (SMRs) (hereinafter also referred to as "new units" or "new plant") (TVA 2016-TN5002). The NRC accepted the application for docketing and detailed technical review on December 30, 2016 (82 FR 3812-TN5084) and the applicant was notified of the acceptance review results on January 5, 2017 (Docket No. 52-047) (NRC 2017-TN5954). On December 15, 2017, TVA submitted Revision 1 of the ESPA (TVA 2017-TN5883). The ESPA is based on a plant parameter envelope (PPE) that considers some of the design information from four light water SMRs under development in the United States by BWX Technologies (BWXT), Holtec, NuScale Power, and Westinghouse.

The proposed site, designated by the applicant as the Clinch River Nuclear (CRN) Site, is located within the city limits of Oak Ridge, Tennessee, in Roane County, adjacent to the Clinch River Arm of the Watts Bar Reservoir, and is approximately 935 ac within a 1,200 ac property owned by the United States of America and managed by TVA. The CRN Site is the location of the former Clinch River Breeder Reactor Project, and is bounded on the east, south, and west by the Clinch River arm of the Watts Bar Reservoir and on the north by the Grassy Creek Habitat Protection Area. Communities located near the site include Kingston (approximately 6.8 mi west), Harriman (approximately 9.2 mi west-northwest), Lenoir City (approximately 8.8 mi southeast), Farragut (approximately 12 mi east), and Knoxville (approximately 25.6 mi east-northeast). ESPA Part 2 (i.e., the Site Safety Analysis Report [SSAR]), Section 2.1, "Geography

and Demography,” provides a more detailed description of the site location, and Figures 2.1-3, “Vicinity Map,” and 2.1-4, “50-Mile Region,” show the CRN Site location and the surrounding 5 mi vicinity and 50 mi region, respectively (TVA 2017-TN5387).

As part of the application, TVA submitted two distinct (onsite) major features emergency plans for the new plant under 10 CFR 52.17(b)(2)(i) (TN251): ESPA Part 5A (Emergency Plan, Site Boundary Emergency Planning Zone [EPZ] [TVA 2017-TN5443]) and ESPA Part 5B (Emergency Plan, 2 mile EPZ [TVA 2017-TN5442]). Both emergency plans (hereinafter referred to as “ESP Plan 5A” and “ESP Plan 5B,” respectively) are based on the existing TVA Generic Emergency Plan. ESP Plan 5A contains the major features of an emergency plan for a plume exposure pathway (PEP) EPZ at the site boundary of the CRN Site (TVA 2017-TN5443). ESP Plan 5B contains the major features of an emergency plan for a PEP EPZ consisting of an area approximately 2 mi (3.22 km) in radius from the site center point (TVA 2017-TN5442). EPZs for commercial nuclear power reactors are addressed in 10 CFR 50.33(g) (TN249), 10 CFR 50.47(b) and (c)(2) (TN249), and Appendix E to 10 CFR Part 50 (TN249), which identify a PEP EPZ of about 10 mi (16 km) in radius from the site, and an ingestion exposure pathway of about 50 mi (80 km) in radius from the site.

The applicant stated that both of the major features emergency plans comply with 10 CFR 50.47(b) (TN249) and Appendix E to 10 CFR Part 50 (TN249), except where they request exemption from the regulation, as described in ESPA Part 6, “Exemptions and Departures” (TVA 2017-TN5444). The application did not include offsite (State or local) Radiological Emergency Preparedness (REP) plans in support of the CRN Site, and stated in SSAR Section 13.3.3.2 (TVA 2017-TN5387), “Ingestion Exposure Pathway,” that the ingestion exposure pathway EPZ for the CRN Site will be described in a possible future combined license (COL) application (hereinafter referred to as “COLA”).

ESPA Part 6 (TVA 2017-TN5444) states that TVA is proposing a dose-based, consequence-oriented approach that could be used to establish an appropriate PEP EPZ size that is consistent with, and based upon, the U.S. Environmental Protection Agency (EPA) protective action guide (PAG) dose criteria for early phase protective actions in the unlikely event of a severe accident (EPA 2017-TN5977).[1] An appropriate PEP EPZ size would be established in a COLA or a construction permit (CP) application referencing the ESP, if issued. SSAR Section 13.3 describes TVA’s dose-based, consequence-oriented approach. Although SSAR Section 13.3 describes only how a COL applicant would implement this methodology, under Permit Condition 1.7-1 (7), a CP applicant referencing the ESP would have to undertake the same activities. The emergency plan (ESP Plan 5A or 5B) ultimately selected for the site in a future COL or CP application would be based upon the selected SMR design’s ability to meet the criteria in the applicable plan, including the PEP EPZ size, and conform to the criteria described in SSAR Section 13.3, “Emergency Preparedness” (TVA 2017-TN5387).

On June 10, 2016, the applicant supplemented the ESPA with an Evacuation Time Estimate Report (hereinafter referred to as the “ETE Report” or “ETE”) (TVA 2016-TN5955). The ETE Report was provided as a part of ESP Plan 5B (TVA 2017-TN5442) to support the NRC staff’s determination (pursuant to 10 CFR 52.18 [TN251]) of whether any physical characteristics of the proposed site that cannot be mitigated or eliminated could pose a significant impediment to the

[1] Table 2-1, “PAGs and Protective Actions for the Early Phase of a Radiological Incident,” (EPA 2017-TN5977) summarizes the PAGs and corresponding protective actions during the early phase of a radiological incident. The January 2017 EPA PAG Manual (EPA 2017-TN5977) supersedes the 1992 (EPA 1992-TN5986), 2013 (EPA 2013-TN5978), and 2016 (EPA 2016-TN6160) EPA PAG Manuals.

development of emergency plans. (The ETE Report [TVA 2016-TN5955] is discussed in Sections 13.3.3.1 and 13.3.3.5.18 of this chapter.)

As described below, the staff reviewed the ESPA, the applicant's responses to requests for additional information (RAIs), and generally available reference materials, in accordance with the guidance provided in NUREG‑0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)" (hereafter the SRP) Section 13.3, "Emergency Planning" (NRC 2007/2018-TN5898).

In a letter dated February 13, 2017 (NRC 2017-TN5956), pursuant to the FEMA-NRC Memorandum of Understanding (FEMA/NRC 2015-TN5963), NRC gave FEMA EP-related portions of the ESPA, and requested that FEMA review the application and give NRC the following determinations:

1. whether there is a significant impediment to the development of offsite emergency plans for the 2 mi PEP EPZ (for ESP Plan 5B), pursuant to 10 CFR 52.17(b)(1) and 10 CFR 52.18); and
2. whether the proposed major features of ESP Plan 5B, specifically related to the exact size and configuration of the 2 mi PEP EPZ, are acceptable.

FEMA responded to the NRC's February 13, 2017, letter (NRC 2017-TN5956) on June 12, 2017 (FEMA 2017-TN5957), and supplemented its response on August 11, 2017 (FEMA 2017-TN5958). In a September 14, 2017, letter to FEMA (NRC 2017-TN5959), the NRC identified nine EP issues raised by FEMA in its June 12, 2017, letter, and provided a detailed response to each issue. On January 24, 2018 (FEMA 2018-TN5960) FEMA supplemented its June 12, 2017, and August 11, 2017, letters. The January 24, 2018, letter provided the two determinations associated with the ESPA that the staff had requested (FEMA 2018-TN5960). The staff reviewed the FEMA findings, and the overall FEMA conclusions for determinations 1 and 2 (above) are reflected in Sections 13.3.3 and 13.3.4, respectively, of this chapter.

13.3.1 Summary of Application

SSAR Section 13.3 (TVA 2017-TN5387) describes emergency preparedness for an SMR facility at the CRN Site, and addresses the submission of major features of an emergency plan for a PEP EPZ at the site boundary (ESP Plan 5A [TVA 2017-TN5443]), and for an area approximately 2 mi in radius from the center point of the site (ESP Plan 5B [TVA 2017-TN5442]). SSAR Section 13.3 (TVA 2017-TN5387) addresses the physical characteristics of the CRN Site, the PEP EPZs for the new plant, the ETE Report (TVA 2016-TN5955), and contacts and agreements with local, State, Federal, and other organizations that have supporting emergency responsibilities. The ESPA did not include any EP Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC), pursuant to 10 CFR 52.17(b)(3) (TN251). The applicant also provided the following EP information in the ESPA:

- <u>Onsite Major Features Emergency Plans</u> – As described in the SSAR (TVA 2017-TN5387), the ESPA emergency plan for a new plant at the CRN Site is provided in ESPA Part 5, and consists of two distinct onsite major features emergency plans. ESPA Part 5A (ESP Plan 5A [TVA 2017-TN5443]) contains the major features of an onsite emergency plan for a PEP EPZ at the site boundary. ESPA Part 5B (ESP Plan 5B [TVA 2017-TN5442]) contains the major features of an onsite emergency plan for the PEP EPZ consisting of an area approximately 2 mi in radius from the site center point of the site. TVA proposed in its application that the NRC approve a methodology that could be used when determining

whether a severe accident in a chosen reactor design would result in exceeding the EPA PAGs (EPA 2017-TN5977) for the site boundary or the 2 mi PEP EPZ, as applicable. ESP Plan 5B (TVA 2017-TN5442) also contains an ETE Report (TVA 2016-TN5955) associated with the 2 mi PEP EPZ. The major features onsite emergency plans, and respective PEP EPZs, are determined based on criteria that the selected SMR design must meet in order for the applicable major features emergency plan and PEP EPZ to apply. Site-specific information is included in Appendix A of both plans to address EP for the CRN Site.

Both major features onsite emergency plans are based on the existing TVA “Nuclear Power Radiological Emergency Plan (NP-REP), Generic Part” (TVA 2015-TN6161), and reflect the requested exemptions that are described in ESPA Part 6 (TVA 2017-TN5444) (addressed in Section 13.3.3.4). The plans address pertinent requirements and associated guidance contained in NUREG–0654/FEMA-REP-1, Revision 1, “Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants” (NRC 1980-TN512; hereinafter referred to as “NUREG–0654”), and Supplement 2, “Criteria for Emergency Planning in an Early Site Permit Application” (NRC 1996-TN5962) to provide major features of the onsite emergency plans. Information that was not available to TVA during the development of the ESPA will need to be addressed at the time of a COLA.

- Offsite Emergency Plans – The ESPA did not include, nor is it required to include, offsite (State or local) REP plans, in support of the CRN Site. However, the ESPA did describe anticipated offsite support from various agencies (e.g., law enforcement, fire departments, ambulance services, etc.).
- Exemption Requests – In ESPA Part 6 (TVA 2017-TN5444) and pursuant to 10 CFR 52.7 (TN251), TVA identified requests for exemption, from various requirements for onsite and offsite emergency plans, and the associated PEP EPZs. Tables 1-1 and 1-2 of EPSA Part 6 (TVA 2017-TN5444) identify specific requirements in 10 CFR 50.33(g), 10 CFR 50.47(b), 10 CFR 50.47(c)(2) (TN249), and Appendix E to 10 CFR Part 50 (TN249), from which TVA is requesting exemptions associated with the site boundary PEP major features emergency plan in ESP Plan 5A (TVA 2017-TN5443). Table 1-3 of ESPA Part 6 (TVA 2017-TN5444) identifies specific requirements in 10 CFR 50.33(g) and 50.47(c)(2) (TN249), from which TVA is requesting exemptions associated with the 2 mi PEP major features emergency plan in ESP Plan 5B (TVA 2017-TN5442). (The staff’s evaluation of the exemption requests is discussed in Section 13.3.3.4 of this chapter.)
- Departures – ESPA Part 6, Section 2.0, “Clinch River Nuclear Site Departures” (TVA 2017-TN5444), states that because TVA has not selected a reactor design, departures from a referenced Design Control Document have not been identified.

13.3.2 Regulatory Basis

The applicable regulatory requirements and guidance for evaluation of the EP information submitted in this ESPA are found in the following sources:

- 10 CFR 50.12, “Specific exemptions” (TN249)
- 10 CFR 50.33, “Contents of applications, general information” (TN249)
- 10 CFR 50.34, “Contents of applications; technical information” (TN249)
- 10 CFR 50.47, “Emergency plans” (TN249)

- 10 CFR 50.72, “Immediate notification requirements for operating nuclear power reactors” (TN249)
- 10 CFR 52.7, “Specific exemptions” (TN251)
- 10 CFR 52.17, “Contents of applications; technical information” (TN251)
- 10 CFR 52.18, “Standards for review of applications” (TN251)
- 10 CFR 100.21, “Non-seismic siting criteria” (TN282)
- 10 CFR Part 50, Appendix E, “Emergency Planning and Preparedness for Production and Utilization Facilities” (TN249)
- U.S. NRC Office Instruction LIC-103, “Exemptions from NRC Regulations,” Revision 1, July 6, 2006 (NRC 2006-TN6162)
- U.S. NRC Final Rule, “10 CFR Parts 50 and 52 – Enhancements to Emergency Preparedness Regulations,” November 23, 2011 (76 FR 72560-TN5999)
- U.S. NRC Final Rule, “10 CFR Parts 50 and 70 – Emergency Planning,” Paragraph II, “Emergency Planning Zone Concept,” and Paragraph III, “Position on Planning Basis for Small Light-Water Reactors and Ft. St. Vrain,” August 19, 1980 (45 FR 55402-TN6024)
- Regulatory Guide (RG) 1.97, “Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants,” Revision 4, June 2006 (NRC 2006-TN5964)
- NUREG–0396/EPA 520/1-78-016, “Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants,” December 1978 (NRC and EPA 1978-TN4441)
- NUREG–0654/FEMA-REP-1, Revision 1, “Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants,” November 1980 (NRC 1980-TN512)
- NUREG–0654/FEMA-REP-1, Revision 1, Supplement 2, “Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants – Criteria for Emergency Planning in an Early Site Permit Application,” April 1996 (NRC 1996-TN5962)
- NUREG–0654/FEMA-REP-1, Revision 1, Supplement 3, “Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants – Guidance for Protective Action Strategies,” November 2011 (NRC 2011-TN5965)
- NUREG–0696, “Functional Criteria for Emergency Response Facilities – Final Report,” February 1981 (NRC 1981-TN5966)
- NUREG–0737, Supplement 1, “Clarification of TMI [Three Mile Island] Action Plan Requirements – Requirements for Emergency Response Capability (Generic Letter No. 82-33),” June 1982 (NRC 1983-TN5967)
- NUREG–0800, Revision 3, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Revision 3, March 2007 (NRC 2007/2018-TN5898)
- NUREG/CR-7002 (SAND2010-0016P), “Criteria for Development of Evacuation Time Estimate Studies,” November 2011 (Jones et al. 2011-TN5968)

- NSIR/DPR-ISG-01, “Interim Staff Guidance – Emergency Planning for Nuclear Power Plants,” Revision 0, November 2011 (NRC 2011-TN5969)
- NSIR/DPR-ISG-02, “Interim Staff Guidance – Emergency Planning Exemption Requests for Decommissioning Nuclear Power Plants,” May 2015 (NRC 2015-TN5971)
- SECY-96-0170, “Assessment of Exceptions Granted for Locations and Staffing Times of Emergency Operation[s] Facilities,” August 5, 1996 (NRC 1996-TN5970)
- SRM to SECY-96-0170, “Staff Requirements Memorandum – Assessment of Exceptions Granted for Locations and Staffing Times of Emergency Operation[s] Facilities,” September 18, 1996 (NRC 1996-TN5972)
- SECY-11-0152, “Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors,” October 28, 2011 (NRC 2011-TN5973)
- SECY-15-0077, “Options for Emergency Preparedness for Small Modular Reactors and Other New Technologies,” May 29, 2015 (NRC 2015-TN5976); and Staff Requirements Memorandum (SRM) SECY-15-0077, August 4, 2015 (NRC 2015-TN5975)
- SECY-16-0012, “Accident Source Terms and Siting for Small Modular Reactors and Non-Light Water Reactors,” February 7, 2016 (NRC 2016-TN5974)
- U.S. EPA “PAG Manual – Protective Action Guides and Planning Guidance for Radiological Incidents,” March 2013 (EPA 2013-TN5978)
- U.S. EPA Report No. EPA-400/R-17/001, “PAG Manual – Protective Action Guides and Planning Guidance for Radiological Incidents,” January 2017 (EPA 2017-TN5977).

13.3.3 Technical Evaluation

Pursuant to 10 CFR 52.17(b)(1) (TN251), an ESPA must identify in the SSAR the physical characteristics of the proposed site, such as egress limitations from the area surrounding the site, that could pose a significant impediment to the development of emergency plans. If such physical characteristics are identified, the application must identify measures that would, when implemented, mitigate or eliminate the significant impediment. In addition, 10 CFR 52.17(b)(2) (TN251) allows an ESP applicant to propose either major features of emergency plans or complete and integrated emergency plans, in accordance with the pertinent standards of 10 CFR 50.47 (TN249) and requirements of Appendix E to 10 CFR Part 50 (TN249).

Major features of emergency plans are defined in 10 CFR 52.1 (TN251) as those aspects of the plans that are necessary to address in whole or in part one or more of the 16 planning standards in 10 CFR 50.47(b) (TN249), or a description of the EPZs as required by 10 CFR 50.33(g) (TN249).[2] For a complete and integrated emergency plan, 10 CFR 52.17(b)(4)

[2] Before the amendment of 10 CFR Parts 50 (TN249) and 52 (TN251) in 2007 (see 72 FR 49351-TN4796 [August 28, 2007]), *major features of the emergency plans* were defined in NUREG–0654, Supplement 2, “Criteria for Emergency Planning in an Early Site Permit Application – Draft Report for Comment,” published in April 1996 (NRC 1996-TN5962). Section V, “Planning Standards and Evaluation Criteria for Major Features of the Emergency Plan,” of Supplement 2 defined major features as a reduced and revised set of NUREG–0654 planning standards and evaluation criteria, which were expanded in the 2007 rulemaking to the full set of NUREG–0654 planning standards and evaluation criteria; thus allowing a major features emergency plan to address any desired scope and depth of the emergency planning requirements, just short of a complete and integrated plan. While the definition of major features in Supplement 2 changed, the remaining guidance in Supplement 2 remains applicable to ESPAs.

(TN251) requires that the applicant make good-faith efforts to obtain certifications from local, State, and Federal governmental agencies that have EP responsibilities. In addition, 10 CFR 52.17(b)(3) (TN251) requires that the complete and integrated emergency plans (if provided in the ESPA) include the proposed ITAAC that will provide reasonable assurance that the facility has been constructed and will be operated in conformity with the emergency plans, the Atomic Energy Act of 1954, as amended (TN663) and the NRC's rules and regulations. Additional guidance applicable to ESPAs is provided in NUREG–0654, Supplement 2 (NRC 1996-TN5962).

TVA proposed major features of an emergency plan for both ESP Plan 5A and ESP Plan 5B, pursuant to 10 CFR 52.17(b)(2)(i) (TN251). SSAR Section 1.2.2, "Site Development," states that TVA has not selected a reactor technology to be constructed at the CRN Site (TVA 2017-TN5387). Instead, a set of bounding plant parameter values has been identified, based upon the available information from various light-water-cooled, SMR designs. This set of bounding values, referred to as the PPE, is presented in SSAR Section 2.0, "Plant Parameter Envelope," and provides the basis for future site development at the CRN Site (TVA 2017-TN5387).

The PPE is based on construction and operation at the CRN Site of two or more SMRs that have a maximum rated thermal power for a single unit of 800 MWt (reactor core) generation capacity. The combined nuclear generating capacity from the site is not to exceed 2,420 MWt (800 MWe). Because a specific reactor technology has not been selected, an area, referred to as the "power block area," has been proposed as the location of the reactor modules on the site. The CRN Site location is shown in SSAR Figure 1.2-1, "Clinch River Nuclear Site Location," while the general plant areas, including the power block area, are illustrated in SSAR Figure 1.2-2, "Clinch River Nuclear Site Plant Areas" (TVA 2017-TN5387).

SSAR Section 1.11, "Overview of Reactor Types," states that the applicant used some of the design information from four conceptual, light-water cooled, SMR designs (listed below) to create a "surrogate plant" (NEI 2012-TN5979, NEI 2012-TN5237) and to develop the site-related design parameter values listed in SSAR Table 2.0-2 of Chapter 2 (TVA 2017-TN5387):

- BWXT mPower (Generation mPower LLC)
- NuScale (NuScale Power, LLC)
- SMR-160 (Holtec SMR, LLC)
- Westinghouse SMR (Westinghouse Electric Company, LLC).

SSAR Section 1.11 further states that all four designs are described as passively safe with minimal or no reliance on offsite power, offsite water, or operator action for safety (TVA 2017-TN5387). Based on their design features, these designs eliminate various conventional design basis events (DBEs; e.g., large-break loss of coolant accidents [LOCAs] precluded by elimination of large-bore piping). All of these designs are integral pressurized-water reactors (iPWRs); that is, pressurized-water reactor designs in which the primary coolant system and all (or most) of its components (i.e., pressurizer, steam generators, and reactor coolant pumps, where applicable) are enclosed in one pressure vessel.

SSAR Section 13.3 states that the surrogate design is reasonable for SMR designs because it has been informed by preliminary information from vendors of SMRs that have had some pre-application discussions (for design certifications) with the NRC (TVA 2017-TN5387). SSAR Section 13.3.3.1.3.1, "Multiple Reactors at the CRN Site," states that the surrogate design in the ESPA PPE includes multiple reactor units, and it is anticipated that the SMR design included in the COLA will also include multiple reactor units (TVA 2017-TN5387). SSAR Section

13.3.3.1.4, “COLA,” states that during preparation of a COLA, when TVA has selected a reactor design, TVA intends to demonstrate that the selected design falls within the design parameters postulated in the ESPA (TVA 2017-TN5387). (See Section 13.3.3.3 of this chapter, which addresses the dose-based, consequence-oriented EPZ sizing associated with the SMR surrogate design.) Because the specific SMR type for the CRN Site has not been selected, technical information from various reactor designs was used to develop bounding parameters (i.e., PPE) intended to envelope the proposed facility characterization necessary to evaluate the suitability of the site for future construction and operation of a nuclear power plant (NPP). The choice of SMR type will be made by a COL or CP applicant that uses the ESP, if granted, as a reference for the CRN Site.

The staff reviewed the information in the ESPA, including SSAR Section 13.3 (TVA 2017-TN5387), and the major features emergency plans (ESP Plans 5A and 5B) for conformance with applicable standards and requirements identified in SRP Section 13.3 (NRC 2007/2018-TN5898), and confirmed that the ESPA addresses the required information related to EP, subject to the requested exemptions identified in ESPA Part 6 (TVA 2017-TN5444). The staff also visited the CRN Site and area on May 16, 2017, to review the various areas within and beyond the 2 mi PEP EPZ proposed in ESP Plan 5B (TVA 2017-TN5442), in order to gain first-hand knowledge of the CRN Site and surrounding areas, as they are addressed in the ESPA.

Consistent with SRP Section 13.3 (NRC 2007/2018-TN5898), the staff’s technical reviews of the ESPA addressed the evaluation criteria for the 16 planning standards contained in Sections II.A through II.P of NUREG-0654 (NRC 1980-TN512), to the extent that TVA addressed them in ESP Plans 5A and 5B.

13.3.3.1 Significant Impediments to the Development of Emergency Plans

Pursuant to 10 CFR 52.17(b)(1) (TN251), an ESPA for a prospective commercial nuclear power reactor(s) must identify the physical characteristics of the proposed site, such as egress limitations from the area surrounding the site, that could pose a significant impediment to the development of emergency plans. If any such physical characteristics are identified, the application must identify measures that would, when implemented, mitigate or eliminate the significant impediment.

The guidance in NUREG-0654, Supplement 2 (NRC 1996-TN5962), defines *significant impediment* as a physical characteristic or combination of physical characteristics that would pose major difficulties for an evacuation or the taking of other protective actions as addressed in Section II, “Early Site Permit – Identification of Physical Characteristics.”. In addition, Section II states that an ESP applicant may identify such unique physical characteristics by performing a preliminary analysis of the time required to evacuate various sectors and distances within the PEP EPZ for transient and permanent populations, noting major impediments to the evacuation or the taking of other protective actions (NRC 1996-TN5962). Further, the ETE (TVA 2016-TN5955) is an EP tool that can be used to assess the feasibility of developing emergency plans for a site, and would serve to demonstrate whether any physical characteristics (or combination of physical characteristics) of the site could pose impediments to the development of emergency plans.

The requirements for developing an ETE are contained in Section IV, “Content of Emergency Plan,” of Appendix E to 10 CFR Part 50 (TN249). Associated guidance is provided in NUREG/CR-7002 (SAND2010-0016P), “Criteria for Development of Evacuation Time Estimate Studies” (Jones et al. 2011-TN5968). In addition, SRP Section 13.3, Subsection II, “Acceptance

Criteria," states the following in Criterion 16 under "SRP Acceptance Criteria" (NRC 2007/2018-TN5898):

> For an ESP application, a preliminary analysis of evacuation times is one example of how some significant impediments to the development of emergency plans may be identified. Other factors, such as the availability of adequate shelter facilities, in consideration of local building practices and land use (e.g., outdoor recreation facilities, including camps, beaches, hunting or fishing areas), and the presence of large institutional or other special needs populations (e.g., schools, hospitals, nursing homes, prisons) should also be addressed when identifying significant impediments to the development of emergency plans. Any ETE analysis or other identification of physical impediments should include the latest population census numbers and reflect the most recent local conditions. Appendix 4 to NUREG-0654/FEMA-REP-1, Revision 1, and Supplement 2 to NUREG-0654/FEMA-REP-1, Revision 1, provide guidance relating to performing an ETE analysis. NUREG/CR-6863 provides additional information on ETEs.

In SSAR Section 13.3.1, "Physical Characteristics," TVA stated that the CRN Site lies north of U.S. Interstate 40, approximately midway between the communities of Harriman and Farragut in the eastern portion of the State of Tennessee (TVA 2017-TN5387). The U.S. Department of Energy's (DOE's) Oak Ridge Reservation (ORR) borders the north and east sides of the Clinch River property, which covers an area of approximately 1,200 ac located adjacent to the Clinch River Arm of the Watts Bar Reservoir in Oak Ridge, Tennessee.

The permanent resident population was estimated using census block data obtained from the U.S. Census 2010 and is projected to 2015 for this analysis. According to the U.S. Census 2010 data, projected to the year 2015, there are 856 permanent residents within the 2 mi PEP EPZ of the CRN Site, and approximately 186,500 permanent residents within 14 mi of the proposed CRN Site. Additional details about the permanent resident population within the 2 mi PEP EPZ are provided in the ETE Report (TVA 2016-TN5955) and in ESP Plan 5B (TVA 2017-TN5442) of the ESPA.[3] A survey of the transient facilities was conducted to obtain information regarding the transient population expected at these locations. There is one campground (i.e., recreation vehicle park) within the 2 mi PEP EPZ that has an estimated peak population of 197 persons.

In SSAR Section 13.3.1.2, "Area Population" (TVA 2017-TN5387), the applicant stated, in part, the following:

> The ETE does not identify any physical characteristics unique to the CRN Site which pose significant impediments to the development of the Emergency Plan for the CRN Site. The roadway network is modeled in the ETE and is shown to be sufficient to handle the volume of traffic in the event of an emergency.

Section 13.3.3.5.18 of this chapter provides a detailed evaluation of the ETE Report. The ETE Report states in the Executive Summary that "[t]his ETE did not identify physical characteristics

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[3] The ESPA did not include an ETE analysis for the site boundary PEP EPZ in ESP Plan 5A (TVA 2017-TN5443) because the site boundary PEP EPZ does not include any permanent residents, transients, or persons in special facilities (i.e., population distributions around the nuclear facility) that would have to be evacuated. This is consistent with the ETE requirements in Section IV of Appendix E to 10 CFR Part 50 (TN249), and the guidance in NUREG–0654 (NRC 1980-TN512) (including Supplement 2).

of the proposed site that could pose a significant impediment to the development of emergency plans" (TVA 2016-TN5955).

13.3.3.1.1 FEMA Consultation

In its February 13, 2017, letter to FEMA, the NRC requested that FEMA review the ESPA and provide the NRC with its determination about whether there is a significant impediment to the development of offsite emergency plans for the 2 mi PEP EPZ (for ESP Plan 5B) (NRC 2017-TN5956).[4] In its August 11, 2017, response to NRC, FEMA stated, in part, the following (FEMA 2017-TN5958):

> Your February 13, 2017 letter requested to know if FEMA identified any significant physical impediments to the development of offsite emergency response plans for the Clinch River Nuclear Site, presuming a 2-mile plume exposure pathway EPZ (for Emergency Plan 5B). FEMA, working with TEMA [Tennessee Emergency Management Agency], has not identified any physical impediments to a 2-mile plume exposure pathway EPZ, including evacuation if needed from that EPZ.

In its January 24, 2018, letter (FEMA 2018-TN5960), FEMA supplemented its June 12, 2017 (FEMA 2017-TN5957) and August 11, 2017 (FEMA 2017-TN5958) letters with the following:

> With respect to the issue of significant impediments, as described in our August 11, 2017 letter, FEMA, working with Tennessee Emergency Management Agency (TEMA), has not identified physical characteristics of the proposed site that could pose a significant impediment to the development of emergency plans, including evacuation if needed from the 2-mile EPZ.

(Section 13.3.3.5 of this chapter also discusses FEMA's ESPA review associated with the exact size and configuration of the 2 mi PEP EPZ.)

The staff finds that the applicant has shown through use of the ETE Report (TVA 2016-TN5955), including consideration of other factors that support the CRN Site (such as FEMA's consultation with TEMA), that there are no physical characteristics unique to the CRN Site that could pose a significant impediment to the development of emergency plans.

13.3.3.1.2 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in Supplement 2 to NUREG–0654 (NRC 1996-TN5962) and the SRP (NRC 2007/2018-TN5898). Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 52.17(b)(1) (TN251) and 10 CFR 52.18 (TN251) to identify physical characteristics of the proposed site that could pose a significant impediment to the development of emergency plans, insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations. The staff concludes that the applicant has demonstrated that there are no physical impediments to the development of

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[4] The scope of FEMA's review for the ESPA is governed by the NRC regulations in 10 CFR 52.17(b)(1) (TN251), (b)(2)(i) and (b)(4); 10 CFR 52.18 (TN251); 10 CFR 50.47(a)(1)(iv) and (a)(2); and Appendix E of 10 CFR Part 50 (TN249).

emergency plans for the proposed 2 mi PEP EPZ, as described in ESP Plan 5B (TVA 2017-TN5442) and the ETE Report (TVA 2016-TN5955).

13.3.3.2 Contacts and Arrangements with Local, State, and Federal Agencies

As part of the ESPA, TVA submitted major features of the emergency plans pursuant to 10 CFR 52.17(b)(2)(i) (TN251). 10 CFR 52.17(b)(4) (TN251) requires that the applicant include in the SSAR a description of contacts and arrangements made with Federal, State, and local governmental agencies that have EP responsibilities. These responsibilities are described in ESP Plan 5A (TVA 2017-TN5443) and ESP Plan 5B (TVA 2017-TN5442), and are discussed below and in Sections 13.3.3.5.3 and 13.3.3.5.4 of this chapter.

Guidance regarding the specific nature of the contacts and arrangements is provided in SRP Section 13.3 (NRC 2007/2018-TN5898), which states in Subsection II (SRP Acceptance Criteria Nos. 15 and 18), that the ESPA should include copies of letters of agreement or other certifications, reflecting contacts and arrangements made with local, State, and Federal agencies (including agreements or other arrangements with Tribal agencies and private organizations) that have supporting EP responsibilities. The agreement information should be up to date when the application is submitted, and should reflect use of the proposed ESP site for possible construction of a new reactor (or reactors). In addition, a discussion of the details associated with any ambiguous or incomplete language in the letters of agreement should be provided in the application. If the applicant is unable to make arrangements with local, State, or Federal governmental agencies that have EP responsibilities, the applicant should discuss its efforts to make such arrangements and describe any compensatory measures the applicant has taken or plans to take because of the lack of such arrangements.

Additional guidance is provided in Section II.B, “Contacts and Arrangements,” of Supplement 2 to NUREG-0654 (NRC 1996-TN5962), which states that the descriptions of contacts and arrangements should include the name and location of the organization contacted, the title and/or position of the person(s) contacted, and the role of the organization in EP.

In SSAR Section 13.3.5, “Contacts and Agreements” (TVA 2017-TN5387), the applicant stated that TVA has held numerous discussions with local, State and county agencies, and emergency response organizations (EROs) that currently support DOE’s ORR. TVA stated that these discussions were productive and indicative of broad support from these organizations in further development of CRN emergency plans, and that the State of Tennessee and Anderson County provided letters of support. The applicant further stated that certification letters from the State of Tennessee, Roane County, and the City of Oak Ridge will be obtained by TVA and provided in the COLA. In addition, the applicant stated that TVA will maintain arrangements with surrounding EROs that currently support DOE’s ORR, including an existing agreement with the DOE’s Radiation Emergency Assistance Center/Training Site (REAC/TS) in Oak Ridge, Tennessee. The applicant also stated that a letter of agreement with each organization (listed below) will be obtained by TVA for the CRN Site and provided in the COLA:

- local medical facility services
- offsite ambulance service
- local firefighting support
- local law enforcement agencies.

The submission to the NRC of certification letters and letters of agreement in a COLA is addressed in Section 13.3.3.5.2 of this chapter.

As previously discussed, the ORR borders the north and east sides of the Clinch River property, which includes the CRN Site, and is located adjacent to the Clinch River Arm of the Watts Bar Reservoir in Oak Ridge, Tennessee. The applicant's reference to EROs that currently support ORR does not reflect an acknowledgment by those organizations of the proposed expanded responsibilities associated with the CRN Site. In addition, the applicant referenced letters from TEMA, and Anderson and Roane Counties, but did not include copies of these letters in the ESPA.

In an e-mail dated May 25, 2017, the NRC provided TVA RAI-1-8761, Question 13.03.1 (NRC 2017-TN5981), which requested copies of all letters and certifications (or other documentation of arrangements) from the local/offsite support organizations referred to in SSAR Section 13.3.5 (TVA 2017-TN5387). These organizations include TEMA, Anderson County, Roane County, City of Oak Ridge (if documentation exists), and the DOE REAC/TS. Consistent with the applicable guidance, the documents should describe each organization's acknowledgment of their support for the addition of a new reactor(s) at the CRN Site, and include the name and location of the organization contacted, the title and/or position of the person(s) contacted, and the role of the organization in EP and response.

In its June 15, 2017, response to RAI-1-8761, Question 13.03-1 (TVA 2017-TN5982), TVA provided copies of letters from TEMA, Anderson County, Roane County, and the City of Oak Ridge (TVA 2017-TN6163; TEMA 2015-TN5983). In addition, TVA provided a copy of the existing letter of agreement with the DOE REAC/TS (TVA 2017-TN6163). With regard to contacts and arrangements made with local, State, and Federal agencies that have EP responsibilities, TVA stated the following:

> TVA has held several productive discussions with these organizations and has received broad support from them, as indicated in the letters of support. Additionally, the letters express the organization's plans to actively participate in all emergency planning and radiological emergency preparedness exercises and evaluations.
>
> The nature and extent of emergency planning support required from organizations referenced in SSAR Section 13.3.5 is not finalized because the ESPA proposes two distinct emergency plans requiring significantly different levels of emergency planning support. Therefore, TVA plans to obtain and provide the certification letters and letters of agreements from local/offsite support organizations at the COLA stage.

The staff reviewed the letters from offsite support organizations, and finds that TVA's response to RAI-1-8761, Question 13.03-1 (TVA 2017-TN5982), provides an adequate description of contacts and arrangements made with Federal, State, and local governmental agencies, including other local/offsite organizations that have EP responsibilities, pursuant to 10 CFR 52.17(b)(4) (TN251). The staff finds the applicant's response to RAI-1-8761 acceptable and, therefore, considers RAI-1-8761, Question 13.03-1 resolved.

With regard to obtaining certification letters from governmental agencies, since TVA has not obtained any certifications, the 10 CFR 52.17(b)(4) requirement to include any certifications that have been obtained does not apply to the ESPA. Further, from the staff's review of the letters that were provided from offsite organizations (described above), there is no indication that certifications cannot be obtained to support a future COL, CP or operating license application,

such that the 10 CFR 52.17(b)(4) requirement that applies when certifications cannot be obtained also does not apply to the ESPA.

13.3.3.2.1 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in Supplement 2 to NUREG–0654 (NRC 1996-TN5962) and the SRP (NRC 2007/2018-TN5898). Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 52.17(b)(4) (TN251) to include a description of contacts and arrangements made with Federal, State, and local governmental agencies that have EP responsibilities, insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations. Specifically, the applicant provided an adequate description of contacts and arrangements made with Federal, State, and local governmental agencies.

13.3.3.3 Dose-Based, Consequence-Oriented EPZ Sizing

The purpose of this section is to address the methodology proposed by TVA in the ESPA that a COL or CP applicant could use to establish a PEP EPZ for SMRs at the CRN Site, which includes the application of a graded approach to demonstrate compliance with EP regulatory requirements. Such an approach uses a consequence-oriented basis for determining the appropriate size of the PEP EPZ that is consistent with EPA early phase PAG criteria (i.e., dose-based) (EPA 2017-TN5977).

13.3.3.3.1 Current Technical Bases for EPZs for Commercial Power Reactors

In 1978, a task force of NRC and EPA representatives established the technical basis for EP for large light water reactors (LLWRs) and published the results in NUREG–0396 (NRC and EPA 1978-TN4441). The task force's report concluded that the objective of emergency response plans should be to produce dose savings for a wide spectrum of accidents that could produce offsite doses in excess of the EPA PAGs. The PAGs, also listed in the updated January 2017 EPA PAG Manual (EPA 2017-TN5977), are reference values for radiation doses that warrant preselected protective actions (e.g., evacuation or sheltering-in-place) for public protection, if the projected dose received by an individual, in the absence of protective action, exceeds the PAGs.

The task force considered that the most important guidance for planning officials is the distance from the nuclear facility that defines the area over which planning for predetermined actions should be carried out. NUREG–0396 (NRC and EPA 1978-TN4441) introduced the concept of the EPZ, stating that the recommended EPZ should be "of sufficient size to provide dose savings to the population in areas where the projected dose from design basis accidents (DBAs) could be expected to exceed the applicable PAGs (under unfavorable atmospheric conditions)." It identified the following two types of EPZs, where each has a distinct distance from the NPP, and defines a zone where advanced planning would be appropriate:

- A PEP EPZ is the zone in which the principal exposure sources from this pathway are (1) whole body external exposure to gamma radiation from the plume and from deposited material, and (2) inhalation exposure from the passing radioactive plume. The PEP EPZ is the zone in which plans are prepared for prompt or urgent actions to protect the public.
- An ingestion exposure pathway EPZ is the zone in which the principal exposure from this pathway would be from ingestion of contaminated water or foods, such as milk or fresh

vegetables. The ingestion exposure pathway EPZ is the zone in which plans are prepared to prevent radioactive material from potentially entering the food chain.

In developing the recommendation, the task force considered several rationales for establishing the size of the EPZs. These rationales included the notions of risk criteria, probability limits, cost effectiveness, public perceptions, and a spectrum of accident consequences. The task force chose to base the rationale on a full spectrum of accidents and corresponding consequences, tempered by probability considerations. The task force stated that emergency plans for LLWRs could be based on a generic distance, out to which predetermined actions would provide dose savings for any such accidents.

13.3.3.3.1.1 *Plume Exposure Pathway EPZ*

The task force recommended a 10 mi (16 km) radius for the PEP EPZ, primarily based on estimation of potential radiological consequences of accidents. The following considerations were used to determine the generic distance (i.e., 10 mi [16 km]) for the PEP EPZ:

- The EPZ would be the area beyond which the projected dose from DBAs would not exceed the EPA early phase PAG levels.
- The EPZ would be the area beyond which the doses from less severe core damage accidents (i.e., not involving large releases of radioactive material to the environment) would not exceed the EPA early phase PAGs.
- The EPZ would be of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt sequence accidents (i.e., beyond-design basis severe events with release of substantial quantities of radioactive materials to the environment). In this case, life-threatening doses would not occur outside the zone.
- Detailed planning for protective actions within the 10 mi (16 km) EPZ should provide a basis for the expansion of response efforts beyond the PEP EPZ, if needed.

The task force stated that the detailed planning within the PEP EPZ would provide a substantial base for expanding response efforts, if necessary for low-probability, high-consequence events, whose effects could extend beyond the PEP EPZ. The task force determined the size of the PEP EPZ by evaluating DBA data from licensees' Final Safety Analysis Reports (FSARs), and accident sequences, risk, and source term data from NUREG–75/014 (WASH 1400), "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," October 1975 (NRC 1975-TN5984).

13.3.3.3.1.2 *Ingestion Exposure Pathway EPZ*

The task force recommended that the ingestion exposure pathway EPZ have a 50 mi (80 km) radius, based on the projected distance intended for longer-term response actions, and at which distance doses to the infant thyroid from the ingestion of milk would not exceed the thyroid exposure PAG for milk ingestion.

13.3.3.3.2 Dose-Based, Consequence-Oriented EPZ Size Concept for SMRs

After public meetings with industry and stakeholders, the staff issued SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors," dated October 28, 2011 (NRC 2011-TN5973). This paper discussed the staff's intent to develop a technology-neutral, dose-based, consequence-oriented EP framework for SMR

sites that takes into account the various designs, modularity and co-location, as well as the size of the EPZ. It also stated that the "staff will work with stakeholders to develop general guidance on calculating the offsite dose, and is anticipating that the industry will develop and implement the detailed calculation method for review and approval by the staff."

In SECY-15-0077, the staff proposed a consequence-oriented approach to establishing requirements commensurate with the potential consequence to public health and safety, and the common defense and security at SMR and other new technology (ONT) facilities (NRC 2015-TN5976). The staff stated that the need to establish an EP framework for SMRs and ONTs is based upon the projected offsite dose in the unlikely occurrence of a severe accident. In the SRM to SECY-15-0077, "Staff Requirements – SECY-15-0077 – Options for Emergency Preparedness for Small Modular Reactors and Other New Technologies," dated August 4, 2015 (NRC 2015-TN5975), the Commission directed the staff to proceed with rulemaking, and that for any SMR reviews conducted prior to the establishment of a rule, the staff should be prepared to adapt an approach to EPZs for SMRs under existing exemption processes, in parallel with its rulemaking efforts. As discussed in SECY-11-0152, a scalable method for determining the EPZ for SMRs is based on offsite dose considerations (NRC 2011-TN5973).

13.3.3.3.3 Method for Determining Plume Exposure Pathway EPZ Size

In the SRM to SECY-15-0077, the Commission has indicated that it is open to considering SMR proposals to change the EPZ size, including exemption requests, until such time as the ongoing EP rulemaking for SMRs and ONTs is complete (NRC 2015-TN5975). Therefore, the staff is evaluating the reasonableness of the applicant's proposal in the ESPA for a method to perform analyses to support the determination of the PEP EPZ size. The staff used NUREG–0396 (NRC and EPA 1978-TN4441) and other regulatory guidance (listed in Section 13.3.2 of this chapter) on accident assessment to perform this review.

SSAR Section 13.3.3.1, "Plume Exposure Pathway Emergency Planning Zone," describes TVA's method for performing analyses to determine an appropriate EPZ size for the CRN Site that a COL or CP applicant could use to determine the size of the PEP EPZ (TVA 2017-TN5387). The approach considers the use of the existing EP regulatory framework, including the dose-saving criteria in NUREG–0396 (NRC and EPA 1978-TN4441). Specifically, the applicant proposed that the technical criteria for determining the PEP EPZ be as follows:

- The PEP EPZ should encompass the areas in which projected dose from DBAs could exceed the EPA early phase PAGs (EPA 2017-TN5977).
- The PEP EPZ should encompass the areas in which consequences of less severe core-melt accidents could exceed the EPA early phase PAGs (EPA 2017-TN5977).
- The PEP EPZ should be of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents.

Similar to the analysis in NUREG–0396 (NRC and EPA 1978-TN4441), the applicant's proposed method for determining PEP EPZ size relies upon consequence analyses for a range of potential accidents, including DBAs and severe accidents. Although the applicant discussed qualitatively the likelihood of the surrogate design used in the ESPA PPE to meet the proposed criteria, the applicant proposed that the COLA that references the CRN Site ESP would confirm that the criteria are met for the selected PEP EPZ, using the specific information related to potential accidents that result in airborne radiological releases for the plant design chosen to be constructed and operated at the CRN Site. Therefore, for the ESPA, the staff is not reviewing or

approving a specific PEP EPZ size that is associated with a specific SMR technology. The staff is evaluating the reasonableness of the applicant's proposed method for determining the PEP EPZ, which are to be used by the COL or CP applicant as justification for the PEP EPZ in the COLA.

The applicant's proposed method for determining the PEP EPZ size would be used to verify that, beyond the proposed PEP EPZ, the dose consequences for most accidents would not exceed the EPA early phase PAGs (EPA 2017-TN5977), and that there would be a substantial reduction in early health effects[5] for releases due to less probable, more severe accidents. The method includes the following steps:

1. Select and categorize the accident scenarios.
2. Develop the fission product release to the environment as a function of time (radiological release source term).
3. Calculate the projected dose consequences at a distance, and compare them to dose criteria for DBAs and less severe accidents.
4. Calculate the probability of dose exceedance at distance, and evaluate the substantial reduction in early health effects criterion for more severe accidents.

13.3.3.3.3.1 <u>*Proposed Criteria*</u>

The applicant proposed dose criteria to aid in determination of EPZ size, that if not exceeded by projected consequences for potential accidents for average meteorological conditions at the site (i.e., mean value of meteorological conditions), would assure that areas outside the PEP EPZ would not require early protective actions, such as evacuation to ensure public health and safety. The dose criteria proposed by the applicant are that beyond the PEP EPZ outer boundary distance from the facility, the consequences of DBAs and less severe accidents would not exceed the EPA early phase PAGs (EPA 2017-TN5977). For more severe accidents, the criterion is that there is a substantial reduction in early health effects in areas beyond the selected PEP EPZ.

The dose criterion for DBAs and less severe accidents is that the projected dose from exposure to airborne releases during the initial 4 days (including exposure to the radioactive plume and deposited radioactive material) is less than 1 roentgen equivalent man (rem) (0.01 sievert [Sv]) total effective dose equivalent (TEDE). This dose criterion is consistent with the lower end of the range of projected TEDEs that would warrant recommending initiation of protective actions for the public, as given in the EPA PAG Manual description of early phase PAGs (EPA 2017-TN5977) to protect against exposure to accident airborne releases. As given in NUREG–0396 (NRC and EPA 1978-TN4441), the 10 mi PEP EPZ in the EP regulations for commercial power reactors is also based on identification of the area where the early phase PAGs would not be exceeded for DBAs and less severe accidents (e.g., more probable core damage accidents with release of radioactive material to the atmosphere). Because the applicant's proposed dose

[5] The EPA PAG Manual (EPA 2017-TN5977) describes the *early phase* for taking protective actions (i.e., sheltering-in-place, evacuation, or administration of stable/radioprotectant potassium iodide) as lasting hours to days following an incident, and for Table 2-1, "PAGs and Protective Actions for the Early Phase of a Radiological Incident" (i.e., early phase PAGs), as occurring over the first 4 days after the anticipated (or actual) start of a radioactive release. The 4-day period is chosen as the duration of exposure during the early phase because it is a reasonable estimate of the time necessary to make measurements, reach decisions, and prepare to implement further protective actions (such as relocation) if necessary. *Early health effects* are generally associated with a period of days to weeks following radiation exposure.

criterion for DBAs and less severe accidents is based upon the same reasoning that was used as the technical basis for the PEP EPZ distance codified in NRC regulations, the staff finds that the proposed dose criterion for DBAs and less severe accidents is acceptable for use in analyses that form the technical basis for PEP EPZ size.

The substantial reduction in the early health effects criterion is that the conditional probability of acute dose exceeding a 200 rem whole body dose from more severe accident scenarios is less than 1×10^{-3} per reactor-year (rx-yr). This criterion is similar to the criterion used to evaluate consequences of very severe accidents (e.g., less probable core damage accidents that release very large quantities of radioactive material to the atmosphere) in NUREG–0396 (NRC and EPA 1978-TN4441), which is the technical basis for the 10 mi PEP EPZ in the EP regulations for commercial power reactors. The NUREG–0396 task force determined that certain features of the more severe core-melt accidents should be considered in planning to assure that some capability exists to reduce the consequences of even the most severe accidents. The projected consequences of very severe accidents were plotted against distance, and showed that for LLWRs, the conditional probability of exceeding a whole body dose of 200 rem decreases rapidly as one approaches 10 mi, which was subsequently chosen to be the PEP EPZ radius based on all factors considered. As stated in the discussion on page I-37 of NUREG–0396, 200 rem whole body is the dose at which significant early injuries start to occur (NRC and EPA 1978-TN4441). Because the applicant's proposed substantial reduction in early health effects criterion is based upon the same reasoning that was used as the technical basis for the PEP EPZ distance, as codified in NRC regulations, the staff finds that the applicant's proposed substantial reduction in the early health effects criterion is acceptable for use in analyses that form the technical basis for PEP EPZ size.

13.3.3.3.3.2 Accident Selection and Categorization

Consistent with the NUREG–0396 analysis (NRC and EPA 1978-TN4441), the applicant proposed to evaluate a range of accidents to determine the PEP EPZ size. As stated in SSAR Section 13.3.3.1.1, "Environmental Protection Agency Protective Action Guides" (TVA 2017-TN5387), the DBA scenarios will be taken from those postulated accidents identified in a future COLA FSAR. The staff will evaluate the acceptability of the identified postulated accidents, as discussed in Chapter 15, "Transient and Accident Analysis," of the SRP (NRC 2007/2018-TN5898), as part of the COLA review.

For severe accidents, the applicant has proposed a methodical procedure for selecting accident scenarios from the plant-specific probabilistic risk assessment (PRA), and categorizing them as less severe or more severe, based on core damage frequency (CDF). The applicant proposed that the less severe accident category should include core-melt accidents with intact containment, beyond-design basis scenarios, and accident scenarios with mean CDFs greater than 1×10^{-6}/rx-yr. Scenarios would be grouped based on similar timing of core damage and similar equipment availability. The applicant proposed that the more severe accident category include core-melt accidents with postulated containment bypass or failure with potential for higher consequences with mean CDFs greater than 1×10^{-7}/rx-yr. For both severe accident categories, the initial accident sequence selection should include accident sequences with mean CDFs greater than 1×10^{-8}/rx-yr.

As noted by the applicant in SSAR Section 13.3.3.1.2, "Substantial Reduction in Early Health Effects" (TVA 2017-TN5387), there are a number of precedents for the use of 1×10^{-7}/year frequency as a basis for accident sequences selection, including information from NUREG–0396 (NRC and EPA 1978-TN4441). Although the frequency bounds for the severe accident

categories presented by the applicant appear to be reasonable based on the stated precedents, the staff is not making a determination about acceptability at this time, and will review the selection and categorization of severe accidents in more detail when the design-specific PRA and EPZ size basis analyses are evaluated as part of a COLA review.

13.3.3.3.3.3 Radiological Release Source Terms

The applicant stated that DBA radiological release source terms will be the same as those defined for postulated accidents in a COLA FSAR Chapter 15. The DBA radiological consequence analyses will be evaluated by the staff in its review of a COLA, as discussed in SRP Section 15.0.3, "Design Basis Accident Radiological Consequence Analyses for Advanced Light Water Reactors" (NRC 2007/2018-TN5898), or a comparable design-specific review standard, if applicable. Similarly, the PEP EPZ size basis analyses, including the applicant's use of the DBA radiological release source terms within the analyses, will be evaluated by the staff during a COLA review. Therefore, the staff finds that the commitment in the ESPA to use COLA FSAR DBA radiological release source terms is acceptable for use in the analyses to support selection of the PEP EPZ size.

The applicant stated that the severe accident radiological release source terms will be determined based on an NRC-accepted methodology. In SSAR Section 13.3.3.1.4, the applicant stated that a COLA will include detailed information about the Level 2 PRA[6] for the selected reactor technology to be constructed and operated at the CRN Site (TVA 2017-TN5387). The Level 2 PRA information is used to define severe accident fission product releases for the selected less severe and more severe accident sequences that are included in the analyses to support the determination of PEP EPZ size. The Level 2 PRA will be evaluated by the staff in its review of a COLA, as discussed in SRP Chapter 19, "Severe Accidents" (NRC 2007/2018-TN5898). Similarly, the PEP EPZ size basis analyses, including the applicant's use of the Level 2 PRA within the analyses, will also be evaluated by the staff during a COLA review. Because an ESP does not permit construction or operation of a power reactor at the site, specific information about reactor design such as a PRA is not provided or reviewed as part of the ESPA. In addition, the applicant is not determining the PEP EPZ size in the ESPA, and has deferred that determination until detailed design information for the specific SMR design is included as part of the COLA. Therefore, the staff finds that the applicant's descriptions of how severe accident radiological release source terms could be determined in a COLA are reasonable.

13.3.3.3.3.4 Consequence Analysis

In SSAR Section 13.3.3.1.1, the applicant described considerations for performing the DBA and less severe accident consequence analyses for comparison to the dose criterion (i.e., EPA early phase PAG of 1 rem TEDE [EPA 2017-TN5977]) (TVA 2017-TN5387). The analyses will

[6] The NRC uses PRA to estimate risk by computing real numbers to determine what can go wrong, its likelihood, and consequences. Thus, PRA provides insights into the strengths and weaknesses of the design and operation of a NPP. For the type of NPP currently operating in the United States, a PRA can estimate three levels of risk, including (1) a Level 1 PRA estimates the frequency of accidents that cause damage to the nuclear reactor core (commonly called CDF); (2) a Level 2 PRA, which starts with the Level 1 core damage accidents, estimates the frequency of accidents that release radioactivity from the NPP; and (3) a Level 3 PRA, which starts with the Level 2 radioactivity release accidents, estimates the consequences in terms of injury to the public and damage to the environment. (Source: https://www.nrc.gov/about-nrc/regulatory/risk-informed/pra.html)

calculate TEDE for the following exposure pathways: external exposure to the cloud (plume), inhalation, ground shine, and re-suspended ground contamination. The TEDE will be calculated for a 4-day period, consistent with the discussion in the PAG Manual for use of the early phase PAGs (EPA 2017-TN5977). The analyses will also use site-specific information about meteorology to develop average expected (50th percentile) dispersion[7] characteristics and plant-specific radiological release source terms. The dose results will be compared to the dose criterion to determine that the EPA early phase PAG of 1 rem TEDE (EPA 2017-TN5977) is not exceeded at the PEP EPZ boundary.

In SSAR Section 13.3.3.1.2, the applicant described considerations for performing the more severe accident consequence analysis, and the calculation of the conditional probability of exceeding the dose at which early health effects may occur (TVA 2017-TN5387). The applicant stated that the dose calculations will be based on the methodology accepted for the selected certified SMR beyond-DBAs. For each of the accident scenarios in the more severe accident category, the probability of exceeding 200 rem whole body acute dose will be calculated as a function of distance. At each given distance, the scenario frequency-weighted probabilities are summed over all scenarios and normalized by total CDF to give a conditional probability of exceeding 200 rem whole body per reactor-year. The normalized conditional probability versus distance is plotted, and the distance where the result drops below 1×10^{-3}/rx-yr is determined. This distance is then confirmed to be within the PEP EPZ.

The staff finds that the applicant's description of the method for performing the consequence analyses to support the determination in a COLA of the PEP EPZ size is reasonable and consistent with the analyses that were described in NUREG–0396 (NRC and EPA 1978-TN4441). The staff is not making a final determination of the acceptability of the PEP EPZ size at this time, and will review the consequence analyses in more detail when the PEP EPZ size basis analyses are evaluated as part of a COLA review.

13.3.3.3.3.5 *Small Modular Reactor Plant Parameters for PEP EPZ Size Considerations*

To support the exemption requests in ESPA Part 6 (TVA 2017-TN5444) and the emergency plans in ESPA Part 5, TVA concluded that a PEP EPZ of 2 mi radius around the CRN Site provides reasonable assurance of public health and safety from potential accidents for any of the four SMRs within the PPE. TVA further stated that it is possible that at least one of the SMR designs will be able to demonstrate that the 1 rem TEDE threshold, established in the EPA PAG Manual, will not be exceeded at the site boundary in the event of an accident. To aid in its evaluation of the exemption requests, in eRAI-8885 (RAI No. 7) (NRC 2017-TN5987) the staff requested that TVA provide additional information to describe whether and how the proposed accident consequence criteria in SSAR 13.3 are met at a given PEP EPZ boundary distance of less than 10 mi (including at the site boundary) for potential reactor facilities that would be encompassed within the PPE, as requested in the ESPA.

By letters dated August 24, 2017 (TVA 2017-TN5988), March 9, 2018 (TVA 2018-TN5989), and March 30, 2018 (TVA 2018-TN5990), in response to eRAI-8885 (RAI No. 7) (NRC 2017-TN5987) and eRAI-9206 (RAI No. 10) (NRC 2017-TN6164), TVA described an example evaluation using information about potential design basis and severe accidents for one of the SMR designs used to develop the ESPA PPE. This evaluation used the EPZ size determination methodology in SSAR Section 13.3 to show that, once a specific SMR design is selected, it is

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[7] 50th percentile dispersion, or 50 percent meteorology, refers to the average atmospheric dispersion characteristics for the site.

likely that the COL or CP applicant will be able to show that the resulting offsite doses would support a PEP EPZ size at the site boundary, or alternatively at a 2 mi radius. Because the analysis used information for an SMR design that is at the lower end of the design rated power that would fit the ESPA PPE (i.e., a range of 160 MWt to 800 MWt (reactor core/reactor), the accident releases and resulting doses are not bounding for any other SMR design considered in the ESPA. The example evaluation results show that the mean doses calculated at the site boundary and at the 2 mi radius for the specific SMR design are much less than the EPA early phase PAG for DBAs (EPA 2017-TN5977) and more probable core-melt accidents. The specific design used in the example analysis does not have accident scenarios in the category for comparison to the SSAR Section 13.3 criterion related to less probable core-melt accidents. Therefore, the example is more likely to meet the dose criteria at the site boundary compared to what would be expected in COLA analyses from the other SMR designs in the PPE, and doesn't necessarily support whether any other SMR in the PPE could support a PEP EPZ of less than 10 mi.

The staff audited the example calculation and related documents supporting the responses to eRAI-8885 (RAI No. 7) and eRAI-9206 (RAI No. 10) (TVA 2017-TN5988 and TVA 2018-TN5990, respectively), which provided source terms and dose results for a DBA and a severe accident using preliminary design information for a specific SMR design. The staff also evaluated key parameters associated with the accident source term to assess their reasonableness for, and representativeness of, the SMR design. The staff's summary of the audit was issued on May 22, 2018 (NRC 2018-TN5991).

The specific accident release source term information used in the example calculation is proprietary to the vendor for the SMR design used in the analysis. The accident source terms for the example analysis are based on a design that uses fuel that is similar to standard LWR fuel, which is representative of the SMR designs under consideration in the CRN Site ESPA. It also assumes a core power level for a single unit of 160 MWt. TVA anticipates that comparable methodologies and techniques that are used for the development of the source terms for LLWRs will be used in the development of the SMR accident source terms to be presented in SMR design documents for evaluation of the radiological consequences of accidents.

The staff determined that the DBA and severe accident scenarios, as well as isotopic release values in the example calculation, are consistent with the information that the SMR vendor supplied in its design certification application FSAR and supporting documents. In addition, the staff determined that the SMR vendor used reasonable assumptions and acceptable computer codes to develop the accident source terms. Therefore, based on its evaluation of the applicant's information, the staff finds the example calculation accident source terms to be not unreasonable for use in evaluation of the likelihood that a COLA would be able to justify an EPZ size of less than a 10 mi radius, with an analysis using SMR design-specific information.

TVA has stated that it does not intend the exemption requests to be applicable only to a specific design as in the example calculation, and it has established plant parameters that will ensure the appropriate application of the exemption requests to support a site-specific PEP EPZ at the CRN Site. Therefore, as described in Enclosure 1 to the March 30, 2018, response to eRAI-9206 (RAI No. 10) (TVA 2018-TN5990), TVA developed non-design-specific plant parameters (i.e., accident atmospheric release source term) for the EPZ exemption requests. This non-design-specific plant parameter accident atmospheric release source term provided in the RAI response describes the bounding isotopic releases for a 4-day release from the proxy plant described in the ESPA PPE, for the purposes of determining the PEP EPZ size using the SSAR 13.3 methodology (TVA 2017-TN5387).

To develop the non-design-specific 4-day total atmospheric release source term, TVA created a composite source term based on vendor information about accident source terms from a spectrum of accidents and SMR vendors. Specifically, TVA used information from the ESPA SSAR Chapter 15 PPE source term (for an 800 MWt [reactor core] SMR design) and the vendor-specific information for the two accident source terms used in the EPZ size consideration example calculation for a separate SMR design of 160 MWt per reactor (TVA 2017-TN5387). Using the information from the three accident source terms for the two SMR designs, TVA took the largest release magnitude for each included isotope, within each analysis release time period, from any of the three source terms. TVA then summed the results for each time period to determine the maximum total release over 4 days for each isotope. To account for design uncertainty and the current analysis maturity for all the SMRs, TVA increased the isotopic releases by a discretionary margin of 25 percent. As a final step, TVA used the non-design-specific accident source term as input to an analysis using the SSAR 13.3 PEP EPZ size determination methodology (TVA 2017-TN5387). The analysis included adjustments to the isotopic activity values necessary for use as input to the MELCOR Accident Consequence Code System (MACCS) computer code, which takes source term input as the fractional release of core inventory per chemical group (e.g., noble gases), instead of per isotope. These adjustments increased the margin to more than 25 percent. The analyses confirmed that the radiological consequences of accidents would not exceed the methodology dose criteria using the source term reported in the RAI response. The staff assessed TVA's assumptions and determined that they were reasonable, and finds that this analysis provides assurance that, if the releases from the specific plant chosen for a COLA are bounded by those in the non-design-specific plant parameter accident atmospheric release source term, it is likely that the COLA evaluation of EPZ size would support the use of either set of EP exemptions. Therefore, the non-design-specific atmospheric release source term, presented below in Table 13.3-1, is based on a range of core-melt accidents for two SMR designs with rated thermal power levels at the lower and upper end of the range of SMRs included in the ESPA PPE.

To evaluate the reasonableness of the non-design-specific plant parameter accident atmospheric release source term, the staff audited the example calculations and related documents supporting the development of the plant parameter source term for the EPZ size determination. The staff evaluated the process associated with the development of the bounding accident source term to assess its reasonableness for, and representativeness of, the range of SMR designs used as the basis for the ESPA PPE. The staff's summary of the audit was issued on May 22, 2018, (NRC 2018-TN5991). The staff finds that the process that TVA used to develop the non-design-specific plant parameter accident atmospheric release source term appropriately considered the currently available design accident release information for two SMR designs within the ESPA PPE, applied a conservative analysis margin, and generalized the source term to be bounding for a range of accidents for any of the SMR designs considered within the ESPA PPE. The staff determined that the DBA and severe accident scenarios and isotopic release values in the example calculation and in SSAR Chapter 15 (TVA 2017-TN5387) are consistent with the information that the SMR vendors supplied to TVA. The staff also found that, by taking the composite maximum releases for each isotope for three accidents from two SMR designs and applying an additional margin of more than 25 percent, both in the TVA composite source term and in the adjustments to the source term input to the MACCS analysis cases, TVA has proposed a reasonably bounding potential accident release source term for a 4-day release from a proxy plant that is representative of a range of SMR designs. Therefore, based on its evaluation of the applicant's information, the staff finds that the non-design-specific plant parameter accident atmospheric release source term is not unreasonable for use in evaluation of the likelihood that a COLA would be able to justify an EPZ size less than a 10 mi radius, with an analysis using SMR information.

Table 13.3-1 Plant Parameter Accident Releases for Determining Emergency Planning Zone Size in Support of Emergency Planning Exemptions

Nuclide	4-Day Total Activity (Ci)	Nuclide	4-Day Total Activity (Ci)
Kr-85	3.29E+03	Ru-106	2.68E+00
Kr-85m	1.94E+03	Rh-103m	4.11E+00
Kr-87	1.10E+03	Rh-106	2.70E+00
Kr-88	3.04E+03	Nb-95	6.45E+01
Xe-133	1.74E+05	Co-58	7.88E-05
Xe-135	1.49E+04	Co-60	8.74E-04
Xe-135m	6.95E+02	Mo-99	6.16E+01
Cs-134	1.26E+02	Tc-99m	5.80E+01
Cs-136	2.82E+01	Nb-97	3.95E+00
Cs-137	8.88E+01	Nb-97m	4.61E-01
Rb-86	9.92E-01	Ce-141	1.31E+00
Rb-88	2.59E+03	Ce-143	1.09E+00
Ba-139	1.22E+01	Ce-144	1.10E+00
Ba-140	4.82E+01	Np-239	1.10E+01
Sr-89	2.20E+01	Pu-238	7.75E-03
Sr-90	7.46E+00	Pu-239	3.21E-04
Sr-91	2.05E+01	Pu-240	6.48E-04
Sr-92	1.27E+01	Pu-241	1.60E-01
Ba-137m	8.00E+01	Zr-95	6.34E-01
I-131	6.79E+02	Zr-97	5.64E-01
I-132	4.35E+02	Am-241	1.06E-04
I-133	9.72E+02	Cm-242	2.61E-02
I-134	2.08E+02	Cm-244	1.09E-02
I-135	6.59E+02	La-140	4.75E+00
Sb-127	1.51E+01	La-141	2.45E-02
Sb-129	1.23E+01	La-142	8.65E-01
Te-127	1.60E+01	Nd-147	6.82E+00
Te-127m	2.86E+00	Pr-143	3.10E-01
Te-129	1.75E+01	Y-90	5.05E-01
Te-129m	8.15E+00	Y-91	2.74E-01
Te-131m	2.22E+01	Y-92	7.46E+00
Te-132	1.78E+02	Y-93	2.90E-01
Te-131	1.09E+01	Y-91m	9.90E+00
Rh-105	2.90E+00	Pr-144	9.65E-01
Ru-103	4.13E+00	Pr-144m	1.72E-02
Ru-105	1.55E+00		

As stated in SSAR Section 1.2.2 (TVA 2017-TN5387), the ESPA PPE is based on construction and operation at the CRN Site of two or more SMRs with a maximum rated thermal power for a single unit of 800 MWt (reactor core), where the combined generating capacity of the site is not to exceed 2,420 MWt. The non-design-specific plant parameters provided by TVA in the March 30, 2018 response to eRAI-9206 (RAI No. 10) (TVA 2018-TN5990) provide a bounding accident atmospheric release source term that would be applicable to the range of SMR designs included in the basis for the ESPA PPE. Therefore, the staff is proposing the following Permit Condition for the exemption, where the COL or CP applicant must demonstrate that the SMR design information (used to support the exemption request) is bounding for the SMR technology selected. If TVA intends to implement the exemptions discussed in this evaluation, or propose similar exemptions related to PEP EPZ size, a COLA must provide an analysis using the methodology and criteria in SSAR Section 13.3 (TVA 2017-TN5387) to justify the PEP EPZ size.

- Permit Condition 13.3-1 (Permit Condition 5): An applicant for a COL or CP that references this ESP shall provide detailed information in the COL or CP application that demonstrates that the accident release source term information for the selected small modular reactor (SMR) design used in analyses to support the determination of the plume exposure pathway emergency planning zone (EPZ) size is bounded by the non-design-specific plant parameter source term information below in Table 13.3-1, "Plant Parameter Accident Releases for Determining Emergency Planning Zone (EPZ) Size in Support of Emergency Planning Exemptions."

Table 13.3-1. Plant Parameter Accident Releases for Determining Emergency Planning Zone (EPZ) Size in Support of Emergency Planning Exemptions

Nuclide	4-Day Total Activity (Ci)	Nuclide	4-Day Total Activity (Ci)
Kr-85	3.29E+03	Ru-106	2.68E+00
Kr-85m	1.94E+03	Rh-103m	4.11E+00
Kr-87	1.10E+03	Rh-106	2.70E+00
Kr-88	3.04E+03	Nb-95	6.45E+01
Xe-133	1.74E+05	Co-58	7.88E-05
Xe-135	1.49E+04	Co-60	8.74E-04
Xe-135m	6.95E+02	Mo-99	6.16E+01
Cs-134	1.26E+02	Tc-99m	5.80E+01
Cs-136	2.82E+01	Nb-97	3.95E+00
Cs-137	8.88E+01	Nb-97m	4.61E-01
Rb-86	9.92E-01	Ce-141	1.31E+00
Rb-88	2.59E+03	Ce-143	1.09E+00
Ba-139	1.22E+01	Ce-144	1.10E+00
Ba-140	4.82E+01	Np-239	1.10E+01
Sr-89	2.20E+01	Pu-238	7.75E-03
Sr-90	7.46E+00	Pu-239	3.21E-04
Sr-91	2.05E+01	Pu-240	6.48E-04
Sr-92	1.27E+01	Pu-241	1.60E-01
Ba-137m	8.00E+01	Zr-95	6.34E-01
I-131	6.79E+02	Zr-97	5.64E-01
I-132	4.35E+02	Am-241	1.06E-04
I-133	9.72E+02	Cm-242	2.61E-02
I-134	2.08E+02	Cm-244	1.09E-02

I-135	6.59E+02	La-140	4.75E+00
Sb-127	1.51E+01	La-141	2.45E-02
Sb-129	1.23E+01	La-142	8.65E-01
Te-127	1.60E+01	Nd-147	6.82E+00
Te-127m	2.86E+00	Pr-143	3.10E-01
Te-129	1.75E+01	Y-90	5.05E-01
Te-129m	8.15E+00	Y-91	2.74E-01
Te-131m	2.22E+01	Y-92	7.46E+00
Te-132	1.78E+02	Y-93	2.90E-01
Te-131	1.09E+01	Y-91m	9.90E+00
Rh-105	2.90E+00	Pr-144	9.65E-01
Ru-103	4.13E+00	Pr-144m	1.72E-02
Ru-105	1.55E+00		

13.3.3.3.3.6 Combined License Application

In SSAR Section 13.3.3.1.4 (TVA 2017-TN5387), the applicant described the information to be provided in a COLA, as a technical basis for a site-specific PEP EPZ size. A COLA will apply the methodology proposed in SSAR Section 13.3.3, "Emergency Planning Zones" (TVA 2017-TN5387), to determine the CRN Site's site-specific PEP EPZ, and further evaluate whether either of the two major features emergency plans (included in ESPA Part 5 [TVA 2017-TN5443, TVA 2017-TN5442]) may be applicable to the COLA PEP EPZ. A COLA will also provide supporting information for the PEP EPZ technical basis analysis, such as the DBA radiological consequence analysis, Level 1 and Level 2 PRA information, and the information about the consequence analyses using the PEP EPZ size methodology described in SSAR Sections 13.3.3.1.1 and 13.3.3.1.2 (TVA 2017-TN5387). While the ESPA does not include any COL Action Items related to the PEP EPZ size, the staff proposed COL Action Item 13.3-1 in Section 13.3.3.4 of this chapter.

13.3.3.3.3.7 Conclusion

The staff concludes that the applicant's proposed methodology (described in SSAR Section 13.3 [TVA 2017-TN5387]) for preparing an analysis, as the technical basis to support the PEP EPZ size determination in a subsequent CRN Site COLA or CP application, is reasonable, consistent with Commission considerations for SMR EPZ size determinations, and consistent with the analyses that form the technical basis for the current regulatory requirement of a PEP EPZ about 10 mi in radius for LLWRs. Therefore, the proposed methodology is acceptable for determining the appropriate size of the PEP EPZ for the CRN Site, subject to approval of the exemptions discussed in Section 13.3.3.4 of this chapter.

13.3.3.4 Exemption Requests – Site Boundary and 2-Mile EPZ

In Part 5 of the ESPA, TVA provided the "major features" of two distinct emergency plans, pursuant to 10 CFR 52.17(b)(2)(i) (TN251), which describe two different PEP EPZs. ESPA Part 5A, "Emergency Plan (Site Boundary EPZ)" (TVA 2017-TN5443), provides the major features of an emergency plan for a PEP EPZ at the site boundary (i.e., ESP Plan 5A), and ESPA Part 5B, "Emergency Plan (2 mile EPZ)" (TVA 2017-TN5442), provides the major features of an emergency plan for a PEP EPZ that consists of an area approximately 2 mi in radius from the CRN Site center point (i.e., ESP Plan 5B).

In ESPA Part 6, “Exemptions and Departures” (TVA 2017-TN5444), TVA provided two sets of requested exemptions from NRC’s EP regulations for NPPs, which are reflected in the respective major features emergency plans. Specifically, ESP Plan 5A (TVA 2017-TN5443) includes the 25 individual requested exemptions in Table 1-1, “Exemptions Requested from 10 CFR 50.33(g), 50.47(b), and (c)(2) (TN249) for the Site Boundary EPZ Emergency Plan,” and Table 1-2, “Exemptions Requested from 10 CFR Part 50, Appendix E (TN249) for the Site Boundary EPZ Emergency Plan.” ESP Plan 5B (TVA 2017-TN5442) includes two individual requested exemptions in Table 1-3, “Exemptions Requested from 10 CFR 50.33(g), 50.47(b), and (c)(2) for the 2 mile EPZ Emergency Plan,” consisting of 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249). Both sets of exemptions reflect the use of an alternative method for emergency planning for use in a COLA to determine the EPZ size, considering that the NRC’s EP regulations require that the PEP EPZ for commercial nuclear power reactors encompasses an area with a radius of approximately 10 mi (16 km) (TVA 2017-TN4921).

TVA requested that NRC review the two distinct major features emergency plans (i.e., ESP Plans 5A and 5B), which are based on the establishment in a COLA of a PEP EPZ that is able to meet the radiological dose-related criteria (set forth in SSAR Section 13.3, “Emergency Preparedness” [TVA 2017-TN5387]) for the SMR technology that will be selected by the COL or CP applicant. The staff’s evaluation of the requested exemptions takes into account the proposed methodology in SSAR Section 13.3 (TVA 2017-TN5387) that a COLA applicant (referencing the CRN Site ESP) would use when determining the adequacy of the PEP EPZ size.

TVA requested exemptions from various NRC requirements associated with onsite (licensee) and offsite (State/local) REP plans related to the two different major features emergency plans the applicant submitted with the ESPA: ESPA Plan 5A (TVA 2017-TN5443) involves the establishment of a PEP EPZ at the site boundary, and ESPA Plan 5B (TVA 2017-TN5442) consists of an area approximately 2 mi in radius from the site center point. SSAR Section 13.3 (TVA 2017-TN5387) provides a general overview of the two major features emergency plans included in ESPA Part 5. It states that both major features emergency plans are based on the existing TVA Generic Emergency Plan, and that they comply with 10 CFR 50.47(b) (TN249) and Appendix E to 10 CFR Part 50 (TN249), in considering the requested exemptions that are described in ESPA Part 6 (TVA 2017-TN5444) (addressed below). ESPA Part 6 states that TVA is proposing a dose-based, consequence-oriented approach to establishing an appropriate PEP EPZ size that is consistent with, and based upon, the EPA PAG dose criteria for early phase protective actions in the unlikely event of a severe accident (TVA 2017-TN5444).

Pursuant to 10 CFR 50.12 (TN249), the Commission may, upon application by any interested person or upon its own initiative, grant exemptions from the requirements of 10 CFR Part 50 (TN249) when (1) the exemptions are authorized by law, will not present an undue risk to public health or safety, and are consistent with the common defense and security; and (2) special circumstances are present. Special circumstances exist when application of the regulation in the particular circumstance would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule (see 10 CFR 50.12(a)(2)(ii) [TN249]).

TVA identified two sets of proposed exemptions, consisting of (1) exemptions for a PEP EPZ at the site boundary (see ESPA Part 6 Table 1-1, “Exemptions Requested from 10 CFR 50.33(g), 50.47(b), and (c)(2) for the Site Boundary EPZ Emergency Plan,” and Table 1-2, “Exemptions Requested from 10 CFR Part 50, Appendix E for the Site Boundary EPZ Emergency Plan”); and (2) exemptions for an approximate 2 mi PEP EPZ (see ESPA Part 6 Table 1-3,

"Exemptions Requested from 10 CFR 50.33(g), 50.47(b), and (c)(2) for the 2 mile EPZ Emergency Plan" [TVA 2017-TN5444]).

With regard to establishing the size of the PEP EPZ, the requirements in 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249) include the statement that "[t]he size of the EPZs also may be determined on a case-by-case basis for gas-cooled reactors and for reactors with an authorized power level less than 250 MW thermal." In addition, 10 CFR Part 50, Appendix E (TN249), provides the flexibility to determine other emergency planning considerations, such as organization, assessment actions, activation of emergency organization, emergency facilities, and equipment, on a case-by-case basis for certain facilities.

However, while there is flexibility in terms of what Appendix E may require, the staff has found that TVA's request for exemption from certain Appendix E requirements is acceptable to allow approval of a site boundary PEP EPZ major features emergency plan where the EPZ selected by a COL or CP applicant would not extend beyond the site boundary to cover offsite areas. This is discussed in greater detail in Section 13.3.3.4.4. Also, a specific reactor technology has not been selected, and the PPE is based on construction and operation at the CRN Site of two or more SMRs with a maximum rated thermal power for a single unit of 800 MWt (reactor core). In addition, the combined nuclear generating capacity from the site is not to exceed 2,420 MWt (800 MWe). Because the proposed PPE for the CRN Site includes power levels that exceed 250 MWt, and do not identify an SMR that is gas-cooled, the proposed exemptions must be reviewed pursuant to NRC's exemption process, rather than on a case-by-case basis.

The staff reviewed the proposed methodology, requested exemptions, and the two major features emergency plans, as part of its review of ESPA Chapter 13. Importantly, the ESPA does not request, and the staff has not approved or determined, a specific PEP EPZ size or reactor technology for the CRN Site. The staff has evaluated the reasonableness of the applicant's proposed criteria and method for determining the PEP EPZ and EP requirements in a future COLA, which will, if submitted, reference a specific reactor design. The regulatory evaluation of the 25 exemption requests for the site boundary PEP EPZ is provided below in Section 13.3.3.4.2. The regulatory evaluation of the two exemption requests for the 2 mi PEP EPZ is provided below in Section 13.3.3.4.3. The staff's technical evaluation of all proposed exemptions is provided below in Section 13.3.3.4.4.

In SSAR Section 13.3, TVA described its approach for establishing the PEP EPZ sizing for the CRN Site (TVA 2017-TN5387). Specifically, the appropriateness of the exemptions requested in ESPA Part 6 (TVA 2017-TN5444) is established using a consequence-based approach for a spectrum of accidents that could produce offsite doses in excess of the EPA early phase PAGs (EPA 2017-TN5977). This approach is consistent with the objective of emergency response plans (i.e., to provide dose savings) and with NUREG–0396 (NRC and EPA 1978-TN4441).

TVA stated that a PEP EPZ less than the "about 10 miles," cited in 10 CFR 50.47(c)(2) (TN249), is justified based upon the significantly reduced risk of radiological release and offsite radiological consequences expected for SMR designs. Specifically, SMR designs will have small radionuclide inventory and source terms; the projected rate of progression of postulated accidents is anticipated to be slower; and various design features may eliminate several normally considered DBAs. Further, beyond-DBAs may be significantly less likely.[8] The ESPA

[8] The possible advantages of SMR designs are addressed in more detail in NRC's July 28, 2017, eRAI-8885 (RAI No. 7) (NRC 2017-TN5987), and TVA's August 24, 2017, response to eRAI-8885 (RAI No. 7) (TVA 2017-TN5988).

uses an EPZ sizing approach—consistent with that recommended by the staff in SECY-15-0077 (NRC 2015-TN5976)—for establishing a PEP EPZ boundary that ensures public protection from dose levels above the 1 rem TEDE threshold established in the PAG Manual (discussed in Section 13.3.3.3.2 of this chapter). TVA concluded that a 2 mi radius from the site center point provides reasonable assurance of public health and safety from any of the four SMR designs within the PPE. Further, it is possible that at least one of the SMR designs will demonstrate that the 1 rem TEDE threshold established in the PAG Manual will not be exceeded at the site boundary. Therefore, TVA has chosen to include two major features emergency plans in its application.

The major features emergency plan associated with the 2 mi PEP EPZ contains the same features as a traditional 10 mi EPZ Emergency Plan. For a PEP EPZ established at the site boundary, TVA proposed that there is no need for a pre-planned, offsite REP plan, as traditionally defined by the NRC and FEMA, because of the very low calculated radiological risk. The hazards from a radiological event from an SMR design are deemed to be roughly equivalent to nonradiological hazards at other industrial or chemical facilities. Therefore, from an offsite planning and preparedness perspective, EP would be similar to that at those types of facilities and addressed in accordance with the State and local Comprehensive Emergency Management Plan (CEMP)[9] (sometimes referred to as an “all hazards plan”). In the case of the Clinch River SMR project, TVA stated that it will coordinate with TEMA to develop a Multijurisdictional Emergency Response Plan for the CRN Site, which would become part of the State’s overall CEMP.

TVA stated that its approach is based on (1) the expectation of enhanced safety inherent in the design of SMRs to significantly reduce the risk of radiological release and offsite consequence, and (2) application of the significant body of risk information available to inform the technical basis for the PEP EPZ size. The proposed technical criteria for determining the EPZ size consider the use of the existing EP regulatory framework and dose-saving criteria established in NUREG-0396 (NRC and EPA 1978-TN4441). In summary, the proposed technical criteria for determining the EPZ size are as follows:

- The EPZ should encompass the areas in which projected dose from DBAs could exceed the EPA early phase PAGs (EPA 2017-TN5977).
- The EPZ should encompass the areas in which consequences of less severe core-melt accidents could exceed the EPA early phase PAGs (EPA 2017-TN5977).
- The EPZ should be of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents.

Implementation of the site boundary PEP EPZ (as described in ESP Plan 5A [TVA 2017-TN5443]) does not rely on specific offsite radiological emergency plans. As addressed in FEMA’s Comprehensive Preparedness Guide (CPG)-101, “Developing and Maintaining Emergency Operations Plans” (FEMA 2010-TN5985), if determined appropriate by government

[9] The CEMP is part of FEMA’s Comprehensive Preparedness Guide (CPG)-101, “Developing and Maintaining Emergency Operations Plans” (https:/www.fema.gov/media-library-data/20130726-1828-25045-0014/cpg_ 101_comprehensive_preparedness_guide_ developing_and_maintaininig_emergency_operations_plans_2010.pdf, visited December 22, 2017 [FEMA 2010-TN5985]). It helps planners at all levels of government in their efforts to develop and maintain viable, all-hazards, all-threats emergency plans. A CEMP is often referred to as “all hazards planning.” See www.tnema.org/ema/response/plans.html, visited December 28, 2017.

officials, they may use a CEMP approach to EP to implement ad hoc protective actions to protect the public.

In SSAR Section 13.3.3.1.4, TVA stated that it intends to include one complete and integrated emergency plan in the COLA based upon the selection of the SMR reactor technology (TVA 2017-TN5387). TVA intends to demonstrate that the design of the facility presented in the COLA falls within the design parameters for the surrogate plant PPE postulated in the ESPA. If the dose consequences of the chosen SMR technology do not exceed the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary, and do not present a substantial risk of doses at which significant early health effects may occur, then TVA could elect to establish the PEP EPZ at the site boundary in the COLA. In this scenario, TVA would coordinate with the applicable offsite response organizations (OROs) regarding establishment of the PEP EPZ at the site boundary. If the dose consequences of the SMR technology do not exceed the EPA early phase PAGs (EPA 2017-TN5977) at a 2 mi radius, and do not present a substantial risk of the occurrence of doses at which significant early health effects may occur, then TVA proposed to be allowed to elect to establish the PEP EPZ at an approximate 2 mi radius from the site center point in the COLA. If the dose consequences of the chosen SMR technology exceed the EPA early phase PAGs (EPA 2017-TN5977) at the 2 mi radius, or present a substantial risk of the occurrence of doses at which significant early health effects may occur for the PEP EPZ boundary at a 2 mi radius, then neither major features emergency plan included in ESPA Part 5 (TVA 2017-TN5443, TVA 2017-TN5442) would be incorporated by reference in the COLA, and a new emergency plan would be included in the COLA for NRC review.

SSAR Section 13.3.3.1.4 further states that the COLA will include detailed information about the selected reactor technology that is pertinent to the emergency plan, and will apply the methodology in SSAR Section 13.3.3.1.1 for EPA early phase PAGs and SSAR Section 13.3.3.1.2 for substantial reduction in early health effects to the selected SMR reactor technology to confirm that either the site boundary or 2 mi PEP EPZ is appropriate, or to determine an acceptable PEP EPZ size (TVA 2017-TN5387). The staff will evaluate the justification of the PEP EPZ size in its review of the COLA. Consistent with the applicant's statements in SSAR Section 13.3.3.1.4 (TVA 2017-TN5387) to address the ability of the SMR reactor technology chosen in a COLA to meet the EPA early phase PAGs (EPA 2017-TN5977) and substantial reduction in early health effects criteria, the staff identified the following COL Action Item:

- COL Action Item 13.3-1: An applicant for a COL or CP that references this ESP should identify the chosen SMR technology for the CRN Site, including the applicable ESP major features emergency plan, or, if appropriate, a new emergency plan for NRC review. In addition, if the accident dose consequences of the chosen SMR technology support the site boundary plume exposure pathway (PEP) EPZ, the applicant will inform the offsite response organizations regarding establishment of the PEP EPZ at the site boundary. The applicant should update the major features emergency plan to reflect the chosen SMR technology, and incorporate it into a complete and integrated emergency plan. In addition, the applicant should provide detailed information that shows the ability of the chosen SMR technology to meet the applicable PEP EPZ, as described in ESPA, Part 2, Section 13.3.3, "Emergency Planning Zones."

13.3.3.4.1 EPA PAG Manual

TVA based its major features emergency plans (including exemption requests) on the 2013 EPA PAG Manual (EPA 2013-TN5978), which was in effect (and had been issued as a draft for

interim use and public comment) when TVA submitted its ESPA to the NRC on May 12, 2016 (TVA 2016-TN5002). The 1992 EPA PAG Manual (EPA 1992-TN5986) had been the most authoritative and widely used (by government and the nuclear industry) version, and most of its PAGs and corresponding protective actions remain unchanged in both the 2013 (EPA 2013-TN5978) and 2017 (EPA 2017-TN5977) EPA PAG Manuals. The staff's review of the ESPA was based on the 2017 EPA PAG Manual (EPA 2017-TN5977), which represents the EPA's current revision in effect at the completion of the staff's review.

In SSAR Section 13.3, TVA stated, in part, that "[t]he revised EPA PAG (issued in 1992 as EPA-400-R-92-001) provides that licensed facilities that can demonstrate that accident doses at the Site Boundary would not exceed the PAG should not be required to have either defined EPZs or comprehensive offsite emergency planning" (TVA 2017-TN5387). This statement is consistent with Section 2.1.2, "Emergency Planning Zones and the PAGs," of the 1992 PAG Manual (EPA 1992-TN5986), which states, in part, that "since it will usually not be necessary to have offsite planning if PAGs cannot be exceeded offsite, EPZs need not be established for such cases."

In Section 2.2.4, "PAGs and Nuclear Facilities Emergency Planning Zones (EPZ)," of the 2017 PAG Manual (EPA 2017-TN5977), the EPA removed a sentence from the 2013 PAG Manual (Section 2.3.5, "PAGs and Nuclear Facilities Emergency Planning Zones [EPZ])," which stated: "EPZs are not necessary at those facilities where it is not possible for PAGs to be exceeded off-site." For purposes of the ESPA review, the staff determined in its review of the 2017 PAG Manual (EPA 2017-TN5977) that the absence of this sentence does not affect the technical basis within the manual that underlies/supports the removed EPA statement. For example, the 2017 PAG Manual retains language in the same paragraph, which states that "the size of the EPZ is based on the maximum distance at which a PAG might be exceeded" (EPA 2017-TN5977). Therefore, the absence of the sentence in the 2017 PAG Manual does not indicate that the removed statement is no longer a valid conclusion that can be reached by the NRC (consistent with current and past policy and practice).

The conclusion that offsite planning (including the establishment of EPZs) is not needed where the EPA early phase PAGs cannot be exceeded offsite (i.e., beyond the site boundary), is still supported by the technical details in the 2017 EPA PAG Manual (EPA 2017-TN5977). Specifically, for the reasons stated below, the staff's review of the 2017 EPA PAG Manual (EPA 2017-TN5977) supports the conclusion that a PEP EPZ is not necessary where the early phase PAGs will not be exceeded offsite:

- The manual states that the size of the EPZ is based on the maximum distance at which a PAG might be exceeded (see above).
- The manual does not recommend offsite EP for dose levels less than EPA early phase PAGs.
- The manual does not recommend early phase protective actions for dose levels less than EPA early phase PAGs.
- Just as EPA early phase PAGs are used by the NRC to establish a PEP EPZ, they can also be used to reduce EPZs by comparing them against projected accident doses.
- The NRC's reliance on the manual and NUREG-0396 (NRC and EPA 1978-TN4441) for using EPA early phase PAGs as the cutoff for PEP EPZs is consistent with NRC's past practice in the context of regulating EP for LLWRs.

Section 13.3.3.4.4 reflects the staff's technical evaluation of TVA's specific exemption requests. The references to the three ESPA Part 6 exemption tables (i.e., Tables 1-1, 1-2, and 1-3 [TVA 2017-TN5444]) are important, because the specific exemptions listed in Tables 1-1 and 1-2 are only applicable to ESP Plan 5A (with a site boundary PEP EPZ) (TVA 2017-TN5443), and Table 1-3 is only applicable to ESP Plan 5B (with a 2 mi PEP EPZ) (TVA 2017-TN5442). There are two common exemptions, consisting of 10 CFR 50.33(g) (TN249) and 10 CFR 50.47(c)(2) (TN249), which apply to both the site boundary and 2 mi PEP EPZ, and they are listed in Table 1-1 and Table 1-3.

The staff is evaluating the exemptions as part of the ESPA review to determine whether the staff can recommend Commission approval of major features emergency plans for either a site boundary or 2 mile PEP EPZ. In the discussion below, the staff evaluates 25 requested exemptions in ESPA Part 6, Tables 1-1 and 1-2 for a site boundary PEP EPZ (hereafter referred to as the "site boundary PEP EPZ"), and two requested exemptions in Table 1-3 for the 2 mi PEP EPZ (TVA 2017-TN5444). Sections 13.3.3.4.2 and 13.3.3.4.3 below address the regulatory evaluation for the site boundary and 2 mi PEP EPZ, respectively. Section 13.3.3.4.4 below provides a detailed ESPA technical safety evaluation supporting both the site boundary and 2 mi PEP EPZs.

Pursuant to 10 CFR 50.12, "Specific Exemptions " (TN249), the Commission may, upon application by any interested person or upon its own initiative, grant exemptions from the requirements of 10 CFR Part 50, "Domestic Licensing of Production and Facilities" (TN249). Section 50.12(a)(1) provides that the requested exemption must be authorized by law, not present an undue risk to the public health and safety, and be consistent with the common defense and security. The provisions of 10 CFR 50.12(a)(2) (TN249) list six special circumstances for which an exemption may be granted. It is necessary for one of these special circumstances to be present in order for NRC to consider granting an exemption request.

Pursuant to 10 CFR 52.7 "Specific Exemptions" (TN251), which is governed by 10 CFR 50.12 (TN249), TVA requested exemptions from various EP requirements in 10 CFR 50.33(g), 10 CFR 50.47(b) and (c)(2), and Appendix E to 10 CFR Part 50 (TN249), which reflect a smaller PEP EPZ at the CRN Site. A future COL or CP applicant will need to demonstrate in their application the adequacy of the selected EPZ size.

The applicant considered the following four SMR designs in developing values in the PPE that the applicant references in its FSAR analysis as a bounding "surrogate" for the SMR reactor technology that may be selected in the COLA:

- BWXT mPower (Generation mPower)
- NuScale (NuScale Power)
- SMR-160 (Holtec SMR)
- Westinghouse SMR (Westinghouse Electric Company).

Features of these four designs were considered when formulating the PPE values for the ESPA; the PPE does not encompass all aspects of each of these designs, and the COL or CP applicant referencing the ESP, if granted, is not required to reference one of these designs in its COLA. The COL or CP applicant would be required to show, using the dose-related methodology in ESPA SSAR Section 13.3 (TVA 2017-TN5387), that the consequences of potential radiological events at the CRN Site for the referenced SMR design would not exceed specific EPA PAGs. The COL or CP applicant would be required to demonstrate the ability of the selected SMR design to meet the EPA early phase PAGs (EPA 2017-TN5977) at either the

site boundary or 2 mile radius using the methodology TVA has provided as part of its requested exemption, in order to use these exemptions and support either a site boundary or 2 mile PEP EPZ in the COLA.

The staff reviewed the requests for exemptions submitted by the applicant in ESPA Part 6, Tables 1-1, 1-2, and 1-3 (TVA 2017-TN5444). The regulatory evaluations of the exemption requests for the site boundary and 2 mi PEP EPZ appear below in Sections 13.3.3.4.2 and 13.3.3.4.3, respectively.

13.3.3.4.2 Regulatory Evaluation of Exemption Request – Site Boundary PEP EPZ

13.3.3.4.2.1 Summary of Exemptions

ESPA Part 6, Table 1-1 (TVA 2017-TN5444) requests an exemption from certain requirements of 10 CFR 50.33(g), 10 CFR 50.47(b), and 10 CFR 50.47(c)(2) (TN249). ESPA Part 6, Table 1-2 (TVA 2017-TN5444) requests an exemption from certain requirements of 10 CFR Part 50, Appendix E (TN249). Together, Tables 1-1 and 1-2 request 25 individual exemptions for the CRN Site, as indicated by the strikeout and bolded text in Section 13.3.3.4.4 of this chapter.

13.3.3.4.2.2 Evaluation of Exemptions

Applicable criteria for when the Commission may grant the requested specific exemption are provided in 10 CFR 50.12(a)(1) and (a)(2) (TN249), as described above. The applicant stated that the requested exemption meets the special circumstances of 10 CFR 50.12(a)(2)(ii) (TN249). That subsection defines special circumstances as when “[a]pplication of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule.” The staff’s analysis of each of these findings is presented below for the site boundary PEP EPZ.

13.3.3.4.2.2.1 Authorized by Law

The exemptions would allow an applicant for a COL or CP that references the ESP, if granted, to adopt a site boundary PEP EPZ that is defined in the ESPA, rather than propose a 10 mi PEP EPZ for the CRN Site. The COL or CP applicant would have to show that the chosen SMR technology meets the applicable EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, in accordance with the criteria in ESPA SSAR Section 13.3 (TVA 2017-TN5387). As stated above, 10 CFR 50.12 (TN249) allows the NRC to grant exemptions from the requirements of 10 CFR 50.33(g), 10 CFR 50.47(b) and (c)(2), and Appendix E to 10 CFR Part 50 (TN249). The staff has determined that granting of the applicant’s proposed exemptions will not result in a violation of the Atomic Energy Act of 1954, as amended (TN663), or the Commission’s regulations. Therefore, the exemption is authorized by law.

13.3.3.4.2.2.2 No Undue Risk to Public Health and Safety

The underlying purpose of the 10 mi PEP EPZ in 10 CFR 50.33(g), 10 CFR 50.47(b) and (c)(2), and Appendix E to 10 CFR Part 50 (TN249) is to ensure that the PEP EPZ is of sufficient size to provide dose savings to the population in areas where the projected dose from DBAs could be expected to exceed the applicable EPA early phase PAGs (EPA 2017-TN5977) under unfavorable atmospheric conditions (see NUREG-0396, Section III.B, “Size of the Emergency Planning Zone” [NRC and EPA 1978-TN4441]). Because the site boundary PEP EPZ is required to meet the same EPA early phase PAGs as the 10 mi PEP EPZs for LLWRs, there is

no change in risk to public health and safety. Based on the above, no new accident precursors are created by reducing the PEP EPZ to the site boundary, thus, the probability of postulated accidents is not increased. Also, based on the above, the consequences of postulated accidents are not increased. Therefore, there is no undue risk to public health and safety.

13.3.3.4.2.2.3 Consistent with Common Defense and Security

The proposed exemptions would allow an applicant for a COL or CP that references the ESP, if granted, to adopt the site boundary PEP EPZ that is defined in the ESPA, rather than propose a 10 mi PEP EPZ for the CRN Site. The COL or CP applicant would have to show that the chosen SMR technology meets the applicable EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, in accordance with the criteria in ESPA SSAR Section 13.3 (TVA 2017-TN5387). These changes to the CRN Site's PEP EPZ are not related to security issues. Therefore, the common defense and security is not affected by these exemptions.

13.3.3.4.2.2.4 Special Circumstances

Special circumstances, in accordance with 10 CFR 50.12(a)(2)(ii) (TN249), are present whenever application of the regulation in the particular circumstances would not serve the underlying purpose of the rule, or is not necessary to achieve the underlying purpose of the rule. The underlying purpose of the 10 mi PEP EPZ in 10 CFR 50.33(g), 10 CFR 50.47(b) and (c)(2), and Appendix E to 10 CFR Part 50 (TN249) is to ensure that the PEP EPZ is of sufficient size to provide dose savings to the population in areas where the projected dose from DBAs could be expected to exceed the applicable EPA early phase PAGs (EPA 2017-TN5977) under unfavorable atmospheric conditions (see NUREG-0396, Section III.B [NRC and EPA 1978-TN4441]). Because the site boundary PEP EPZ would be subject to the same EPA early phase PAGs, the underlying purpose would be met under the terms of the proposed exemptions, pursuant to meeting Permit Condition 13.3-1 (Permit Condition 5). Therefore, as discussed above in Section 13.3.3.4.2.2 and below in Section 13.3.3.4.4, because the underlying purpose of 10 CFR 50.33(g), 10 CFR 50.47(b) and (c)(2), and Appendix E to 10 CFR Part 50 (TN249) is achieved, the special circumstances required by 10 CFR 50.12(a)(2)(ii) (TN249) for the granting of the exemptions from 10 CFR 50.33(g), 10 CFR 50.47(b) and (c)(2), and Appendix E to 10 CFR Part 50 (TN249) exist.

13.3.3.4.2.2.4.1 Characteristics of SMRs that Support the Exemption Requests

In ESPA Part 6, Section 1.3.4, TVA stated that special circumstances exist at the CRN Site because the enhanced safety features inherent in the design of SMRs, which result in significant enhancements in nuclear safety, provide for significant additional confidence in the protection of public health and safety (TVA 2017-TN5444). TVA also stated that the exemption requests were developed using risk-informed considerations and the understanding that the SMR designs evaluated under the CRN ESPA PPE include enhanced safety features.

TVA stated that a PEP EPZ with a radius of less than the "about 10 miles," cited in 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249), is justified based upon the significantly reduced risk of radiological release and offsite radiological consequences expected for SMR designs. Specifically, SMR designs may have small radionuclide inventories and source terms; the projected rate of progression of postulated accidents is anticipated to be slower; and various design features may eliminate several normally considered DBAs. Further, beyond-DBAs may be significantly less likely. By letters dated August 24, 2017, and March 30, 2018 (TVA 2017-TN5988 and TVA 2018-TN5990, respectively), in response to RAIs eRAI-8885 (RAI No. 7) and

eRAI-9602 (RAI No. 10), TVA provided information to describe the SMR design features and characteristics that result in the expected significantly reduced risk of radiological release and offsite radiological consequences. The RAI response also includes tables that provide comparisons of specific design features or characteristics between a range of SMRs, traditional LLWRs, and the Advance Passive 1000 (AP1000) certified design. Discussion of each of the characteristics that lead to the reduced radiological risk and consequences is given below.

The reduced likelihood of accidents is demonstrated by the reduced CDF and large release frequency (LRF) values of SMRs compared to LLWRs. As described in the RAI responses, SMRs can be expected to reduce CDF values from those of traditional LLWRs by three orders of magnitude or more as a design goal. CDF and LRF reductions are supported in SMR design, in part, by eliminating multiple historically considered DBEs. The elimination of large-break LOCAs is a primary example. Given that some SMR designs do not include large-bore reactor coolant system piping, the possibility of large-break LOCAs may be eliminated. An additional example is the elimination of events related to a loss or reduction of forced reactor coolant flow. By designing a reactor that does not have reactor coolant pumps, and instead relies on natural circulation for core cooling, events related to a loss or reduction of forced reactor coolant flow and pump seal failures have been eliminated.

As described in the responses to RAIs eRAI-8885 (RAI No. 7) and eRAI-9602 (RAI No. 10) (TVA 2017-TN5988 and TVA 2018-TN5990, respectively), another key to reducing CDF and LRF in SMRs is the design goal of reduced complexity of systems and the inclusion of passive processes in those systems. The use of fewer safety systems with fewer components eliminates a significant number of opportunities for system or component failure. SMR designs may be able to achieve safety goals with fewer safety-related systems compared to a traditional LLWR. Additionally, many of these systems include passive processes, which eliminate failure mechanisms related to use of active systems (e.g., pump failure). The use of passive processes in safety functions in SMR designs has a positive influence on the CDF and LRF values. Additionally, SMR design is aided by use of PRA insights and information, which result in SMR designs that may be inherently less likely than the current industry plants to undergo a severe accident requiring offsite protective measures.

Slower accident progression is demonstrated by the time it takes for the coolant water level to uncover the core after initiation of an event. For LLWRs, core uncovery can occur within seconds during a DBE. As described in the RAI responses, for SMRs in general, it is expected that it will take more than 96 hours until the core is uncovered, while some designs under consideration for the CRN Site may be able to show that the core never uncovers during DBEs. For beyond-DBEs, it can take more than 27 hours to reach core uncovery for some SMR designs. A key to slowing accident progression is the amount of coolant available to provide core cooling. The more coolant that is available compared to the heat generated by the core, the longer it will take to reach core uncovery. As described in the RAI responses, the ratio of primary system liquid mass to core power for SMR designs is expected to be more than four times that of a typical LLWR.

Reduced accident consequences are demonstrated by reduced doses from a range of accidents. As an example of the expected differences, the response to eRAI-9206 (RAI No. 10) provides a comparison of offsite doses as a result of a design basis LOCA for a range of SMRs, traditional LLWRs, and the AP1000. Doses provided in the RAI response are calculated at each design's respective assumed exclusion area boundary (EAB) distance and atmospheric dispersion conditions. Because the assumed EAB distance for each dose result is not the same, the doses are not directly comparable. However, considering that the doses calculated

for the SMR designs presented in the RAI response have assumed smaller EAB distances than the traditional LLWRs (which may result in a higher dose due to reduced dispersion), the differences in dose demonstrated in the Table 4 in the RAI response are expected to be larger when applied to similar EAB distances and meteorological conditions. Regardless, the doses from SMRs are estimated to be lower than those for LLWRs and the AP1000.

The primary factor in reducing the accident dose consequences for SMRs is the reduction in accident release source terms. Reductions in estimated accident release source terms for SMRs are primarily driven by reduced core power, which results in less fuel in the core. Because there is less fissile material, and therefore fewer fission products and activated material, there is less radioactive material that can be released from the core. Additionally, in the event of a core release accident, a goal of SMR designs is to provide for enhanced removal of radioisotopes using engineered passive features. For example, aerosol scrubbing in submerged SMR containments is improved, compared to LLWRs, due to designed higher surface area to volume ratios, along with enhanced condensation on the interior of the containment surface. The increased deposition surface area, condensation surface area, and higher condensation rates lead to higher fission product aerosol removal rates and decontamination factors. In the response to eRAI-9206 (RAI No. 10) Key Issue 1, dated March 30, 2018, Table 2 includes a comparison of the core parameters and approximate total source term activity for a range of SMRs, traditional LLWRs, and the AP1000 (TVA 2018-TN5990).

The staff evaluated TVA's description of the expected features and characteristics of SMRs, as described in the responses to RAIs eRAI-8885 (RAI No. 7) and eRAI-9206 (RAI No. 10) (TVA 2017-TN5988 and TVA 2018-TN5990, respectively), and agrees that the SMR designs under consideration for the CRN Site may result in significant reductions in the risk of radiological release and offsite radiological consequences from accidents.

13.3.3.4.2.3 Conclusion

For the reasons given above, and as discussed in Section 13.3.3.4.4 below, as set forth in 10 CFR 50.12(a) (TN249), the staff concludes that the proposed exemptions specified in ESPA Part 6, Tables 1-1 and 1-2 (TVA 2017-TN5444) are authorized by law, will not present an undue risk to the public health and safety, and are consistent with the common defense and security. Also, the special circumstances in 10 CFR 50.12(a)(2)(ii) (TN249) are present, in that the application of the regulations in 10 CFR 50.33(g), 10 CFR 50.47(b) and (c)(2), and Appendix E to 10 CFR Part 50 (TN249) in the particular circumstances is not necessary to achieve the underlying purpose of the rule. Therefore, the staff concludes that the proposed exemptions should be granted.

13.3.3.4.3 Regulatory Evaluation of Exemption Request – 2 Mile PEP EPZ

13.3.3.4.3.1 Summary of Exemptions

SSAR Table 1-3 requests an exemption from certain requirements of 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249) for the CRN Site, as indicated by the strikeout and bolded text in Section 13.3.3.4.4 in this chapter.

13.3.3.4.3.2 Evaluation of Exemptions

Applicable criteria for when the Commission may grant the requested specific exemption are provided in 10 CFR 50.12(a)(1) and (a)(2) (TN249), as described above. The applicant stated

that the requested exemption meets the special circumstances of 10 CFR 50.12(a)(2)(ii) (TN249). That subsection defines special circumstances as when "[a]pplication of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule." The staff's analysis of each of these findings is presented below for the 2 mi PEP EPZ.

13.3.3.4.3.2.1 Authorized by Law

The exemptions would allow an applicant for a COL that references the ESP, if granted, to adopt the 2 mi PEP EPZ that is defined in the ESPA, rather than propose a 10 mi PEP EPZ for the CRN Site. The COL or CP applicant would have to show that the chosen SMR technology meets the applicable EPA early phase PAGs (EPA 2017-TN5977) at the 2 mi PEP EPZ, in accordance with the criteria in SSAR Section 13.3 (TVA 2017-TN5387). As stated above, 10 CFR 50.12 (TN249) allows the NRC to grant exemptions from the requirements of 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249). The staff has determined that granting of the applicant's proposed exemptions will not result in a violation of the Atomic Energy Act of 1954, as amended (TN663), or the Commission's regulations. Therefore, the exemption is authorized by law.

13.3.3.4.3.2.2 No Undue Risk to Public Health and Safety

The underlying purpose of the 10 mi PEP EPZ in 10 CFR 50.33(g) (TN249) and 10 CFR 50.47(c)(2) (TN249) is to ensure that the PEP EPZ is of sufficient size to provide dose savings to the population in areas where the projected dose from DBAs could be expected to exceed the applicable EPA early phase PAGs (EPA 2017-TN5977) under unfavorable atmospheric conditions (see NUREG-0396, Section III.B, "Size of the Emergency Planning Zone" [NRC and EPA 1978-TN4441]). Because the 2 mi PEP EPZ is required to meet the same EPA early phase PAGs as the 10 mi PEP EPZs for LLWRs, there is no change in risk to public health and safety. For these reasons, no new accident precursors are created by reducing the PEP EPZ to 2 mi, thus, the probability of postulated accidents is not increased. Also, based on the above, the consequences of postulated accidents are not increased. Therefore, there would be no undue risk to public health and safety.

13.3.3.4.3.2.3 Consistent with Common Defense and Security

The proposed exemptions would allow an applicant for a COL that references the ESP, if granted, to adopt the 2 mi PEP EPZ that is defined in the ESPA, rather than propose a 10 mi PEP EPZ for the CRN Site. The COL or CP applicant would have to show that the chosen SMR technology meets the applicable EPA early phase PAGs (EPA 2017-TN5977) at the 2 mi PEP EPZ, in accordance with the criteria in ESPA SSAR Section 13.3 (TVA 2017-TN5387). These changes to the CRN Site's PEP EPZ are not related to security issues. Therefore, the common defense and security is not affected by these exemptions.

13.3.3.4.3.2.4 Special Circumstances

Special circumstances, in accordance with 10 CFR 50.12(a)(2)(ii) (TN249), are present whenever application of the regulation in the particular circumstances would not serve the underlying purpose of the rule, or is not necessary to achieve the underlying purpose of the rule. The underlying purpose of the 10 mi PEP EPZ in 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249) is to ensure that the PEP EPZ is of sufficient size to provide dose savings to the population in areas where the projected dose from DBAs could be expected to exceed the

applicable EPA early phase PAGs (EPA 2017-TN5977) under unfavorable atmospheric conditions (see NUREG-0396, Section III.B [NRC and EPA 1978-TN4441]). Because the 2 mi PEP EPZ would be subject to the same EPA early phase PAGs, the underlying purpose would be met under the terms of the proposed exemptions, pursuant to meeting Permit Condition 13.3-1 (Permit Condition 5). Therefore, as discussed above in Section 13.3.3.4.3.2 and below in Sections 13.3.3.4.4.1 and 13.3.3.4.4.1.7, because the underlying purpose of 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249) is achieved, the special circumstances required by 10 CFR 50.12(a)(2)(ii) (TN249) for the granting of the exemptions from 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249) exist.

Characteristics of SMRs that Support the Exemption Requests

In ESPA Part 6, Section 1.3.4, TVA stated that special circumstances exist at the CRN Site because the enhanced safety features inherent in the design of SMRs, which result in significant enhancements in nuclear safety, provide for significant additional confidence in the protection of public health and safety (TVA 2017-TN5444). TVA also stated that the exemption requests were developed using risk-informed considerations and were based on the understanding that the SMR designs evaluated under the CRN ESPA PPE include enhanced safety features.

TVA stated that a PEP EPZ with a radius of less than the “about 10 miles,” cited in 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249), is justified based upon the significantly reduced risk of radiological release and offsite radiological consequences expected for SMR designs. Specifically, SMR designs may have small radionuclide inventory and source terms; the projected rate of progression of postulated accidents is anticipated to be slower; and various design features may eliminate several normally considered DBAs. Further, beyond-DBAs are significantly less likely. By letters dated August 24, 2017, and March 30, 2018 (TVA 2017-TN5988 and TVA 2018-TN5990, respectively), in response to eRAI-8885 (RAI No. 7) and eRAI-9602 (RAI No. 10), TVA provided information to describe the SMR design features and characteristics that result in the expected significantly reduced risk of radiological release and offsite radiological consequences. The RAI response also includes tables that compare the specific design features or characteristics of a range of SMRs, traditional LWRs, and the AP1000 certified design. The characteristics that lead to the reduced radiological risk and consequences are discussed below.

The reduced likelihood of accidents is demonstrated by the reduced CDF and LRF values of referenced SMRs compared to those of LLWRs. As described in the RAI responses, SMRs can be expected to reduce CDF values from traditional LLWRs by three orders of magnitude or more as a design goal. CDF and LRF reductions are supported in SMR design, in part, by eliminating multiple historically considered DBEs. The elimination of large-break LOCAs is a primary example. Given that some SMR designs do not include large-bore reactor coolant system piping, the possibility of large-break LOCAs may be eliminated. An additional example is the elimination of events related to a loss or reduction of forced reactor coolant flow. By designing a reactor that does not have reactor coolant pumps, and instead relies on natural circulation for core cooling, events related to a loss or reduction of forced reactor coolant flow and pump seal failures have been eliminated.

As described in the responses to eRAI-8885 (RAI No. 7) and eRAI-9602 (RAI No. 10) (TVA 2017-TN5988 and TVA 2018-TN5990, respectively), another key to reducing CDF and LRF in SMRs is the design goal of reduced complexity of systems and the inclusion of passive processes in those systems. Use of fewer safety systems with fewer components eliminates a significant number of opportunities for system or component failure. SMR designs may be able

to achieve safety goals with fewer safety-related systems compared to a traditional LLWR. Additionally, many of these systems include passive processes, which eliminates failure mechanisms related to the use of active systems (e.g., pump failure). The use of passive processes in safety functions in SMR designs has a positive influence on the CDF and LRF values. Additionally, SMR design is aided by the use of PRA insights and information, which result in SMR designs that may be inherently less likely than the current industry plants to undergo a severe accident requiring offsite protective measures.

Slower accident progression is demonstrated by the time it takes for the coolant water level to uncover the core after initiation of an event. For LLWRs, core uncovery can occur within seconds during a DBE. As described in the RAI responses, for SMRs in general it is expected that it will take more than 96 hours until the core is uncovered, while some designs under consideration for the CRN Site may be able to show that the core is never uncovered during DBEs. For beyond-DBEs, it can take more than 27 hours to uncover the core for some SMR designs. A key to slowing accident progression is the amount of coolant available to provide core cooling. The more coolant that is available compared to the heat generated by the core, the longer it will take to reach core uncovery. As described in the RAI responses, the ratio of primary system liquid mass to core power for SMR designs is expected to be more than four times that of a typical LLWR.

Reduced accident consequences are demonstrated by reduced doses from a range of accidents. As an example of the expected differences, the response to eRAI-9206 (RAI No. 10) provides a comparison of offsite doses as a result of a design basis LOCA, for a range of SMRs, traditional LLWRs, and the AP1000. Doses provided in the RAI response are calculated at each design's respective assumed EAB distance and atmospheric dispersion conditions. Because the assumed EAB distance for each dose result is not the same, the doses are not directly comparable. However, considering that the doses calculated for the SMR designs presented in the RAI response have assumed smaller EAB distances than the traditional LLWRs (which may result in higher dose due to reduced dispersion), the differences in dose demonstrated in the Table-4, "Comparison of Accident Consequences Between SMRs and Large LWRs," in the response to eRAI-9206 (RAI No. 10) are expected to be larger when applied to similar EAB distances and meteorological conditions. Regardless, the doses from SMRs are estimated to be lower than those for LLWRs and the AP1000.

The primary factor in reducing the accident dose consequences for SMRs is the reduction in accident release source terms. Reductions in estimated accident release source terms for SMRs are primarily driven by reduced core power, which results in less fuel in the core. Because there is less fissile material, and therefore fewer fission products and activated material, there is less radioactive material that can be released from the core. Additionally, in the event of a core release accident, a goal of SMR designs is to provide for enhanced removal of radioisotopes using engineered passive features. For example, aerosol scrubbing in submerged SMR containments is improved compared to LLWRs due to designed higher surface area to volume ratios, along with enhanced condensation on the interior of the containment surface. The increased deposition surface area, condensation surface area, and higher condensation rates lead to higher fission product aerosol removal rates and decontamination factors. Table 2 in the response to eRAI-9206 (RAI No. 10) (Key Issue 1), dated March 30, 2018, includes a comparison of the core parameters and approximate total source term activity for a range of SMRs, traditional LLWRs, and the AP1000 (TVA 2018-TN5990).

The staff evaluated TVA's description of the expected features and characteristics of SMRs, as described in the responses to eRAI-8885 (RAI No. 7) and eRAI-9206 (RAI No. 10) (TVA 2017-

TN5988 and TVA 2018-TN5990, respectively), and agrees that the SMR designs under consideration for the CRN Site may result in significant reductions in the risk of radiological release and offsite radiological consequences from accidents.

13.3.3.4.3.3 *Conclusion*

For the reasons given above and as discussed below in Section 13.3.3.4.4, as set forth in 10 CFR 50.12(a) (TN249), the staff concludes that the proposed exemptions specified in ESPA Part 6, Table 1-3 (TVA 2017-TN5444) are authorized by law, will not present an undue risk to the public health and safety, and are consistent with common defense and security. Also, the special circumstances in 10 CFR 50.12(a)(2)(ii) (TN249) are present, in that the application of the regulations in 10 CFR 50.33(g) and 10 CFR 50.47(c)(2) (TN249) in the particular circumstances is not necessary to achieve the underlying purpose of the rule. Therefore, the staff concludes that the proposed exemptions should be granted.

13.3.3.4.4 Technical Evaluation of Exemption Requests

13.3.3.4.4.1 *Specific Exemptions for 10 CFR 50.33(g)*

ESPA Part 6, Table 1-1 (for the site boundary PEP EPZ) and Table 1-3 (for the 2 mi PEP EPZ) (TVA 2017-TN5444), request an exemption from certain requirements (as indicated by strikeout and bolded text) of 10 CFR 50.33(g) (TN249) for the CRN Site. The regulatory evaluation of the exemption requests appears above in Sections 13.3.3.4.2 and 13.3.3.4.3. The following exemption for 10 CFR 50.33(g) (TN249) applies to both the site boundary and 2 mi PEP EPZ:

13.3.3.4.4.1.1 10 CFR 50.33(g)

> If the application is for an operating license or combined license for a nuclear power reactor, or if the application is for an early site permit and contains plans for coping with emergencies under § 52.17(b)(2)(ii) of this chapter, the applicant shall submit radiological emergency response plans of State and local government entities in the United States that are wholly or partially within the plume exposure pathway emergency planning zone (EPZ), as well as the plans of State governments wholly or partially within the ingestion pathway EPZ. If the application is for an early site permit that, under 10 CFR 52.17(b)(2)(i), proposes major features of the emergency plans describing the EPZs, then the descriptions of the EPZs must meet the requirements of this paragraph. Generally, ~~**the plume exposure pathway EPZ for nuclear power reactors shall consist of an area about 10 miles (16 km) in radius and**~~ the ingestion pathway EPZ shall consist of an area about 50 miles (80 km) in radius. The exact size and configuration of the EPZs surrounding a particular nuclear power reactor shall be determined in relation to the local emergency response needs and capabilities as they are affected by such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries. The size of the EPZs also may be determined on a case-by-case basis for gas-cooled reactors and for reactors with an authorized power level less than 250 MW thermal. The plans for the ingestion pathway shall focus on such actions as are appropriate to protect the food ingestion pathway.

TVA's exemption request states in Table 1-1 (site boundary PEP EPZ) and Table 1-3 (2 mi PEP EPZ) that the basis for the exemption is that the criteria established in SSAR Section 13.3 (TVA 2017-TN5387) provide for adequate protection of public health and safety by providing an EPZ that encompasses the areas in which the plume exposure doses could exceed the early phase EPA PAG, and for which there is a substantial reduction in risk of significant early health effects. Table 1-1 adds that because there are no offsite consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), defined EPZs and formal offsite radiological emergency response plans are not necessary.

SSAR Section 13.3 states that the site boundary and 2 mi PEP EPZs encompass the areas in which the plume exposure doses could exceed the EPA early phase PAGs (EPA 2017-TN5977), and for which there is a substantial risk of doses at which significant early health effects may occur (TVA 2017-TN5387). The ESPA establishes a PEP EPZ boundary that ensures public protection from dose levels above the 1 rem TEDE threshold established in the PAG Manual (EPA 2017-TN5977). The primary purpose of the CRN Site PEP EPZ is to encompass the areas in which the plume exposure doses from DBAs and less severe core-melt accidents could exceed the EPA PAG. Thus, areas outside of the CRN Site PEP EPZ would meet the EPA PAG dose threshold of less than 1 rem TEDE using average expected (50th percentile) dispersion characteristics based on site-specific meteorology.

The PAG Manual provides radiological protection criteria for application to all incidents that would require consideration of protective actions (EPA 2017-TN5977). These include recommended numerical PAGs for the principal protective actions available to public officials during a radiological incident. Section 1.3.4, "Special Circumstances," of ESPA Part 6 (TVA 2017-TN5444) states that the underlying purpose of the requirements in 10 CFR 50.33(g), 10 CFR 50.47, and Section IV to Appendix E of 10 CFR Part 50 (TN249) is to (1) ensure that licensees maintain effective onsite and offsite radiological emergency response plans, (2) ensure that there is reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency, and (3) establish plume exposure and ingestion pathway EPZs for NPPs. The staff agrees with this description of the underlying purpose. The underlying objectives of the recommended (PEP and ingestion pathway) EPZs in NUREG–0396 (NRC and EPA 1978-TN4441) were to ensure that pre-planned protective actions would be identified and practiced, and to reduce dose in the unlikely event of a large release that would exceed the EPA PAGs offsite.[10]

NUREG–0396 introduced the concept of generic (10 mi and 50 mi) EPZs as the basis for pre-planned response actions that would result in dose savings in the environs of a nuclear facilities in the event of a serious power reactor accident (NRC and EPA 1978-TN4441). EPZs are designated as the areas for which planning is recommended to assure that prompt and effective actions can be taken to protect the public in the event of an accident. As established by the PAG Manual (EPA 2017-TN5977), the 10 mi and 50 mi EPZs provide bounding distances for LLWRs, beyond which radiation exposures would not likely exceed the EPA PAGs.[11] In NUREG–0396 (NRC and EPA 1978-TN4441), the task force concluded the following:

[10] See SECY-15-0077 (NRC 2015-TN5976).

[11] The NRC has licensed LWRs with relatively low power (e.g., Big Rock Point and La Crosse) and a high-temperature gas-cooled reactor (i.e., Fort St. Vrain)—each with a PEP EPZ size that was smaller than those for LLWRs. The PEP EPZs for Fort St. Vrain, Big Rock Point, and La Crosse were each established at 5 mi (8 km). See Docket Nos. 05000267, 05000155, and 05000409, respectively.

The establishment of Emergency Planning Zones of about 10 miles for the plume exposure pathway and about 50 miles for the ingestion pathway is sufficient to scope the areas in which planning for the initiation of predetermined protective action is warranted for any given nuclear power plant.

Section I.D of NUREG–0654 (NRC 1980-TN512) states that the NRC and FEMA concluded that the guidance in NUREG-0396 (NRC and EPA 1978-TN4441) should be used as the planning basis for emergency preparedness around nuclear power facilities. The development of EP requirements, including the 10 mi and 50 mi EPZs, complemented the prevention and mitigation measures existing in the NRC's defense-in-depth approach to protecting people and the environment against the harms of radiation in the unlikely event of a severe radiological accident resulting in offsite dose.

The staff finds that the basis for the establishment of a site boundary and 2 mi PEP EPZ in the ESPA maintains the same level of protection (i.e., dose savings) in the environs of the CRN Site, as that which exists at the 10 mi PEP EPZ for LLWRs. The staff's basis for this conclusion is that the methodology that is, or would be, used to determine the acceptability of all three distances (i.e., site boundary, 2 mi, and 10 mi PEP EPZs) uses the same radiation exposure bounding criteria/limits, which ensure that any radiation exposures beyond the PEP EPZ would be highly unlikely to exceed the EPA early phase PAGs (EPA 2017-TN5977). As such, the establishment of the basis for the site boundary and 2 mi PEP EPZs for the CRN Site is acceptable because it meets the same radiation protection criteria (i.e., the EPA early phase PAGs [EPA 2017-TN5977]) that are required for LLWRs. When TVA selects an SMR technology in a COLA, the ability of that SMR design to meet the EPA early phase PAGs (for either the site boundary or 2 mi PEP EPZ) must be confirmed by the NRC pursuant to COL Action Item 13.3-1.

In the absence of a specific reactor design, the staff cannot evaluate the applicant's assertions that there are no offsite consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387). However, for the above-stated reasons, this determination does not affect the staff's conclusions regarding the acceptability of the method for which the applicant seeks approval, or the acceptability of the exemption request.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary or 2 mi PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the site boundary PEP EPZ. Offsite plans would still be required for the 2 mi PEP EPZ. Therefore, the requirement for a 10 mi PEP EPZ would not be needed.

Based on the above analysis and as discussed above in Section 13.3.3.4.2 and Section 13.3.3.4.3, the staff concludes that the exempted language from 10 CFR 50.33(g) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the

PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249). A COL or CP applicant will address COL Action Item 13.3-1.

13.3.3.4.4.2 *Specific Exemptions for 10 CFR 50.47*

ESPA Part 6, Table 1-1 (for the site boundary PEP EPZ) and Table 1-3 (10 CFR to 50.47(c)(2) only) (for the 2 mi PEP EPZ) (TVA 2017-TN5444), request an exemption from certain requirements (as indicated by strikeout and bolded text) of 10 CFR 50.47 (TN249) for the CRN Site. The regulatory evaluation of the exemption requests appears above in Section 13.3.3.4.2 and Section 13.3.3.4.3. The following exemptions for 10 CFR 50.47(b), (b)(4), (b)(5), (b)(6), (b)(9), and (b)(10) (TN249) apply only to the site boundary PEP EPZ. The exemption for 10 CFR 50.47(c)(2) (TN249) applies to both the site boundary and 2 mi PEP EPZ.

13.3.3.4.4.2.1 10 CFR 50.47(b)

> The onsite ~~**and, except as provided in paragraph (d) of this section, offsite**~~ emergency response plans for nuclear power reactors must meet the following standards:

TVA's exemption request states in Table 1-1 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite radiological emergency response plans are not necessary.

The cited paragraph (d) (i.e., 10 CFR 50.47(d) [TN249]) states, in part, that no NRC or FEMA review findings, or determinations concerning the state of offsite emergency preparedness or adequacy of offsite emergency plans, are required prior to issuance of an operating license authorizing only fuel loading or low power testing and training (up to 5 percent of the rated thermal power).

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in a COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement related to NRC or FEMA review findings, or determinations concerning the state of offsite emergency preparedness or adequacy of offsite emergency plans, would not be needed.

Based on the above analysis and the analysis provided in Section 13.3.3.4.4.1.1 of this chapter, the staff concludes that the exempted language from 10 CFR 50.47(b) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.2.2 10 CFR 50.47(b)(4)

> A standard emergency classification and action level scheme, the basis of which include facility system and effluent parameters, is in use by the nuclear facility licensee~~**, and State and local response plans call for reliance on information provided by facility licensees for determinations of minimum initial offsite response measures**~~.

TVA's exemption request states in Table 1-1 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. In addition, although the likelihood of an accident or event resulting in offsite radiological doses exceeding the EPA PAGs beyond the site boundary is extremely remote, TVA's Emergency Plan will describe the capabilities to determine whether a radiological release is occurring and promptly communicate that information to OROs for their consideration.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement for minimum initial offsite response measures would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR 50.47(b)(4) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.2.3 10 CFR 50.47(b)(5)

> Procedures have been established for notification, by the licensee, of State and local response organizations and for notification of emergency personnel by all organizations; the content of initial and followup messages to response organizations ~~**and the public**~~ has been established~~**; and means to provide early notification and clear instruction to the populace within the plume exposure pathway Emergency Planning Zone have been established**~~.

TVA's exemption request states in Table 1-1 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that defined EPZs and formal offsite REP plans are not necessary. In addition, the PEP EPZ would be within the site boundary, so there is no populace within the PEP that would require early notification or instructions. Notification and instructions to members of the public that may be

onsite are addressed in 10 CFR 50.47(b)(10) (TN249) (see Section 13.3.3.4.4.2.6 of this chapter).

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, a means to provide early notification and clear instruction to the populace within a designated PEP EPZ would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR 50.47(b)(5) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.2.4 10 CFR 50.47(b)(6)

> Provisions exist for prompt communications among principal response organizations to emergency personnel ~~**and to the public**~~.

TVA's exemption request states in Table 1-1 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, there is no need to require prompt communications to the public beyond the site boundary.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to provide prompt communication to the public, with regard to initial or predetermined protective actions within a designated PEP EPZ, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR 50.47(b)(6) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.2.5 10 CFR 50.47(b)(9)

> Adequate methods, systems, and equipment for assessing and monitoring actual or potential ~~**offsite**~~ consequences of a radiological emergency condition are in use.

TVA's exemption request states in Table 1-1 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. TVA will maintain the capability to assess the impact of radiological releases, and communicate the results to the OROs.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement for assessing or monitoring offsite consequences beyond the site boundary would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR 50.47(b)(9) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.2.6 10 CFR 50.47(b)(10)

> A range of protective actions has been developed for the plume exposure pathway EPZ for emergency workers and the public. ~~**In developing this range of actions, consideration has been given to evacuation, sheltering, and, as a supplement to these, the prophylactic use of potassium iodide (KI), as appropriate. Evacuation time estimates have been developed by applicants and licensees. Licensees shall update the evacuation time estimates on a periodic basis.**~~ Guidelines for the choice of ~~**protective actions during an emergency, consistent with Federal guidance, are developed and in place, and**~~ protective actions for the ingestion exposure pathway EPZ appropriate to the locale have been developed.

TVA's exemption request states in Table 1-1 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, the language regarding the range of actions to be considered, with respect to the public beyond the site boundary and the development of an ETE, is not applicable.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the consideration of a range of protective actions consistent with Federal guidance for the public beyond the site boundary and development of an ETE, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR 50.47(b)(10) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.2.7 10 CFR 50.47(c)(2)

> Generally, ~~**the plume exposure pathway EPZ for nuclear power plants shall consist of an area about 10 miles (16 km) in radius and**~~ the ingestion pathway EPZ shall consist of an area about 50 miles (80 km) in radius. The exact size and configuration of the EPZs surrounding a particular nuclear power reactor shall be determined in relation to local emergency response needs and capabilities as they are affected by such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries. The size of the EPZs also may be determined on a case-by-case basis for gas cooled nuclear reactors and for reactors with an authorized power level less than 250 MW thermal. The plans for the ingestion pathway shall focus on such actions as are appropriate to protect the food ingestion pathway.

This exemption for 10 CFR 50.47(c)(2) (TN249) applies to both the site boundary and 2 mi PEP EPZ. TVA's exemption request states in Table 1-1 (site boundary PEP EPZ) and Table 1-3 (2 mi PEP EPZ) that the basis for the exemption is that the criteria established in SSAR Section 13.3 (TVA 2017-TN5387) provide for adequate protection of public health and safety by providing an EPZ that encompasses the areas in which the plume exposure doses could exceed the early phase EPA PAGs, and for which there is a substantial reduction in risk of significant early health effects. For the site boundary PEP EPZ, TVA further stated in Table 1-1 that because there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), formal offsite REP plans are not necessary.

TVA's exemption request for 10 CFR 50.47(c)(2) (TN249) in Table 1-1 (site boundary PEP EPZ) and Table 1-3 (2 mi PEP EPZ) is the same as that for 10 CFR 50.33(g) (TN249) in Tables 1-1 and 1-3. Therefore, the analysis provided in Section 13.3.3.4.4.1.1 of this chapter for 10 CFR 50.33(g) (TN249) is also applicable to 10 CFR 50.47(c)(2) (TN249).

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary or 2 mi PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the site boundary PEP EPZ. Offsite plans would still be required for the 2 mi PEP EPZ. Therefore, the requirement for a 10 mi PEP EPZ would not be needed.

Based on the above analysis and the analysis provided in Section 13.3.3.4.4.1.1 of this chapter, the staff concludes that the exempted language from 10 CFR 50.47(c)(2) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3 Specific Exemptions for 10 CFR Part 50, Appendix E, Section IV

ESPA Part 6, Table 1-2 (for the site boundary PEP EPZ) requests an exemption from certain requirements (as indicated by strikeout and bolded text) of Appendix E to 10 CFR Part 50 (TN249) for the CRN Site (TVA 2017-TN5444). The regulatory evaluation of the exemption requests appears above in Sections 13.3.3.4.2 and 13.3.3.4.3. The following exemptions for Section IV of Appendix E to 10 CFR Part 50 (TN249) apply only to the site boundary PEP EPZ.

13.3.3.4.4.3.1 10 CFR Part 50, Appendix E, Section IV.2

> **~~This nuclear power reactor license application shall also provide an analysis of the time required to evacuate various sectors and distances within the plume exposure pathway EPZ for transient and permanent populations, using the most recent U.S. Census Bureau data as of the date the applicant submits its application to the NRC.~~**

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, there is no need for ETEs in support of detailed evacuation preplanning.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA

2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement for ETEs would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.2 (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.2 10 CFR Part 50, Appendix E, Section IV.3

> ~~**Nuclear power reactor licensees shall use NRC approved evacuation time estimates (ETEs) and updates to the ETEs in the formulation of protective action recommendations and shall provide the ETEs and ETE updates to State and local governmental authorities for use in developing offsite protective action strategies.**~~

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, there is no need for ETEs in support of detailed evacuation preplanning.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to develop an ETE and provide it to State and local governmental authorities for use in developing offsite protective action strategies would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.3 (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.3 10 CFR Part 50, Appendix E, Section IV.4

> ~~**Within 365 days of the later of the date of the availability of the most recent decennial census data from the U.S. Census Bureau or December 23, 2011, nuclear power reactor licensees shall develop an ETE analysis using this decennial data and submit it under § 50.4 to the NRC. These licensees shall submit this ETE analysis to the NRC at least 180 days before using it to form protective action recommendations and providing it to State and local governmental authorities for use in developing offsite protective action strategies.**~~

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, there is no need for ETEs, or to update ETEs, in support of detailed evacuation preplanning.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to have an ETE and to perform an update to the ETE would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.4 (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.4 10 CFR Part 50, Appendix E, Section IV.5

> ~~**During the years between decennial censuses, nuclear power reactor licensees shall estimate EPZ permanent resident population changes once a year, but no later than 365 days from the date of the previous estimate, using the most recent U.S. Census Bureau annual resident population estimate and State/local government population data, if available. These licensees shall maintain these estimates so that they are available for NRC inspection during the period between decennial censuses and shall submit these estimates to the NRC with any updated ETE analysis.**~~

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal

offsite REP plans are not necessary. Therefore, there is no need for ETEs, or to update ETEs, in support of detailed evacuation preplanning.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to have an ETE and to perform an update to the ETE would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.5 (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

10 CFR Part 50, Appendix E, Section IV.6

> ~~**If at any time during the decennial period, the EPZ permanent resident population increases such that it causes the longest ETE value for the 2-mile zone or 5-mile zone, including all affected Emergency Response Planning Areas, or for the entire 10-mile EPZ to increase by 25 percent or 30 minutes, whichever is less, from the nuclear power reactor licensee's currently NRC approved or updated ETE, the licensee shall update the ETE analysis to reflect the impact of that population increase. The licensee shall submit the updated ETE analysis to the NRC under § 50.4 no later than 365 days after the licensee's determination that the criteria for updating the ETE have been met and at least 180 days before using it to form protective action recommendations and providing it to State and local governmental authorities for use in developing offsite protective action strategies.**~~

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, there is no need for ETEs, or to update ETEs, in support of detailed evacuation preplanning.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt

accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to have an ETE and to perform an update to the ETE would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.6 (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.5 10 CFR Part 50, Appendix E, Section IV.7

> **~~After an applicant for a combined license under part 52 of this chapter receives its license, the licensee shall conduct at least one review of any changes in the population of its EPZ at least 365 days prior to its scheduled fuel load. The licensee shall estimate EPZ permanent resident population changes using the most recent U.S. Census Bureau annual resident population estimate and State/local government population data, if available. If the EPZ permanent resident population increases such that it causes the longest ETE value for the 2-mile zone or 5- mile zone, including all affected Emergency Response Planning Areas, or for the entire 10-mile EPZ, to increase by 25 percent or 30 minutes, whichever is less, from the licensee's currently approved ETE, the licensee shall update the ETE analysis to reflect the impact of that population increase. The licensee shall submit the updated ETE analysis to the NRC for review under § 50.4 of this chapter no later than 365 days before the licensee's scheduled fuel load.~~**

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, there is no need for ETEs, or to update ETEs, in support of detailed evacuation preplanning.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to have an ETE and to perform an update to the ETE would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.7 (TN249), above, is not necessary to achieve the underlying

purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.6 10 CFR Part 50, Appendix E, Section IV.D.1

> Administrative and physical means for notifying local, State, and Federal officials and agencies ~~**and agreements reached with these officials and agencies for the prompt notification of the public and for public evacuation or other protective measures, should they become necessary,**~~ shall be described. This description shall include identification ~~**of the appropriate officials, by title and agency,**~~ of the State and local government agencies within the EPZs.

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Although the likelihood of an accident or event resulting in offsite radiological doses exceeding the EPA PAGs beyond the site boundary is extremely remote, TVA's Emergency Plan will describe the capabilities to determine whether a radiological release is occurring and promptly communicate that information to OROs for their consideration.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement for prompt notification of the public, and for public evacuation or other protective measures, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.D.1 (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.7 10 CFR Part 50, Appendix E, Section IV.D.3

> A licensee shall have the capability to notify responsible State and local governmental agencies within 15 minutes after declaring an emergency. ~~**The licensee shall demonstrate that the appropriate governmental authorities have the capability to make a public alerting and notification decision promptly on being informed by the licensee of an emergency condition. Prior to initial operation greater than 5 percent of rated thermal power of the first reactor at a site, each nuclear power reactor licensee shall demonstrate that administrative and physical means have been established**~~

~~**for alerting and providing prompt instructions to the public within the plume exposure pathway EPZ. The design objective of the prompt public alert and notification system shall be to have the capability to essentially complete the initial alerting and initiate notification of the public within the plume exposure EPZ within about 15 minutes. The use of this alerting and notification capability will range from immediate alerting and notification of the public (within 15 minutes of the time that State and local officials are notified that a situation exists requiring urgent action) to the more likely events where there is substantial time available for the appropriate governmental authorities to make a judgment whether or not to activate the public alert and notification system. The alerting and notification capability shall additionally include administrative and physical means for a backup method of public alerting and notification capable of being used in the event the primary method of alerting and notification is unavailable during an emergency to alert or notify all or portions of the plume exposure pathway EPZ population. The backup method shall have the capability to alert and notify the public within the plume exposure pathway EPZ, but does not need to meet the 15-minute design objective for the primary prompt public alert and notification system. When there is a decision to activate the alert and notification system, the appropriate governmental authorities will determine whether to activate the entire alert and notification system simultaneously or in a graduated or staged manner. The responsibility for activating such a public alert and notification system shall remain with the appropriate governmental authorities.**~~

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, there would be no members of the public within the PEP EPZ to alert and inform, and no need for action by governmental authorities beyond the site boundary. TVA will maintain the capability to assess, classify, and declare an emergency condition and notify offsite governmental organizations within times specified in the Emergency Plan.

Table 1-2 states that the elimination of the regulatory required time to alert and notify the public is acceptable because there is no need for State or local response organizations to implement immediate protective actions. Table 1-2 further states that the 10 CFR 50.72(a)(3) (TN249) requirement to complete an Emergency Notification System (ENS) notification (to NRC) of the declaration of an Emergency Class within 1 hour after the time TVA declares one of the Emergency Classes is not impacted by this exemption.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA

early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement for prompt notification of the public would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.D.3 (TN249), above, is not necessary to achieve the underlying purpose of this requirement as it applies to the CRN Site if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.8 10 CFR Part 50, Appendix E, Section IV.D.4

> ~~**If FEMA has approved a nuclear power reactor site's alert and notification design report, including the backup alert and notification capability, as of December 23, 2011, then the backup alert and notification capability requirements in Section IV.D.3 must be implemented by December 24, 2012. If the alert and notification design report does not include a backup alert and notification capability or needs revision to ensure adequate backup alert and notification capability, then a revision of the alert and notification design report must be submitted to FEMA for review by June 24, 2013, and the FEMA-approved backup alert and notification means must be implemented within 365 days after FEMA approval. However, the total time period to implement a FEMA-approved backup alert and notification means must not exceed June 22, 2015.**~~

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is the same as that for 10 CFR Part 50, Appendix E, Section IV.D.3 (TN249), regarding the Alert and Notification System (ANS) requirements.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement for a FEMA-approved alert and notification design report, including the backup alert and notification capability, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.3.8 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.D.4 (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.9 10 CFR Part 50, Appendix E, Section IV.F.2

> The plan shall describe provisions for the conduct of emergency preparedness exercises as follows: Exercises shall test the adequacy of timing and content of implementing procedures and methods, test emergency equipment and communications networks, ~~**test the public alert and notification system,**~~ and ensure that emergency organization personnel are familiar with their duties.

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, a dedicated public ANS would not be used and no testing is required.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement for prompt notification of the public, including a test of the public ANS, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.F.2 (TN249), above, is not necessary to achieve the underlying purpose of this requirement as it applies to the CRN Site if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.10 10 CFR Part 50, Appendix E, Section IV.F.2.a

> A[n] ~~**full participation**~~ exercise which tests as much of the licensee~~**, State, and local**~~ emergency plans as is reasonably achievable ~~**without mandatory public participation**~~ shall be conducted for each site at which a power reactor is located. Nuclear power reactor licensees shall submit exercise scenarios under § 50.4 at least 60 days before use in a[n] ~~**full participation**~~ exercise required by this paragraph 2.a.

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, a full participation exercise, which would involve demonstrating the implementation of formal offsite REP plans, is not required. TVA would continue to invite State and local support organizations to participate in the periodic drills and exercises conducted.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption

request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to conduct a full participation exercise with State and local agencies, which would involve demonstrating the implementation of formal offsite REP plans, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.2.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.F.2.a (TN249), above, is not necessary to achieve the underlying purpose of this requirement as it applies to the CRN Site if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.11 10 CFR Part 50, Appendix E, Section IV.F.2.a.(i)

> For an operating license issued under this part, this exercise must be conducted within two years before the issuance of the first operation license for full power (one authorizing operation above 5 percent of rated power) of the first reactor and shall include participation by ~~**each State and local government within the plume exposure pathway EPZ and**~~ each state within the ingestion exposure pathway EPZ. If the ~~**full participation**~~ exercise is conducted more than 1 year prior to issuance of an operating licensee [sic] for full power, an exercise which tests the licensee's onsite emergency plans must be conducted within one year before issuance of an operating license for full power. ~~**This exercise need not have State or local government participation.**~~

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that TVA would be exempt from those portions of 10 CFR Part 50, Appendix E, Section IV.F.2.a.(i)-(iii) (TN249) related to offsite participation in exercises, because TVA would be exempt from the umbrella provisions of 10 CFR Part 50, Appendix E, Section IV.F.2.a (TN249).

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to conduct a full participation exercise with State and local agencies, which would involve demonstrating the implementation of offsite REP plans, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.3.11 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.F.2.a.(i) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.12 10 CFR Part 50, Appendix E, Section IV.F.2.a.(ii)

> For a combined license issued under part 52 of this chapter, this exercise must be conducted within two years of the scheduled date for initial loading of fuel. If the first ~~**full participation**~~ exercise is conducted more than one year before the scheduled date for initial loading of fuel, an exercise which tests the licensee's onsite emergency plans must be conducted within one year before the scheduled date for initial loading of fuel. ~~**This exercise need not have State or local government participation. If FEMA identifies one or more deficiencies in the state of offsite emergency preparedness as the result of the first full participation exercise, or i**~~**[I]f** the Commission finds that the state of emergency preparedness does not provide reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency, the provisions of § 50.54(gg) apply.

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that TVA would be exempt from those portions of 10 CFR Part 50, Appendix E, Section IV.F.2.a.(i)-(iii) (TN249) related to offsite participation in exercises, because TVA would be exempt from the umbrella provisions of 10 CFR Part 50, Appendix E, Section IV.F.2.a (TN249).

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to conduct a full participation exercise with State and local agencies, which would involve demonstrating the implementation of formal offsite REP plans and FEMA assessment of formal offsite REP plans, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.3.11 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.F.2.a.(ii) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.13 <u>10 CFR Part 50, Appendix E, Section IV.F.2.a.(iii)</u>

> For a combined license issued under part 52 of this chapter, if the applicant currently has an operating reactor at the site, an exercise, **~~either full or partial participation,~~** shall be conducted for each subsequent reactor constructed on the site. This exercise may be incorporated in the exercise requirements of Sections IV.F.2.b. and c. in this appendix. **~~If FEMA identifies one or more deficiencies in the state of offsite emergency preparedness as the result of this exercise for the new reactor, or i~~[I]f** the Commission finds that the state of emergency preparedness does not provide reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency, the provisions of § 50.54(gg) apply.

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that TVA would be exempt from those portions of 10 CFR Part 50, Appendix E, Section IV.F.2.a.(i)-(iii) (TN249) related to offsite participation in exercises, because TVA would be exempt from the umbrella provisions of 10 CFR Part 50, Appendix E, Section IV.F.2.a (TN249).

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to conduct a full participation exercise with State and local agencies, which would involve demonstrating the implementation of formal offsite REP plans and FEMA assessment of formal offsite REP plans, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.3.11 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.F.2.a.(iii) (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.14 <u>10 CFR Part 50, Appendix E, Section IV.F.2.b</u>

> Each licensee at each site shall conduct a subsequent exercise of its onsite emergency plan every 2 years. Nuclear power reactor licensees shall submit exercise scenarios under § 50.4 at least 60 days before use in an exercise required by this paragraph 2.b. **~~The exercise may be included in the full participation biennial exercise required by paragraph 2.c. of this section.~~** In addition, the licensee shall take actions necessary to ensure that adequate emergency response capabilities are maintained during the interval between biennial exercises by conducting drills, including at least one drill involving a combination of some of the principal functional areas of the licensee's onsite

emergency response capabilities. The principal functional areas of emergency response include activities such as management and coordination of emergency response, accident assessment, event classification, notification of offsite authorities, assessment of the onsite ~~**and offsite**~~ impact of radiological releases**,** ~~**protective action recommendation development, protective action decision making,**~~ plant system repair and mitigative action implementation. During these drills, activation of all of the licensee's emergency response facilities (Technical Support Center (TSC), Operations Support Center (OSC), and Emergency Operations Facility (EOF)) would not be necessary, licensees would have the opportunity to consider accident management strategies, supervised instruction would be permitted, operating staff in all participating facilities would have the opportunity to resolve problems (success paths) rather than have controllers intervene, and the drills may focus on the onsite exercise training objectives.

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that TVA would be exempt from those portions of 10 CFR Part 50, Appendix E, Section IV.F.2.a.(i)-(iii) (TN249) related to offsite participation in exercises, because TVA would be exempt from the umbrella provisions of 10 CFR Part 50, Appendix E, Section IV.F.2.a (TN249).[12] The relief from the requirements for offsite exercises would include the relief from offsite exercises required by 10 CFR Part 50, Appendix E, Section IV.F.2.b (TN249).

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement to conduct a full participation exercise with State and local agencies, which would involve demonstrating the implementation of formal offsite REP plans, would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1 and 13.3.3.4.4.3.11 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.F.2.b (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.15 <u>10 CFR Part 50, Appendix E, Section IV.F.2.c</u>

~~**Offsite plans for each site shall be exercised biennially with full participation by each offsite authority having a role under the radiological response plan. Where the offsite authority has a role under a radiological response plan for more than one site, it shall fully participate in one**~~

[12] See also, TVA Letter No. CNL-18-071, April 27, 2018, "Supplemental Information Related to Emergency Planning Exemption Requests in Support of Early Site Permit Application for Clinch River Nuclear Site" (TVA 2018-TN5992).

~~**exercise every two years and shall, at least, partially participate in other offsite plan exercises in this period. If two different licensees each have licensed facilities located either on the same site or on adjacent, contiguous sites, and share most of the elements defining co-located licensees, then each licensee shall:**~~

~~**(1) Conduct an exercise biennially of its onsite emergency plan;**~~

~~**(2) Participate quadrennially in an offsite biennial full or partial participation exercise;**~~

~~**(3) Conduct emergency preparedness activities and interactions in the years between its participation in the offsite full or partial participation exercise with offsite authorities, to test and maintain interface among the affected State and local authorities and the licensee. Co-located licensees shall also participate in emergency preparedness activities and interaction with offsite authorities for the period between exercises;**~~

~~**(4) Conduct a hostile action exercise of its onsite emergency plan in each exercise cycle; and**~~

~~**(5) Participate in an offsite biennial full or partial participation hostile action exercise in alternating exercise cycles.**~~

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, there is no need for OROs to participate in biennial exercises. Although the likelihood of an accident or event resulting in offsite radiological doses exceeding the EPA PAGs (EPA 2017-TN5977) beyond the site boundary is extremely remote, TVA's Emergency Plan will describe the capabilities to determine whether a radiological release is occurring and promptly communicate that information to OROs for their consideration. Formal offsite REP plans would not be required. Therefore, a full participation exercise is not required.[13]

Table 1-2 further states that TVA would continue to invite State and local support organizations to participate in the periodic drills and exercises conducted. Those portions of F.2.c related to co-located facilities are not applicable to the CRN Site ESPA. However, if in the future, the CRN Site became a co-located facility, those portions of F.2.c applicable to the CRN Site are addressed elsewhere in 10 CFR Part 50, Appendix E, Section IV.F.2 (TN249).

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt

[13] See also, request for additional information (eRAI-9227), addressed in Section 13.3.3.4.4.3.16, which addressed a minor revisions to this requested exemption.

accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement for exercising offsite response capabilities by each offsite authority having a role under a formal REP plan would not be needed.

Based on the above analysis and the analysis provided in Sections 13.3.3.4.4.1.1, 13.3.3.4.4.2.1, 13.3.3.4.4.2.2, and 13.3.3.4.4.3.11 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.F.2.c (TN249), above, is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.16 10 CFR Part 50, Appendix E, Section IV.F.2.d

> Each State with responsibility for nuclear power reactor emergency preparedness should fully participate in the ingestion pathway portion of exercises at least once every exercise cycle. In States with more than one nuclear power reactor plume exposure pathway EPZ, the State should rotate this participation from site to site. ~~**Each State with responsibility for nuclear power emergency preparedness should fully participate in a hostile action exercise at least once every cycle and should fully participate in one hostile action exercise by December 31, 2015. States with more than one nuclear power reactor plume exposure pathway EPZ should rotate this participation from site to site.**~~

TVA's exemption request states in Table 1-2 (site boundary PEP EPZ) that the basis for the exemption is that there are no offsite radiological consequences from any credible event in excess of the criteria provided in SSAR Section 13.3 (TVA 2017-TN5387), such that formal offsite REP plans are not necessary. Therefore, there is no need for OROs to participate in hostile action exercises. Although the likelihood of an accident or event resulting in offsite radiological doses exceeding the EPA PAG (EPA 2017-TN5977) beyond the site boundary is extremely remote, TVA's Emergency Plan will describe the capabilities to determine whether a radiological release is occurring and promptly communicate that information to OROs for their consideration. Formal offsite radiological emergency response plans would not be required. Therefore, offsite participation in a hostile action exercise is not required. TVA would continue to invite State and local support organizations to participate in the periodic drills and exercises conducted to assess its ability to perform responsibilities related to an emergency at the facility.

In its December 21, 2017, eRAI-9227 (RAI No. 11) (NRC 2017-TN5993), the staff asked TVA to address the proposed exemption from Section IV.F.2.d of Appendix E, with regard to removal of the requirements associated with exercising the ingestion pathway, that were not addressed in the ESPA. In its January 22, 2018, response to eRAI-9227 (RAI No. 11) (TVA 2018-TN5407), TVA revised the requested exemption to retain the requirement associated with the ingestion exposure pathway EPZ, and stated that the ingestion exposure pathway EPZ for the CRN Site will be addressed in a COLA (which is consistent with SSAR Section 13.3.3.2 [TVA 2017-TN5387]). On February 20, 2018, and April 27, 2018, TVA supplemented its January 22, 2018, response to eRAI-9227 (RAI No. 11) (See TVA Letter No. CNL-18-019, February 20, 2018, "Replacement Pages for Response to Request for Additional Information Related to Emergency Planning Exemption Requests in Support of Early Site Permit Application for Clinch River Nuclear Site" [TVA 2018-TN5427], and TVA Letter No. CNL-18-071, April 27, 2018,

"Supplemental Information Related to Emergency Planning Exemption Requests in Support of Early site Permit Application for Clinch River Nuclear Site" [TVA 2018-TN5992]). The staff identified as Confirmatory Item 13.3-1, the ESPA revisions in Enclosures 2 and 3 to TVA Letter No. CNL-18-071 (TVA 2018-TN5992), regarding the withdrawal of exemption request Item No. 19 (for Section IV.F.2.f of Appendix E to 10 CFR Part 50). The staff reviewed the applicant's responses to eRAI-9227 (RAI No. 11) and finds the responses acceptable. Therefore, the staff considers eRAI-9227 (RAI No. 11) resolved. In ESPA Revision 2 (TVA 2019-TN5855), TVA withdrew the requested exemption for Section IV.F.2.f of Appendix E, and reflected this change in Table 1-2 of ESPA Part 6 (TVA 2019-TN5856). Therefore, Confirmatory Item 13.3-1 is closed.

The NRC requires a level of licensee emergency preparedness commensurate with the potential consequences to public health and safety at the licensee's site. TVA's exemption request includes a dose-based, consequence-oriented methodology for determining the PEP EPZ that, when applied in the COLA, may show that the radiological consequences of DBAs or less severe core-melt accidents will not exceed the limits of the EPA early phase PAGs (EPA 2017-TN5977) at the site boundary PEP EPZ, and that the EPZ is of sufficient size to provide for substantial reduction in early severe health effects in the event of more severe core-melt accidents. If this demonstration is made, considering that the areas outside the PEP EPZ would also meet this criterion, offsite REP plans would not be necessary for the CRN Site if the EPA early phase PAGs are not exceeded beyond the PEP EPZ. Therefore, the requirement for States to participate in a hostile action exercise would not be needed.

Based on the above analysis, and the analysis provided in Section 13.3.3.4.4.1.1 of this chapter, the staff concludes that the exempted language from 10 CFR Part 50, Appendix E, Section IV.F.2.d, above (TN249), is not necessary to achieve the underlying purpose of this requirement, as it applies to the CRN Site, if the EPA early phase PAGs (EPA 2017-TN5977) are not exceeded beyond the PEP EPZ. Therefore, it meets the special circumstances provisions of 10 CFR 50.12(a)(2)(ii) (TN249).

13.3.3.4.4.3.17 <u>Conclusion</u>

For the reasons given above, the staff concludes that the proposed exemptions specified in ESPA Part 6, Tables 1-1, 1-2, and 1-3 (TVA 2017-TN5444), are acceptable. In addition, as set forth in 10 CFR 50.12(a) (TN249), the staff concludes that the proposed exemptions are authorized by law and will not present an undue risk to the public health and safety. Also, the special circumstances in 10 CFR 50.12(a)(2)(ii) (TN249) are present, in that the application of the regulations in 10 CFR 50.33(g), 10 CFR 50.47(b) and (c)(2), and Appendix E to 10 CFR Part 50 (TN249) in the particular circumstances is not necessary to achieve the underlying purpose of the rule. The COL or CP applicant will address COL Action Item 13.3-1. Therefore, the staff concludes that the proposed exemptions should be granted.

13.3.3.5 Major Features Emergency Plan

As described in the introductory paragraphs of this chapter, TVA submitted two separate onsite major features emergency plans for the new plant at the CRN Site under 10 CFR 52.17(b)(2)(i) (TN251), consisting of ESP Plan 5A (with a site boundary PEP EPZ) (TVA 2017-TN5443) and ESP Plan 5B (with a 2 mi PEP EPZ) (TVA 2017-TN5442). The application did not address the ingestion pathway EPZ, which will be described in a COLA that references the CRN Site ESP. As required by 10 CFR 52.17(b)(2)(i) (TN251) and Section III of Appendix E to 10 CFR Part 50 (TN249), an ESPA that proposes major features of the emergency plans must address the

relevant provisions in 10 CFR 50.47 and Appendix E to 10 CFR Part 50 (TN249). An applicant is not required to address all of the major features of an emergency plan in the ESPA, as identified in Supplement 2 to NUREG–0654 (NRC 1996-TN5962). Pursuant to 10 CFR 52.18 (TN251), the staff evaluated the acceptability of both ESP plans, in accordance with the applicable standards of 10 CFR 50.47 (TN249) and the requirements of Appendix E to 10 CFR Part 50 (TN249).

Because the major features of each emergency plan address only a limited portion of the total EP requirements in 10 CFR 50.47 (TN249) and Appendix E to 10 CFR Part 50 (TN249), the staff's evaluation only addresses the acceptability of those limited major features. A COL applicant will be required to submit complete and integrated emergency plans that supplement the major features in either ESP Plan 5A (TVA 2017-TN5443) or ESP Plan 5B (TVA 2017-TN5442), or an entirely new emergency plan, depending upon the selected SMR technology, with information that meets all of the EP requirements in 10 CFR 50.47 (TN249) and Appendix E to 10 CFR Part 50 (TN249). A similar requirement would apply to CP and OL applicants referencing the ESP, except that the OL applicant is required to submit a complete and integrated emergency plan, while the CP applicant under 10 CFR 50.34(a)(10) is required to provide "preliminary plans for coping with emergencies."

Sections 13.3.3.5.2 through 13.3.3.5.18 of this chapter describe the staff's technical evaluation of the information provided in the ESPA. The section designations of the technical evaluation generally correspond to the 16 planning standards in NUREG–0654, Section II (NRC 1980-TN512). Specifically, Sections 13.3.3.5.2 through 13.3.3.5.17 of this chapter address NUREG–0654, Section II, Planning Standards A through P, respectively (NRC 1980-TN512). The format of the staff's review of ESP Plan 5A (TVA 2017-TN5443) and ESP Plan 5B (TVA 2017-TN5442) is patterned after these 16 planning standards, which reflect the requirements in 10 CFR 50.47(b)(1) through 10 CFR 50.47(b)(16) (TN249). 10 CFR Part 50, Appendix E (TN249) provides additional requirements that duplicate and supplement the evaluation criteria associated with the planning standards. The staff's evaluation of the various aspects of 10 CFR Part 50, Appendix E (TN249) is included within the staff's review.

While the ESPA includes two separate major features emergency plans, the details of both plans are either identical or very similar in content. This is because both plans (1) reflect the same CRN Site; (2) are limited to the onsite emergency plan; and (3) describe the same limited scope and depth of the chosen EP major features. To take advantage of the similarities between the two plans, the staff's review findings for each major feature apply to both plans. This is reflected by references to the "ESP Plan," which means that the evaluation and findings apply to both ESP Plan 5A (TVA 2017-TN5443) and ESP Plan 5B (TVA 2017-TN5442). Where the staff identified differences between ESP Plan 5A and ESP Plan 5B, those differences (and related findings) are clearly identified.

As discussed above, 10 CFR 52.17(b)(2) (TN251) allows an ESP applicant to propose major features of emergency plans, in accordance with the pertinent standards of 10 CFR 50.47 (TN249) and requirements of Appendix E to 10 CFR Part 50 (TN249). The staff's review of the major features is similar to the review of the complete and integrated emergency plan, except that the review of the major features examines a reduced scope of the full EP requirements. This reduced scope reflects the limited extent of the emergency plans (i.e., major features) that the applicant chooses to have reviewed as part of the ESPA, and provides flexibility for the applicant to tailor the details of the major features, in order to obtain an early review and associated finality for selected EP details associated with the proposed ESP site. When an application for a COL references the ESP, if granted, the remaining details associated with

complete and integrated emergency plans for the CRN Site (i.e., the delta) must be addressed. That is, the difference between the approved major features, and what is required for complete and integrated emergency plans, must be addressed in a COLA.

The following review of the CRN Site's major features emergency plans includes numerous COL Action Items (identified by both TVA and the NRC staff), which reflect various requirements of complete and integrated emergency plans that must be addressed in a COLA. These COL Action Items do not necessarily constitute a full list of all aspects of complete and integrated emergency plans, but represent the differences between the approved major features emergency plan and complete and integrated emergency plans that must be identified and adequately addressed by the COL or CP applicant. As such, a COL or CP applicant that references the ESP, if granted, is responsible for identifying and adequately addressing all required aspects of complete and integrated emergency plans that were not addressed and found adequate in the ESPA, in accordance with applicable requirements and guidance.

In seeking approval for aspects of the major features, the applicant did not specify acceptance criteria under each planning standard for which they sought credit. Therefore, in each section of the FSER below, the staff compared the information provided against the relevant acceptance criteria provided in NRC guidance to determine the extent to which finality could be granted. The outcome of that comparison for each planning standard is discussed in the respective sections below. The NRC staff does not need to find that the ESPA complies with each planning standard, either fully or partially, since approval of a complete and integrated emergency plan is not required at the ESP phase. Planning standard acceptance criteria not addressed during the ESP review would need to be considered in the review of a COL or CP application referencing the ESP.

13.3.3.5.1 FEMA Consultation

In its February 13, 2017, letter to FEMA, the NRC (2017-TN5956) requested that FEMA review the ESPA and provide the NRC with its determination about whether the proposed major features of the emergency plan, specifically related to the exact size and configuration of the 2 mi PEP EPZ, are acceptable for ESP Plan 5B (TVA 2017-TN5442).[14] FEMA responded to NRC's February 13, 2017, letter on June 12, 2017 (FEMA 2017-TN5957), and supplemented its response on August 11, 2017, and January 24, 2018. In its January 24, 2018, letter (FEMA 2018-TN5960), FEMA stated, in part, the following:

> With respect to the issue of whether the proposed major features of the emergency plan, specifically related to the exact size and configuration of the 2-mile PEP EPZ, is acceptable (for Emergency Plan 5B), FEMA and NRC staffs have engaged in multiple discussions to better clarify the appropriate FEMA deliverable. Specifically, the NRC has not requested FEMA's approval of the 2-mile radius for the PEP EPZ. Rather, NRC requests FEMA's determination, as part of a limited major feature review, that the exact size and configuration of the 2-mile PEP EPZ for Emergency Plan 5B was established relative to local

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[14] TVA is requesting NRC approval of the ESPA's description of the 2 mi PEP EPZ. TVA is not requesting approval of the application of the 2 mi PEP EPZ to the CRN Site, because this would be addressed in a COLA. The extent of NRC approval of the description of the 2 mi PEP EPZ is limited to whether that description reflects such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries, in accordance with Section I.3 of Appendix E to 10 CFR Part 50 (TN249). See also, Sections 13.3.3.3.3 and 13.3.3.5.18 of this chapter.

emergency response needs and capabilities as they are affected by such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries, in accordance with Section I.3 of Appendix E to 10 CFR Part 50 (TN249). Therefore, NRC seeks a FEMA determination whether the boundary established for the proposed 2-mile PEP EPZ, as described in Emergency Plan 5B and the ETE report, adequately addresses these criteria.

Accordingly, FEMA, working with the TEMA, has determined that the boundary established for the proposed 2-mile PEP EPZ (as reflected in Emergency Plan 5B and its ETE Report), was established relative to local emergency response needs and capabilities, as they are affected by such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries. This finding does not, however, endorse or determine the adequacy of a proposed 2-mile PEP EPZ for the CRN Site if proposed during the licensing process.

Notwithstanding these determinations, as the licensing process moves forward and the NRC staff reviews TVA's exemption request that would permit the use of a methodology for establishing a scalable PEP EPZ boundary for the small modular reactor (SMR) design that will later be selected for the combined license (COL), FEMA looks forward to providing continued consultative support to the NRC consistent with each agency's statutes, applicable regulations, and the joint FEMA/NRC memorandum of understanding.

Section 13.3.3.1 of this chapter documents FEMA's ESPA review of significant impediments to the development of offsite emergency plans for the 2 mi PEP EPZ.

13.3.3.5.2 Assignment of Responsibility (Organization Control)

As reflected in NUREG-0654, Section II, Planning Standard A, "Assignment of Responsibility (Organization Control)" (NRC 1980-TN512), 10 CFR 50.47(b)(1) (TN249) requires that primary responsibilities for emergency response by the nuclear facility licensee and by State and local organizations within the EPZs have been assigned, the emergency responsibilities of the various supporting organizations have been specifically established, and each principal response organization has staff to respond and augment its initial response on a continuous basis. In addition, 10 CFR Part 50, Appendix E, Section III (TN249) requires that the emergency plans incorporate information about the emergency response roles of supporting organizations and offsite agencies, and that the incorporated information shall be sufficient to provide assurance of coordination among the supporting groups and with the licensee. In addition, 10 CFR Part 50, Appendix E, Section IV.A (TN249) requires a description of the local offsite services to be provided in support of the licensee's emergency organization; identification of and a description of the assistance expected from appropriate local, State, and Federal agencies that have responsibilities for coping with emergencies, including hostile actions at the site; and identification of the State and/or local officials responsible for planning for, ordering, and controlling appropriate protective actions, including evacuations when necessary.

In the following ESP Plan sections, the applicant described the responsibilities of TVA and various local, State, and Federal agencies, as well as private sector organizations that are part of the ERO for the CRN Site and might be needed to respond to an emergency onsite at the CRN Site:

- ESP Plan Section 2.3, "State Radiological Emergency Plan,"
- ESP Plan Section 3.1, "Roles and Responsibilities,"
- ESP Plan Section 3.2, "Onsite Organization,"
- ESP Plan Section 3.3, "Offsite Organization,"
- ESP Plan Section 5.2, "Offsite,"
- ESP Plan Section 16.5, "Agreement Letters,"
- ESP Plan Section A.3, "Site Emergency Organization (Concept of Operations)," of Appendix A,
- ESP Plan Section A.4.5.2, "First Aid and Medical Facilities," of Appendix A,
- ESP Plan Section A.4.6, "Additional Local Support," of Appendix A, and
- ESP Plan Section A.5.1, "Responsibility for the Emergency Preparedness Effort," of Appendix A.

The staff reviewed these sections, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG-0654, Section II, Planning Standard A (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(1) (TN249).

In ESP Plan Section A.5.1 of Appendix A, the applicant stated that the Site Vice President maintains overall authority and responsibility for radiological emergency response planning. The Director of Emergency Preparedness is assigned responsibility for coordinating emergency preparedness efforts, including activities related to the development of emergency plans and procedures and coordination of the plans and procedures with supporting organizations to ensure the overall effectiveness of the program. ESP Plan Section A.3.6.1, "Site Vice President," of Appendix A includes the responsibilities of the Site Vice President.

ESP Plan Section 2.3 states that the State Radiological Emergency Plan, which is referenced in Appendix A, Attachment 1, "State Multijurisdictional Radiological Emergency Response Plan," provides for the coordinated response of the State and affected local governments, and defines roles and responsibilities. ESP Plan Table 2-1, "Principal Organizational Responsibilities," identifies the responsibilities of the major organizations, including local, State, and TVA. ESP Plan 5B, Section 2.3, further states that the State and local governments include those within the CRN Site ingestion exposure pathway EPZ (TVA 2017-TN5442). ESP Plan 5A, Section 2.3 (TVA 2017-TN5443), does not include a reference to the CRN Site ingestion exposure pathway EPZ, but adds the following:

> As addressed in the Federal Emergency Management Agency's (FEMA) Comprehensive Preparedness Guide 101, "Developing and Maintaining Emergency Operations Plans" (CPG-101), if determined appropriate, government

officials may utilize a CEMP [Comprehensive Emergency Management Plan] approach to emergency planning to implement ad hoc protective actions to protect the public.

ESP Plan Section 3.1.1, “Emergency Management Organization (Concept of Operations),” states that the CRN Site Emergency Management Organization (also referred to as the ERO), is divided into two categories: the onsite organization and the offsite emergency organization. The onsite organization is composed of the Site Emergency Director (SED) and technical staff located in the TSC, a Control Room staff of Operations personnel, and additional support personnel located in the OSC. The onsite organization is responsible for the onsite response to an emergency condition. Onsite activities are directed by the SED to include such functions as Control Room operations, technical assessment, emergency mitigation analysis, onsite radiation surveys, and dose tracking for site personnel. ESP Plan 5B, Section A.3.6.2, “Site Emergency Director,” of Appendix A includes an additional responsibility for the SED to make recommendations for protective actions (if necessary) to the State and local agencies prior to the Central Emergency Control Center (CECC) being staffed—at which time this responsibility can be transferred only to the CECC Director (TVA 2017-TN5442). (The ESP Plan relies on the use of the CECC as the EOF for the CRN Site, as discussed in Section 13.3.3.5.4 of this chapter.)

The TVA offsite organization is designated as the CECC staff, which comprises a CECC Director, a supporting group of technical assistants, and representatives of other TVA organizations. The CECC Director and supporting technical assistants report to the CECC during an emergency, as required. Other TVA organizations will send representatives to the CECC, as requested by the CECC Director. The CECC is responsible for directing and coordinating the overall TVA response to an emergency condition. Functions such as offsite radiological monitoring and dose assessment, public information, State and local government coordination, and additional plant assessment are handled by the CECC, relieving the onsite organization of the many peripheral duties necessary for the successful emergency response. ESP Plan Figure 3-1, “Offsite Emergency Organization,” illustrates in a block diagram the interrelationships of TVA’s offsite emergency organization.

ESP Plan Section 3.2 states that the CRN Site is staffed on a continual 24-hour basis, and that minimum staffing requirements for plant operations established in the plant Technical Specifications, and the staff responsibilities for normal operations identified in plant Technical Specifications, remain unchanged during an emergency. In ESP Plan Section A.3 of Appendix A, the applicant provided a general description of the organization TVA maintains that is capable of responding to a radiological emergency, and stated that the on-shift staff is present on a 24-hour basis. In addition, ESP Plan Section 5.2 states that essential emergency positions are covered on a 24-hour-a-day basis by duty personnel. Specifically, 24-hour per day staffing of communications links is discussed in Section 13.3.3.5.7 of this chapter.

ESP Plan Section 3.2 further states that under emergency conditions, the normal plant staff is supplemented, as shown in ESP Plan Appendix A (i.e., Figure A.3-1, “Technical Support Center Organization,” and Figure A.3-2, “Operations Support Center Organization”), which also provides descriptions of the responsibilities of the personnel who augment the normal plant operating organization. The person primarily responsible for mitigation of an emergency is the SED. Upon declaration of an emergency, the on-duty Shift Manager (SM) initially fills the position of SED and directs emergency response from the Control Room. This position is transferred to the TSC when the facility is activated, at which time the TSC provides technical support to the Control Room as part of their overall response to the emergency.

The onsite organization augments the on-shift normal plant operating organization. If members of the onsite organization are not present when an emergency occurs, the on-duty SM (or a designated Unit Supervisor when acting as the SM) is designated the SED and acts as such until relieved by the SED assigned to the TSC. The interrelationships of TVA's onsite organization are illustrated in block diagrams in ESP Plan Figure A.3-1, "Technical Support Center Organization," of Appendix A, and ESP Plan Figure A.3-2, "Operations Support Center Organization," of Appendix A. The onsite emergency organization is addressed further in ESP Plan Section A.3.6, "Onsite Emergency Management Organization," of Appendix A, and discussed in Section 13.3.3.5.3 of this chapter.

Upon detection of a known or suspected emergency, the on-duty SM refers to a CRN Emergency Plan Implementing Procedures (EPIP) to determine the emergency classification. ESP Plan Section A.8, "Emergency Plan Implementing Procedures," of Appendix A lists a CRN-EPIP topic entitled "Emergency Classification." In addition, emergency classification is addressed in ESP Plan Section 4.0, "Emergency Conditions," and discussed in Section 13.3.3.5.5 of this chapter.

After determining the classification of the incident, the SM assumes the responsibilities of SED (under declaration of an emergency) and initiates the appropriate procedure referenced by the CRN-EPIP. Emergency communications/notifications with local, State, and Federal agencies, along with staffing instructions for the emergency response facilities are specified in CRN-EPIPs. CRN-EPIPs designate personnel who will staff the ENS and Health Physics Network (HPN) communication functions using the NRC Federal Telecommunications System (FTS) 2000 System to interface with the NRC during TSC operation. (Emergency communications are addressed in ESP Plan Section 6.0, "Communications," and discussed in Section 13.3.3.5.7 of this chapter.)

ESP Plan Section 3.3 identifies the titles and responsibilities of the positions that compose TVA's offsite organization that augments the normal plant operating organization (also shown in ESP Plan Figure 3-1), and lists the specific responsibilities. ESP Plan Section 3.3.1, "CECC Director," states that the CECC Director has overall responsibility and authority for ensuring adequate TVA response, and directs and coordinates TVA's emergency response. This includes responsibility for ensuring 24-hour/day operations are established during the emergency, if required. ESP Plan 5B, Section 3.3.1 adds that the CECC Director ensures adequate TVA response to affected State/local governments in protecting the health and safety of the public, and makes protective action recommendations (PARs) to the State (TVA 2017-TN5442). Protective actions are addressed in ESP Plan Section 10.0, "Protective Response," and discussed in Section 13.3.3.5.11 of this chapter.

In contrast, ESP Plan 5A, Section 3.3.1 (TVA 2017-TN5443) states that the CECC Director:

> Ensures sufficient information relative to the plant status, radiological impacts, and protective measures is made available to government officials to enable them to implement ad hoc protective measures . . . for the protection of the public, should they be determined appropriate by offsite officials.

Offsite support organizations that are intended to respond onsite to an emergency at the CRN Site are described in ESP Plan Section 3.3.24, "Local Support," which states that TVA maintains agreements with police departments, fire departments, ambulance services, and hospitals near the CRN Site to provide appropriate services for a response onsite, as requested. Arrangements for ambulance services and local medical facilities are also addressed in ESP

Plan Section 12.0, "Medical Support," ESP Plan Section A.4.5.2.3, "Receiving Hospitals and Supplies" of Appendix A, and ESP Plan Section A.4.5.2.4, "Ambulance Service" of Appendix A, and discussed further in Section 13.3.3.5.13 of this chapter.

ESP Plan Section 3.3.25, "Federal Agency Support," states that TVA maintains an agreement with DOE REAC/TS. Other Federal support would be requested through the National Response Framework (NRF), which is addressed in ESP Plan Section 2.4, "National Response Framework," and discussed in Section 13.3.3.5.4 of this chapter (FEMA 2008-TN6186; 73 FR 4887-TN6185). ESP Plan Section 3.3.26, "Vendor Support," states that TVA may obtain technical support from the Nuclear Steam Supply System (NSSS) vendor during emergency situations, and may procure other vendor support, as needed. Finally, ESP Plan Section 3.3.27, "INPO," states that TVA maintains an agreement with the Institute of Nuclear Power Operations (INPO), a consortium of nuclear utilities and other nuclear industries, to obtain any necessary support available from the industry during an emergency.

In ESP Plan Section 16.5, the applicant also stated that the detailed agreements with TEMA, DOE, Roane County, and the City of Oak Ridge will be addressed in the COLA, and documented in a Multijurisdictional Emergency Response Plan. (See ESP Plan Appendix A, Attachment 1, referenced above, which identifies the "State of Tennessee Multijurisdictional Radiological Emergency Response Plan.") Arrangements for offsite support are also addressed in ESP Plan Section A.4.6 of Appendix A, and discussed in Section 13.3.3.5.4 of this chapter.

With regard to the guidance in NUREG‑0654, Section II, Evaluation Criterion II.A.3 (NRC 1980-TN512), the applicant did not include in the ESPA written agreements referring to the concept of operations developed between Federal, State, and local agencies and other support organizations that have an emergency response role within the EPZs. (The staff's evaluation of contacts and arrangements with local, State, and Federal agencies are addressed in Section 13.3.3.2 of this chapter.)

Pursuant to 10 CFR 52.39(b) (TN251), an applicant for a COL that references this ESP, if granted, shall update the EP information that was provided under 10 CFR 52.17(b) (TN251), including written agreements with offsite agencies, and discuss whether the updated information materially changes the bases for compliance with applicable NRC requirements. Consistent with this requirement and related guidance, as well as the applicant's statement above to address various detailed agreements with offsite emergency support entities in a COLA, the staff identified the following COL Action Item to address necessary agreements with offsite support organizations:

- COL Action Item 13.3-2: An applicant for a COL or CP that references this ESP should submit to the NRC up-to-date letters of agreement or memoranda of understanding with offsite support organizations, which address the concept of operations in support of their respective emergency response roles associated with the chosen plant design, including hostile actions at the CRN Site, consistent with applicable requirements and guidance, including 10 CFR 52.79(a)(22)(i) and (ii) and 10 CFR 50.47(b), (c).

13.3.3.5.2.1 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG‑0654, Section II, Planning Standard A (NRC 1980-TN512). A COL or CP applicant will address COL Action Item 13.3-2. Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(1) (TN249) and 10 CFR

Part 50, Appendix E, Sections III and IV.A (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.3 Onsite Emergency Organization

As reflected in NUREG‑0654, Section II, Planning Standard B, “Onsite Emergency Organization” (NRC 1980-TN512), 10 CFR 50.47(b)(2) (TN249) requires that on-shift facility licensee responsibilities for emergency response are unambiguously defined, that adequate staffing to provide initial facility accident response in key functional areas is maintained at all times, that timely augmentation of response capabilities is available, and that interfaces among various onsite response activities and offsite support and response activities are specified. In addition, 10 CFR Part 50, Appendix E, Section IV.A (TN249) requires a description of the organization for coping with radiological emergencies, including definition of the authorities, responsibilities, and duties of individuals assigned to the licensee’s emergency organization, and the means for notification of such individuals in the event of an emergency. This shall include a description of the normal plant operating organization, onsite ERO, headquarters personnel who will augment the onsite emergency organization, and local offsite services to be provided in support of the licensee’s emergency organization. The emergency plan shall identify persons within the licensee organization who will be responsible for making offsite dose projections, and other employees with special qualifications for coping with emergency conditions that might arise. Other persons with special qualifications, who are not licensee employees and who may be called on for assistance, shall also be identified, including a description of their special qualifications. In 10 CFR Part 50, Appendix E, Section IV.A.9 (TN249) requires a detailed analysis demonstrating that on-shift personnel assigned emergency plan implementation functions are not assigned responsibilities that would prevent the timely performance of their assigned functions, as specified in the emergency plan.

In the following ESP Plan sections, the applicant described the ERO and its key positions and associated responsibilities, including outlining the staffing requirements that provide initial emergency response actions and provisions for timely augmentation of on-shift personnel when required.

- ESP Plan Section 3.1.1, “Emergency Management Organization (Concept of Operations),”
- ESP Plan Section 3.2, “Onsite Organization,”
- ESP Plan Section 3.3, “Offsite Organization,”
- ESP Plan Section 5.2, “Offsite,”
- ESP Plan Section 7.0, “Public Information and Education,”
- ESP Plan Section 12.0, “Medical Support,”
- ESP Plan Section 13.0, “Termination and Recovery,”
- ESP Plan Section 16.5, “Agreement Letters,”
- ESP Plan Section A.3, “Site Emergency Organization (Concept of Operations),” of Appendix A,
- ESP Plan Section A.4.5.2, “First Aid and Medical Facilities,” of Appendix A, and
- ESP Plan Section A.4.6, “Additional Local Support,” of Appendix A.

The staff reviewed these sections, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG–0654, Section II, Planning Standard B (NRC 1980-TN512), and Section IV.C, "On-Shift Staffing Analysis," of NSIR/DPR-ISG-01, "Emergency Planning for Nuclear Power Plants" (NRC 2011-TN5969), which provide the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(2) (TN249).

ESP Plan Section 3.1.1 states that the CRN Site Emergency Management Organization is divided into two categories: the onsite organization and the offsite emergency organization. The onsite organization comprises the SED and technical staff located in the TSC, a Control Room staff of Operations personnel, and additional support personnel located in the OSC. The onsite organization is responsible for the onsite response to an emergency condition. Onsite activities are directed by the SED and include functions such as Control Room operations, technical assessment, emergency mitigation analysis, onsite radiation surveys, and dose tracking for site personnel. ESP Plan Figures A.3-1 and A.3-2 of Appendix A illustrate in block diagrams the interrelationships of TVA's onsite organization.

The offsite organization is designated as the CECC staff, which comprises a CECC Director, a supporting group of technical assistants, and representatives of other TVA organizations. The CECC Director and supporting technical assistants report to the CECC during an emergency, as required. Other TVA organizations will send representatives to the CECC, as requested by the CECC Director. The CECC is responsible for directing and coordinating the overall TVA response to an emergency condition. (ESP Plan Section 9.2.1, "General Information," lists CECC-EPIP-18, "Transportation and Staffing Under Abnormal Conditions.") Functions such as offsite radiological monitoring and dose assessment, public information, State and local government coordination, and additional plant assessment are handled by the CECC, thereby relieving the onsite organization of the many peripheral duties necessary for the successful emergency response. ESP Plan Figure 3-1 illustrates in a block diagram the interrelationships of TVA's offsite emergency organization.

ESP Plan Section 3.2 states that under normal conditions the Site Vice President is in charge of activities at the site, and the Plant Manager is responsible for the safe efficient operation of the plant. Management-level interface by the Site Vice President with governmental authorities is addressed in ESP Plan Section A.3.6.1 of Appendix A, and discussed further in Section 13.3.3.5.2 of this chapter. The ERO position primarily responsible for mitigation of an emergency is the SED. Upon declaration of an emergency, the on-duty SM initially fills the position of SED and directs emergency response from the Control Room. This position is transferred to the TSC when the facility is activated, at which time the TSC provides technical support to the Control Room as part of their overall response to the emergency.

ESP Plan Section A.3.6.2 describes SED responsibilities, and identifies which responsibilities cannot be delegated. ESP Plan 5B, Section A.3.6.2 of Appendix A includes an additional responsibility for the SED to recommend protective actions (if necessary) to the State and local agencies prior to the CECC being staffed (TVA 2017-TN5442). This responsibility can be transferred only to the CECC Director. The authority and responsibilities of the SED, including various aspects of the onsite and offsite organizations, are discussed further in Section 13.3.3.5.2 of this chapter.

ESP Plan Section 3.2 states that the CRN Site is staffed on a continual 24-hour basis, and that minimum staffing requirements for plant operations established in the plant Technical Specifications, and the staff responsibilities for normal operations identified in plant Technical Specifications remain unchanged during an emergency. In ESP Plan Section A.3 of Appendix A, the applicant provided a general description of the organization TVA maintains that is capable of responding to a radiological emergency, and stated that the on-shift staff is continually present on a 24-hour basis. The applicant also stated that TVA will specify on-shift staffing in the COLA. In addition, ESP Plan Section 5.2 states that essential emergency positions are covered on a 24-hour-a-day basis by duty personnel.

ESP Plan Section 3.2 further states that under emergency conditions, the normal plant staff is supplemented, as shown in ESP Plan Appendix A, which also provides descriptions of the responsibilities of the personnel who augment the normal plant operating organization. Support personnel will be notified to report as required by the situation. Staffing time for the augmenting forces is indicated in ESP Plan Appendix A. Staff notifications are addressed in ESP Plan Section 5.0, "Emergency Notification and Activation of Plan," and discussed in Section 13.3.3.5.6 of this chapter.

The onsite organization augments the shift operations crew. If members of the onsite organization are not present when an emergency occurs, the on-duty SM (or a designated Unit Supervisor, when acting as the SM) is designated the SED, and acts as such until relieved by the SED assigned to the TSC. Upon detection of a known or suspected emergency, the on-duty SM refers to a CRN-EPIP to determine the emergency classification. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP topic entitled "Emergency Classification." In addition, emergency classification is addressed in ESP Plan Section 4.0 and discussed in Section 13.3.3.5.5 of this chapter.) After determining the classification of the incident, the SM assumes the responsibilities of SED and initiates the appropriate procedure referenced by the CRN-EPIP. Emergency communications/notifications with local, State, and Federal agencies, along with staffing instructions for the emergency response facilities are specified in CRN-EPIPs. CRN-EPIPs designate personnel who staff the ENS and HPN communication systems, as well as interface with the NRC during TSC operation. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP topic entitled "Staffing and Operation of Emergency Response Facilities.")

ESP Plan Section 3.3 identifies the titles and responsibilities of those positions that compose TVA's offsite organization that augments the plant staff (also shown in ESP Plan Figure 3-1), and lists the specific responsibilities. The applicant also stated that the prescribed response times for the offsite organization will be addressed in the COLA. (Notification and activation of emergency response personnel are addressed in ESP Plan Section 5.0 and discussed in Section 13.3.3.5.6 of this chapter.) ESP Plan Section 3.3.1 states that the CECC Director has overall responsibility and authority for ensuring adequate TVA response, and directs and coordinates TVA's emergency response. This includes responsibility for ensuring 24-hour/day operations are established, if required. ESP Plan 5B, Section 3.3.1 (TVA 2017-TN5442) adds that the CECC Director ensures adequate TVA response to affected State/local governments in protecting the health and safety of the public, and makes PARs to the State. (Protective actions are addressed in ESP Plan Section 10.0 and discussed in Section 13.3.3.5.11 of this chapter.) In contrast, ESP Plan 5A, Section 3.3.1 (TVA 2017-TN5443) includes the following additional responsibility for the CECC Director:

> Ensures sufficient information relative to the plant status, radiological impacts, and protective measures is made available to government officials to enable

them to implement ad hoc protective measures . . . for the protection of the public, should they be determined appropriate by offsite officials.

In ESP Plan Section 3.3.13, “Public Information Manager,” the applicant listed the Public Information Manager’s responsibilities, which include providing information to inform the public and news media in response to an emergency. ESP Plan Section 7.0 identifies the support personnel who are responsible for the approval and release of information to the news media during an emergency. TVA’s emergency public information program is discussed further in Section 13.3.3.5.8 of this chapter.

Consistent with the applicant’s intention to address the on-shift ERO staffing in a COLA (described above), the staff identified the following COL Action Item.

- COL Action Item 13.3-3: An applicant for a COL or CP that references this ESP should update the emergency plan to describe on-shift emergency response organization staffing in support of the chosen SMR technology for the CRN Site, including the capability for Tennessee Valley Authority’s (TVA’s) onsite and offsite emergency response organization positions to be staffed and emergency response facilities activated, consistent with the applicable requirements and guidance.

Logistical support for emergency personnel is addressed in ESP Plan Section 3.3.23, “Management Services,” which states that Management Services provides for clerical support, food and water, sanitary facilities, TVA transportation services, lodging, specialized equipment and supplies, communications, drawings, and controlled documents. In addition, Management Services is authorized to issue checks to outside firms for payment for emergency services.

Offsite support organizations that are intended to be part of the overall response organization are described in ESP Plan Section 3.3.24, which states that TVA maintains agreements with police departments, fire departments, ambulance services, and hospitals near the CRN Site to provide appropriate services, as requested. Arrangements for ambulance services and local medical facilities are also addressed in ESP Plan Section 12.0, ESP Plan Section A.4.5.2.3 and A.4.5.2.4 of Appendix A, and discussed further in Section 13.3.3.5.13 of this chapter.

ESP Plan Section 3.3.25 states that TVA maintains an agreement with DOE REAC/TS, and that other Federal support would be requested through the NRF. (The NRF is addressed in ESP Plan Section 2.4 and discussed in Section 13.3.3.5.4 of this chapter.) ESP Plan Section 3.3.26 states that TVA may obtain technical support from the NSSS vendor during emergency situations, and may procure other vendor support, as needed. Finally, ESP Plan Section 3.3.27 states that TVA maintains an agreement with INPO, a consortium of nuclear utilities and other nuclear industries, to obtain any necessary support available from the industry during an emergency. ESP Plan Table 2-1 identifies the responsibilities of the major organizations, including local, State, and TVA. Emergency response roles of supporting organizations and offsite agencies, including arrangements and agreements reached in support of the CRN Site (addressed in ESP Plan Section 16.5), are discussed further in Section 13.3.3.5.2 of this chapter.

13.3.3.5.3.1 Fukushima Dai-ichi – Near-Term Task Force Recommendation 9.3

TVA’s ESPA did not address Recommendation 9.3 of the Near-Term Task Force (NTTF) (NRC 2012-TN2903), which reviewed the NRC’s regulations and processes to determine whether the agency should make safety improvements to the NRC’s regulatory system in light of events at the Fukushima Dai-ichi NPP. In the advanced safety evaluation report, the staff proposed

permit conditions for staffing and communications that addressed NTTF Recommendation 9.3. The proposed permit conditions were consistent with conditions in the Public Service Enterprise Group ESP and recently issued COLs and also with provisions in the 2015 proposed rule on mitigation of beyond-design basis external events (80 FR 70610-TN6027). However, in the SRM for the draft final rule (NRC 2019-TN6137), the Commission decided not to impose regulatory requirements for staffing and communications. As explained in the revised *Federal Register* notice included in the SRM, staffing and communications are supporting elements for the overarching requirement to develop, implement, and maintain mitigation strategies for beyond-design basis external events. The Commission concluded that separate requirements for staffing and communications were not necessary and could constrain the development of innovative mitigation strategies that do not rely on staffing or communications. Consistent with the SRM, the staff has eliminated the proposed permit conditions. Compliance with the final rule requirements is outside the scope of this ESPA review and would be addressed by a COL or operating license applicant referencing the ESP, if granted.

13.3.3.5.3.2 <u>Enhancements to Emergency Preparedness Regulations</u>

10 CFR Part 50, Appendix E, Section IV.A.9 (TN249) requires that nuclear power reactor licensees provide a detailed analysis demonstrating that on-shift personnel assigned emergency plan implementation functions are not assigned responsibilities that would prevent the timely performance of their assigned functions, as specified in the emergency plan.

In support of this requirement, the NRC issued associated guidance in Interim Staff Guidance NSIR/DPR-ISG-01 (NRC 2011-TN5969). In Section IV.C of NSIR/DPR-ISG-01, NRC-endorsed Nuclear Energy Institute (NEI) technical report NEI 10-05, "Assessment of On-Shift Emergency Response Organization Staffing and Capabilities," Revision 0, dated June 2011 (NEI 2011-TN5994), stating, in part, that NEI 10-05 establishes a standard methodology for a licensee to perform the required staffing analysis (in 10 CFR Part 50, Appendix E, Section IV.A.9 [TN249]), and that the NRC has reviewed NEI 10-05 and finds it to be an acceptable methodology for this purpose.

TVA did not include a detailed on-shift staffing analysis in the ESPA. Because the staffing provisions are an essential part of the staff's review of the onsite emergency organization, in support of full-power operations, the staff identified the following Permit Condition, which addresses the actions that will be taken to analyze on-shift personnel assigned emergency plan implementation function.

- <u>Permit Condition 13.3-2 (Permit Condition 6)</u>: An applicant for a COL or CP that references this ESP shall update the emergency plan to describe the on-shift personnel assigned to emergency plan implementing functions based on the chosen SMR technology and the number of proposed reactor units.

  In addition, if a COL applicant references this ESP, the COL applicant shall propose a license condition for the COL holder to perform the following:

  (i) No later than 18 months before the latest date set forth in the schedule submitted in accordance with 10 CFR 52.99(a) for completing the inspections, tests, and analyses in the Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC), the licensee shall have performed a detailed staffing analysis, in accordance with the latest NRC-endorsed revision of Nuclear Energy Institute (NEI) 10-05, "Assessment of On-Shift Emergency Response Organization Staffing and Capabilities."

(ii) No later than 180 days before the date scheduled for initial fuel loading set forth in the notification submitted in accordance with 10 CFR 52.103(a), the licensee shall have revised the emergency plan to incorporate any changes identified in the staffing analysis that are needed to bring staffing to the required levels.

If a CP applicant references this ESP, the CP applicant shall propose a permit condition for the operating license applicant to:

(i) Perform a detailed staffing analysis, in accordance with the latest NRC-endorsed revision of Nuclear Energy Institute (NEI) 10-05, "Assessment of On-Shift Emergency Response Organization Staffing and Capabilities."

(ii) Revise the emergency plan to incorporate any changes identified in the staffing analysis that are needed to bring staffing to the required levels.

Subject to Permit Condition 13.3-2 (Permit Condition 6), the staff finds that the applicant unambiguously defined its responsibilities for emergency response, has adequate staffing to provide and maintain at all times initial facility accident response in key functional areas, and is capable of timely augmentation of the response capabilities. The applicant adequately specified the interfaces among various onsite and offsite support and response activities. In addition, the applicant described the organization for coping with radiological emergencies, including the authorities, responsibilities, and duties of individuals assigned to the licensee's emergency organization and the means for their notification in the event of an emergency. The applicant also described the normal plant operating organization, the onsite ERO, and the headquarters and local offsite personnel and services that will augment and support the onsite organization. Further, licensee employees who are responsible for making offsite dose projections, and licensee and other persons with special qualifications for coping with emergency conditions, are also identified.

13.3.3.5.3.3 *Conclusion*

Subject to Permit Condition 13.3-2 (Permit Condition 6), the staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG-0654, Section II, Planning Standard B (NRC 1980-TN512) and NSIR/DPR-ISG-01, Section IV.C (NRC 2011-TN5969). A COL or CP applicant will address COL Action Item 13.3-3. Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(2) (TN249) and 10 CFR Part 50, Appendix E, Section IV.A (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.4 Emergency Response Support and Resources

As reflected in NUREG-0654, Section II, Planning Standard C, "Emergency Response Support and Resources" (NRC 1980-TN512), 10 CFR 50.47(b)(3) (TN249) requires that arrangements for requesting and effectively using assistance resources have been made, arrangements to accommodate State and local staff at the licensee's EOF have been made, and other organizations capable of augmenting the planned response have been identified. In addition, 10 CFR Part 50, Appendix E, Section III (TN249) requires that the emergency plans incorporate information about the emergency response roles of supporting organizations and offsite agencies, and that the information shall be sufficient to provide assurance of coordination among the supporting groups and with the licensee. In addition, 10 CFR Part 50, Appendix E,

Section IV.A.7 (TN249) requires identification of, and a description of the assistance expected from, appropriate local, State, and Federal agencies that have responsibilities for coping with emergencies, including hostile action at the site.

In the following ESP Plan sections, the applicant described the provisions for requesting and effectively using support resources and for accommodating offsite officials at the emergency response facilities:

- ESP Plan Section 2.4, “National Response Framework,”
- ESP Plan Section 3.3, “Offsite Organization,”
- ESP Plan Section 5.2.3, “Site Area Emergency,”
- ESP Plan Section 8.2, “Central Emergency Control Center,”
- ESP Plan Section 9.2, “Offsite,”
- ESP Plan Section 10.2, “Onsite Protective Actions for Hostile Action Events,”
- ESP Plan 5A/5B Section 12.3/12.4, “Interagency Assistance from REAC/TS,”
- ESP Plan Section 16.5, “Agreement Letters,”
- ESP Plan Attachment 1, “Justification for the Central Emergency Control Center,” and
- ESP Plan Section A.4, “Emergency Response Facilities, Equipment, and Supplies,” of Appendix A.

The staff reviewed these sections, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff’s primary focus was to evaluate the emergency plan against NUREG‑0654, Section II, Planning Standard C (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirement in 10 CFR 50.47(b)(3) (TN249).

In ESP Plan Section 8.2, the applicant stated that the CECC coordinates with offsite Federal agencies, such as the NRC and DOE, to ensure the availability of additional outside resources to TVA. The CECC is provided with direct communication links to State emergency response centers, other TVA EROs and nuclear plant sites, the Joint Information Center (JIC), and offsite Federal and State organizations. ESP Plan Attachment 1 states that the ESP Plan relies on the use of the CECC as the EOF for the CRN Site, and that the CECC, discussed in Section 13.3.3.5.9 of this chapter, meets the functional and design criteria provided in NUREG‑0696 (NRC 1981-TN5966) for an EOF, including working space to accommodate State and local staff. In addition, ESP Plan Section 5.2.3 states that upon declaration of the Site Area Emergency classification, TVA personnel knowledgeable of plant systems for the selected reactor technology are dispatched to the State Emergency Operations Center (SEOC).

ESP Plan Section 2.4 states that the NRF Nuclear/Radiological Incident Annex (NRIA) provides for timely, coordinated response by Federal agencies to a fixed NPP facility incident. The NRF NRIA provides the Federal government’s concept of operations for responding to radiological emergencies (i.e., offsite response), and supports State and local governments. The NRF is activated by either the affected State notifying the DHS, or the utility notifying the NRC of a radiological emergency at a nuclear plant site. The CECC Director is the TVA representative

authorized to request Federal assistance from the NRC. Because of the close proximity of the DOE ORR to the CRN Site, requested DOE response is expected within 1 to 2 hours.

In ESP Plan 5A, Section 12.3 (TVA 2017-TN5443), and ESP Plan 5B, Section 12.4 (TVA 2017-TN5442), "Interagency Assistance from REAC/TS," the applicant stated that TVA maintains arrangements with DOE's REAC/TS as the CRN Site receiving hospital. REAC/TS, which is in close proximity to the CRN Site, is a DOE-sponsored facility operated by Oak Ridge Associated Universities Medical and Health Sciences Division, in cooperation with Oak Ridge Methodist Medical Center in Oak Ridge, Tennessee. The University of Tennessee Medical Center in Knoxville serves as a backup to REAC/TS. Specialized facilities and expert personnel are available at both medical facilities for definitive care for radiation emergency victims, and TVA maintains letters of agreement for services with each. In addition, ESP Plan Section 3.3.25 states that TVA maintains an agreement with DOE REAC/TS, and that other Federal support would be requested through the NRF.

In ESP Plan Section 16.5, the applicant provided a list of agreements or contracts that TVA maintains for services of outside organizations during an emergency. These offsite organizations include law enforcement, ambulance and fire department services, other offsite organizations, and DOE REAC/TS support. Arrangements for offsite support are also discussed in ESP Plan Sections 3.3.24, 3.3.26, and 3.3.27, and ESP Plan Section A.4.6 of Appendix A. Contacts and arrangements with local, State, and Federal agencies are addressed in Section 13.3.3.2 of this chapter.

With regard to offsite radiological support, ESP Plan 5B, Section 9.2.2, "Sampling Team," states that State agencies have the responsibility to coordinate and evaluate offsite assessment action, and additional environmental monitoring assistance is available from the DOE offices at Oak Ridge, Tennessee, or Aiken, South Carolina (TVA 2017-TN5442). The EPA Office in Montgomery, Alabama, can also provide assistance, including environmental monitoring teams and mobile radioanalytical laboratories. In addition, ESP Plan Section A.4.3, "Laboratory and Equipment," states that TVA provides laboratory facilities for chemical and radiological analysis of solid, liquid, and air samples. (Environmental monitoring assistance from DOE is also addressed in ESP Plan Section 9.0, "Accident Assessment," and discussed in Section 13.3.3.5.10 of this chapter.)

13.3.3.5.4.1 <u>Conclusion</u>

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG-0654, Section II, Planning Standard C (NRC 1980-TN512). Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(3) (TN249) and 10 CFR Part 50, Appendix E, Sections III and IV.A.7 (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.5 Emergency Classification System

As reflected in NUREG-0654, Section II, Planning Standard D, "Emergency Classification System" (NRC 1980-TN512), 10 CFR 50.47(b)(4) (TN249) requires that a standard emergency classification and action level scheme, the bases of which include facility system and effluent parameters, is in use by the nuclear facility licensee, and that State and local response plans call for reliance on information provided by facility licensees for determinations of minimum initial offsite response measures. In addition, 10 CFR Part 50, Appendix E, Section IV.B

(TN249) requires a description of the means to be used for determining the magnitude, and for continually assessing the impact, of the release of radioactive materials, including emergency action levels (EALs) that are to be used as criteria for determining the need for offsite agency notifications and participation, and when and what types of protective measures should be considered. The EALs must include hostile actions that might adversely affect the NPP. The initial EALs shall be discussed and agreed on by the applicant or licensee and State and local governmental authorities, and approved by the NRC. Thereafter, EALs shall be reviewed with State and local governmental authorities on an annual basis. In addition, 10 CFR Part 50, Appendix E, Section IV.C (TN249) requires a description of EALs and emergency conditions that involve alerting or activating the total emergency organization, including communication steps to be taken under each emergency classification level (ECL) (also referred to as “emergency class”). The emergency classes defined shall include (1) Notification of Unusual Event, (2) Alert, (3) Site Area Emergency, and (4) General Emergency. In addition, 10 CFR Part 50, Appendix E, Section IV.C.2 (TN249) requires the capability to assess, classify, and declare an emergency condition within 15 minutes after the availability of indications to plant operators that an EAL has been exceeded, and to promptly declare the emergency conditions as soon as possible after the identification of the appropriate ECL.

In ESP Plan Section 4.0, the applicant described the emergency classifications used to determine the minimum response to an abnormal event at the plant. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff’s primary focus was to evaluate the emergency plan against NUREG-0654, Section II, Planning Standard D (NRC 1980-TN512), which provides detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(4) (TN249).

In an ESPA (with a proposed complete and integrated emergency plan), as well as in a COLA, the requisite EAL information is limited and consists of four critical elements: (1) an overview of the EAL scheme, including a definition of the four ECLs and general list of licensee actions; (2) a commitment to develop the remainder of the EAL scheme using a specified NRC-endorsed guidance document; (3) a proposed license condition that addresses EAL completion, agreement with State and local officials (as appropriate), and submission of the fully developed EAL scheme to the NRC; and (4) maintenance of the EAL scheme in a document controlled by 10 CFR 50.54(q) (TN249). The information associated with these critical elements provides a sufficient level of application detail to support the staff’s reasonable assurance evaluation.

Pursuant to 10 CFR 52.17(b)(2)(i) (TN251), TVA submitted an ESPA for the CRN Site. In ESP Plan Section 4.0, the applicant provided a limited description of the emergency, which includes the major features of the onsite emergency plan for both ESP Plan 5A (TVA 2017-TN5443) and ESP Plan 5B (TVA 2017-TN5442) classification system. The staff reviewed this limited (major features) description for each plan, and determined that neither plan fully addresses any of the four critical elements of an emergency classification system (described above), in support of the four conceptual SMR designs identified for the CRN Site.

With regard to critical element (1), in ESP Plan Section 4.0, TVA provided an overview of the EAL scheme, consisting of the definition of the four ECLs (i.e., Notification of Unusual Event [NOUE], Alert, Site Area Emergency, and General Emergency), and a general list of licensee actions for each ECL. ESP Plan Section A.8 of Appendix A lists a CRN-EPIP topic entitled “Emergency Classification.” In addition, ESP Plan 5A, Section 4.1, “Classification System” (TVA 2017-TN5443), states that NEI 99-01, Revision 6, “Development of Emergency Action Levels for

Non-Passive Reactors" (NEI 2012-TN5995), provides definitions of the ECLs, and that not all elements of these definitions apply to SMR technology; further stating that the differences are addressed in ESP Plan 5A, Section 4.1.1, "NOUE"; Section 4.1.2, "Alert"; Section 4.1.3, "Site Area Emergency"; and Section 4.1.4, "General Emergency" (TVA 2017-TN5443). In contrast, ESP Plan 5B, Section 4.1, "Classification System" (TVA 2017-TN5442), does not include a similar reference to NEI 99-01, Revision 6 (NEI 2012-TN5995), or a statement that not all elements of the NEI 99-01 definitions apply to SMR technology.

In ESP Plan 5A, Section 4.1.4, the applicant stated (in part) that "[d]ue to the SMR design, releases are not expected to exceed EPA PAG exposure levels offsite" (TVA 2017-TN5443). This statement is consistent with a Site Area Emergency definition in Appendix 1, "Emergency Action Level Guidelines for Nuclear Power Plants," of NUREG-0654 (NRC 1980-TN512), which states (in part) in the Class Description table that "[a]ny releases [are] not expected to exceed EPA Protective Action Guideline exposure levels except near site boundary." However, the description of a General Emergency in ESP Plan 5A, Section 4.1.4 (TVA 2017-TN5443) is not consistent with the comparable Appendix 1 Class Description for a General Emergency, which states (in part) that "[r]eleases can be reasonably expected to exceed EPA Protective Action Guideline exposure levels offsite for more than the immediate site area."

Further, the descriptions of expected releases for a Site Area Emergency and General Emergency in ESP Plan 5A appear to be the same. Specifically, ESP Plan 5A, Section 4.1.3 states that (for a Site Area Emergency) "[a]ny releases are not expected to result in exposure levels which exceed EPA PAG exposure levels beyond the site boundary," while ESP Plan 5A, Section 4.1.4 states that (for a General Emergency) "releases are not expected to exceed EPA PAG exposure levels offsite" (TVA 2017-TN5443). Because releases are not expected to exceed EPA PAG exposure levels offsite for ESP Plan 5A, the definition of a General Emergency in Appendix 1 appears to indicate that this classification is not necessary for ESP Plan 5A.

For the reasons discussed above, and because the SMR technology is not yet available, the staff determined that ESP Plan Sections 4.1.1, 4.1.2, 4.1.3, and 4.1.4, which define the four ECLs and list general licensee actions, (1) do not adequately address the extent to which the definitions of the emergency classifications apply to SMR technology, and (2) do not adequately address whether a General Emergency classification is needed for ESP Plan 5A. As such, the EAL information provided in ESP Plan Section 4.0 does not satisfy critical element (1). In addition, ESP Plan Section 4.0 does not address critical elements (2) and (3). Finally, with regard to critical element (4), ESP Plan Section 4.2, "Identification of Emergency Classes," states that "[t]he instrument readings and parameters required for determination of these EALs are detailed in the CRN-EPIPs." Because the applicant did not indicate that these CRN-EPIPs are documents that are controlled by 10 CFR 50.54(q) (TN249), the application does not satisfy critical element (4).

Therefore, the staff finds that the applicant has not adequately addressed any of the four critical elements associated with providing a standard emergency classification and action level scheme for the identified SMR technologies, and that there is no partial approval of the limited (major features) description of the SMR emergency classification system in ESP Plan Section 4.0. As such, the staff identified the following COL Action Item to address the need for a COL or CP applicant to provide an emergency classification and action level scheme for the SMR technology that is chosen for the CRN Site, consistent with applicable requirements and the above discussion.

- COL Action Item 13.3-4: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the emergency classification and action level scheme applicable to the chosen SMR technology for the CRN Site, consistent with the applicable requirements and guidance.

13.3.3.5.5.1 Conclusion

For the reasons described above, the staff concludes that the information provided in the ESPA does not fully address any of the four critical elements of an emergency classification system and is not consistent with the guidelines in NUREG‑0654, Section II, Planning Standard D (NRC 1980-TN512). Therefore, the staff finds the information does not fully address the relevant NUREG-0654 acceptance criteria associated with the respective planning standard. As such, it does not meet the relevant requirements of 10 CFR 50.47(b)(4) (TN249) and 10 CFR Part 50, Appendix E, Sections IV.B and IV.C (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations. Therefore, the emergency classification system major feature is not approved as part of this ESPA review, and will need to be addressed by any future applicant that incorporates this ESP. A COL or CP applicant will address COL Action Item 13.3-4 in a COLA that references a specific SMR design. This is acceptable in a major features emergency plan because the applicant may request approval of only limited parts of one or more of the 16 planning standards in 10 CFR 50.47(b) and requirements of Appendix E to 10 CFR Part 50, pursuant to 10 CFR 52.17(b)(2)(i) and the definition of “major features” in 10 CFR 52.1.

13.3.3.5.6 Notification Methods and Procedures

As reflected in NUREG‑0654, Section II, Planning Standard E, “Notification Methods and Procedures” (NRC 1980-TN512), 10 CFR 50.47(b)(5) (TN249) requires that procedures have been established for notification, by the licensee, of State and local response organizations and for notification of emergency personnel by all organizations; that the content of initial and followup messages to response organizations and the public has been established; and that the means of providing early notification and clear instruction to the populace within the 16 km (10 mi) PEP EPZ have been established. In addition, 10 CFR Part 50, Appendix E, Section IV.A.4 (TN249) requires a description of how offsite dose projections will be made and how the results will be transmitted to State and local authorities, NRC, and other appropriate governmental entities. In addition, 10 CFR Part 50, Appendix E, Section IV.C (TN249) requires a description of EALs and emergency conditions that involve alerting or activating the emergency organization, including communication steps to be taken under each ECL, and the existence of a message-authentication scheme. In addition, 10 CFR Part 50, Appendix E, Section IV.D.1 (TN249) requires a description of the administrative and physical means for notifying local, State, and Federal officials and agencies and agreements reached with these officials and agencies for the prompt notification of the public and for public evacuation or other protective measures. The description shall include identification of the appropriate officials, by title and agency, of the State and local government agencies within the EPZs. In addition, 10 CFR Part 50, Appendix E, Section IV.D.3 (TN249) requires the licensee to have the capability to notify responsible State and local governmental agencies within 15 minutes after declaring an emergency. The licensee shall demonstrate that appropriate governmental authorities have the capability to make a public alerting and notification decision promptly upon being informed by the licensee of an emergency condition, and that administrative and physical means have been established for alerting and providing prompt instructions to the public within the PEP EPZ. The alerting and notification capability shall include a backup method. Finally, 10 CFR 50.72(a)(3) (TN249) requires NRC notification no later than 1 hour after declaring an emergency, and

50.72(a)(4) requires activation of the Emergency Response Data System (ERDS) as soon as possible, but no later than 1 hour, after declaring an emergency class of Alert, Site Area Emergency, or General Emergency.

In ESP Plan Section 5.0, the applicant described notification of ERO personnel and State, county, and Federal agencies during a declared emergency. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG−0654, Section II, Planning Standard E (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(5) (TN249).

ESP Plan Section 5.0 states that emergency measures are developed to aid the mitigation of emergency conditions. Emergency measures begin with the declaration of an emergency class and activation of associated emergency organizations. ESP Plan Section 5.0 describes these measures in general terms for each emergency class, and includes actions for assessment, correction, and protection. Details of these emergency measures are found in the appropriate sections of the CRN-EPIPs. When an emergency is declared, TVA initiates certain predetermined actions based on the emergency classification. Notification is carried out as shown in ESP Plan Figure 5-1, "Chains of Notification," to alert ERO personnel to handle the emergency situation.

ESP Plan Section 5.1, "Onsite," states that upon detection of a known or suspected emergency, the on-duty SM will use a CRN-EPIP to determine the classification of the emergency. After declaring the appropriate emergency classification, the SED will initiate the appropriate procedures referenced by the CRN-EPIP. Each procedure referenced by the CRN-EPIP gives specific instructions for notifying appropriate offsite authorities, the Operations Duty Specialist (ODS), and the NRC. ESP Plan Section 3.3.5, "TVA Operations Duty Specialist," states that the position of ODS is staffed 7 days a week, 24 hours a day. After being notified of an emergency from the CRN Site, the ODS is responsible for making initial notification to the TVA REP Emergency Management Organization. In addition, pursuant to 10 CFR 50.72(a)(4) (TN249), ESP Plan Section A.4.4.5, "Emergency Response Data System," of Appendix A states that the ODS activates the ERDS, which transmits selected plant monitoring data to the NRC, within 1 hour of the declaration of an Alert or higher level emergency classification. (ESP Plan Section 9.2.1 lists CECC-EPIP-2, "Operations Duty Specialist Procedures for Notification of Unusual Event," and CECC-EPIP-3, "Operations Duty Specialist Procedure for Alert, Site Area Emergency, or General Emergency.")

ESP Plan Section 3.3.6, "Emergency Duty Officer," states that the Emergency Duty Officer (EDO) is responsible for establishing initial operation of the CECC in the event the NP-REP is activated at the Alert or higher emergency classification. The EDO is responsible for ensuring that appropriate initial notifications of TVA and offsite emergency organizations have been made for each ECL. (ESP Plan Section 9.2.1 lists CECC-EPIP-21, "Emergency Duty Officer Procedure for Notification of Unusual Event, Alert, Site Area Emergency, and General Emergency"; and ESP Plan Section 4.0 describes the emergency classification and action level scheme, which is discussed in Section 13.3.3.5.5 of this chapter.)

ESP Plan Section 5.2, “Offsite,” states that implementing procedures are provided to activate emergency staffs. Essential emergency positions are covered on a 24-hour-a-day basis by duty personnel. Emergency response facilities are located to ensure rapid and effective response of personnel.

The applicant described the actions that TVA will initiate for the four ECLs in ESP Plan Sections 5.2.1, 5.2.2, 5.2.3, and 5.2.4. TVA will notify and relay information to the State within 15 minutes of the declaration of an ECL. TVA uses a dedicated “ring-down” phone to make the notifications, and has an available commercial telephone line as a backup method. TVA will notify the NRC immediately after notifying the State, but not later than 1 hour after the emergency declaration is made. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIPs entitled “Notifications Associated with Emergency Conditions,” and “Activation of the Emergency Response Organization.”) TVA initiates additional actions, consisting of the following:

- The ODS in Chattanooga, Tennessee, is notified of the event by the Control Room and records the details of the event in accordance with the appropriate EPIP. (ESP Plan Section 9.2.1 lists CECC-EPIP-2, “Operations Duty Specialist Procedure for Notification of Unusual Event,” and CECC-EPIP-3, “Operations Duty Specialist Procedure for Alert, Site Area Emergency, or General Emergency.”)
- The ODS notifies and relays the information to the EDO and CECC Director, and the EDO keeps the CECC Director and the Public Information Manager informed of the situation, as necessary. (ESP Plan Section 9.2.1 lists CECC-EPIP-21, “Emergency Duty Officer Procedure for Notification of Unusual Event, Alert, Site Area Emergency, and General Emergency.”)
- The Public Information Manager notifies the Site Communications Consultant, Director, Public Relations & Corporate Information, and the TVA News Bureau (Knoxville, Tennessee). (The distribution of information to the public is addressed in ESP Plan Section 7.0, “Public Information and Education,” and discussed in Section 13.3.3.5.8 of this chapter. ESP Plan Section 9.2.1 lists CECC-EPIP-14, “Nuclear Emergency Public Information Organization and Operations.”)
- The SED augments plant on-shift personnel, as necessary, to initiate corrective actions. (ESP Plan 5B, Section 5.2.1.G [TVA 2017-TN5442] includes the initiation of corrective or protective actions.)

For an Alert or higher classification, TVA will update the State agencies hourly (or more often, as necessary) through the CECC about appropriate plant status and environmental conditions (as listed in ESP Plan Section 5.2.2). ESP Plan 5B, Section 5.2.2.F includes an additional condition, which consists of the projected dose rates and integrated dose at about 0.5, 1, and 2 mi (TVA 2017-TN5442). For the Site Area Emergency and General Emergency, ESP Plans 5A (TVA 2017-TN5443) and 5B (TVA 2017-TN5442) include various differences that reflect the existence of a PEP EPZ beyond the site boundary for the ESP Plan 5B.

Specifically, ESP Plan Section 5.2.3 states that upon declaration of the Site Area Emergency classification, personnel knowledgeable of plant systems are dispatched to the SEOC. ESP Plan 5A, Section 5.2.3.B adds that the personnel will be dispatched to the SEOC “if determined appropriate by the CECC Director and if offsite officials elect to activate the SEOC” (TVA 2017-TN5443). In addition, ESP Plan 5B, Section 5.2.3.C states that the CECC recommends appropriate protective actions for the public to State agencies (TVA 2017-TN5442). In contrast, ESP Plan 5A, Section 5.2.3.C (TVA 2017-TN5443) states the following:

> Upon declaration of this classification . . . [s]ufficient information relative to the plant status, radiological impacts, and protective measures is made available to government officials to enable them to implement ad hoc protective measures (in accordance with a CEMP) for the protection of the public should they be determined appropriate by offsite officials.

ESP Plan 5B, Section 5.2.4 states that "[a]ppropriate PARs to the State are required upon declaration of General Emergency," and "[i]f this is the initial classification, the Control Room notifies the local government agencies within 15 minutes and provides the PARs" (TVA 2017-TN5442). In contrast, ESP Plan 5A, Section 5.2.4.B (TVA 2017-TN5443) states the following:

> Upon declaration of this classification . . . [i]f this is the initial classification, the Control Room notifies the local government agencies within 15 minutes. Performance of Subsection 5.2.2, Step 6, enables government officials to implement ad hoc protective measures for protection of the public per a CEMP should they be determined appropriate by offsite officials.

With regard to PARs, ESP Plans 5A (TVA 2017-TN5443) and 5B (TVA 2017-TN5442) include additional differences in ESP Plan Section 3.3.1 that are associated with the CECC Director's responsibilities. Specifically, ESP Plan 5B states that the CECC Director has overall responsibility and authority for ensuring adequate TVA response, adding that this response is "to affected State/local governments in protecting the health and safety of the public" (TVA 2017-TN5442). In addition, the CECC Director "[m]akes Protective Action Recommendations (PARs) to the State." In contrast, ESP Plan 5A, Section 3.3.1 (TVA 2017-TN5443) states the following:

> The CECC Director . . . [e]nsures sufficient information relative to the plant status, radiological impacts, and protective measures is made available to government officials to enable them to implement ad hoc protective measures (in accordance with a CEMP) for the protection of the public should they be determined appropriate by offsite officials.

(The responsibilities of the CECC Director are discussed further in Section 13.3.3.5.2 of this chapter.) Additional information is provided in ESP Plan Section 9.2.1, which includes differences between ESP Plans 5A and 5B, and addresses timely notifications by the CECC, including messages that contain PARs for the public. Specifically, ESP Plan 5A, Section 9.2.1 states that "TVA maintains the capability to assess the consequences of potential or actual releases of radioactivity offsite. If determined appropriate by State and local agencies, protective actions for the protection of the public may be implemented using an all hazards approach to emergency planning" (TVA 2017-TN5443). In contrast, ESP Plan 5B, Section 9.2.1 (TVA 2017-TN5442) states the following:

> TVA and State agencies are prepared to assess the consequences of potential or actual releases of radioactivity offsite. State and local agencies implement protective actions for the public. Written messages have been prepared which give the public instructions with regard to specific protective actions to be taken by occupants of affected areas. These messages are included in the State Plan referenced in Appendix A, Attachment 1.

ESP Plan Section 9.2.1 further states that implementing procedures have been developed for the CECC to ensure that emergencies are properly evaluated, timely notifications are made,

and assessment and protective actions are performed. Once an SMR technology is selected, the details of staffing levels, response times, and accident progression rates will be known and can be reflected in a set of EPIPs (similar to the CECC-EPIP list in ESP Plan Section 9.2.1). (See Section 13.3.3.5.17 of this chapter.) Activation and staffing of the emergency facilities, including staff-identified COL Action Items, are addressed in ESP Plan Sections 3.2 and 3.3 (discussed in Section 13.3.3.5.3 of this chapter), and ESP Plan Section 8.0, "Emergency Response Facilities, Equipment, and Supplies" (discussed in Section 13.3.3.5.9 of this chapter). Accident assessments are addressed in ESP Plan Section 9.0 and discussed in Section 13.3.3.5.10 of this chapter.

ESP Plan 5B, Section 8.5, "Alert and Notification System" (TVA 2017-TN5442), states that information regarding the CRN Site ANS is provided in ESP Plan Appendix A, and that additional details describing the CRN Site ANS will be addressed in the CRN Site COLA. (In contrast, ESP Plan 5A (TVA 2017-TN5443) does not include a comparable Section 8.5.) ESP Plan 5B, Section A.6, "Alert and Notification System" (TVA 2017-TN5442), states that the network consists of one or more alerting and notification systems. Various technologies may be employed as TVA and the affected State and local agencies assess and consider these technologies. The ANS network is under the control of the State or local emergency management agencies. The systems are designed to provide alert signals and instructional messages to the population within the PEP EPZ of the CRN Site within 15 minutes of the decision to notify the public. In contrast, the applicant stated that ESP Plan 5A, Section A.6 is not applicable (TVA 2017-TN5443). Consistent with the applicant's intention to assess various technologies associated with the ANS network (described above), the NRC staff identified the following COL Action Item.

- <u>COL Action Item 13.3-5</u>: An applicant for a COL or CP that references this ESP, including the Part 5B Emergency Plan (2-Mile Emergency Planning Zone [EPZ]), should update the emergency plan to describe the chosen Alert and Notification System (ANS) network(s), which reflects the assessment of the various technologies by TVA and the affected State and local agencies, and meets the applicable requirements and guidance.

13.3.3.5.6.1 <u>Conclusion</u>

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG-0654, Section II, Planning Standard E (NRC 1980-TN512). A COL or CP applicant will address COL Action Item 13.3-5. Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(5) (TN249), 10 CFR 50.72(a)(3) (TN249), 10 CFR 50.72(a)(4) (TN249), and 10 CFR Part 50, Appendix E, Sections IV.A.4, IV.C, IV.D.1, and IV.D.3 (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.7 Emergency Communications

As reflected in NUREG-0654, Section II, Planning Standard F, "Emergency Communications" (NRC 1980-TN512), 10 CFR 50.47(b)(6) (TN249) requires that provisions exist for prompt communications among principal response organizations, to emergency personnel, and to the public. In addition, 10 CFR Part 50, Appendix E, Section IV.E.9 (TN249) requires onsite and offsite communication systems with backup power sources, including provisions for communications with State and local governments within the plume exposure EPZ, and Federal EROs and the NRC. Also required are provisions for communications among the Control

Room, TSC, EOF, principal State and local EOCs, and field assessment teams. Communication systems shall be tested at designated frequencies.

In ESP Plan Section 6.0, the applicant described the provisions used for radiological emergency communications. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG-0654, Section II, Planning Standard F (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(6) (TN249).

ESP Plan Section 6.0 states that the radiological emergency communications network consists of the EP telephone system, the EP notification system, and the EP radio system. These systems are designed to complement each other in the overall plan for REP communications. The communications facilities described in ESP Plan Section 6.0 are integrated with the requirements for communications to local and State response organizations. TVA conducts testing of these systems in accordance with established procedures.

The EP telephone system includes communications equipment installed at the CRN Site and the CECC, a number of leased commercial circuits, and privately owned circuits connecting the CRN Site to the required locations. The telephone switching equipment installed at the CRN Site consists of one or more switching centers equipped with fully redundant common logic and redundant power sources. The majority of plant telecommunications services are served from this switching equipment. ESP Plan Section 6.3, "Plant or Building Loudspeaker Paging," states that the paging system(s) may be accessed from the plant telephone system, and is used for normal plant operations (plant paging) and to instruct and notify personnel during an emergency.

ESP Plan Section 6.6, "TVA Enterprise Emergency Notification System" (TEENS), states that TEENS is a hosted notification system that notifies Emergency Management Organization personnel by contacting devices such as assigned office, mobile, and home telephones; work e-mail; and assigned pagers. TEENS is an automated system that is used to notify key TVA personnel during nuclear emergencies, and has provisions to periodically monitor its own performance to detect and report equipment failures.

The EP radio system is a very high frequency (VHF) mobile radio system that provides redundant radio coverage. ESP Plan 5B further states that the EP radio system provides redundant radio coverage of the PEP EPZ (TVA 2017-TN5442). In addition, the EP radio system provides radiological monitoring vehicles with mobile communications to other vehicles, and to Radiation Protection at the CRN Site, TSC, Control Room, and the CECC.

ESP Plan Section 6.8, "Other Radio Communications," states that Nuclear Security Services uses an in-plant repeater system, which enables transmission without interruption to various areas of the plant. A separate radio located in the plant Central Alarm Station is a direct link to the local law enforcement agency officials. The plant ambulance has a radio used for communication with the local hospitals and the plant. Portable two-way radios are available for additional site communications.

ESP Plan Section 6.4, "Offsite Telephone Communications," states that the offsite communications network is used to communicate with Federal, State, and other supporting

agencies. Access to these agencies is provided through several redundant, diverse routes. This diversity provides offsite routing through more than one type of facility. These facilities include, but are not limited to commercial facilities, such as central office trunks, tie-lines and digital services, plus privately owned and maintained microwave and fiber-optic systems. The offsite telecommunications network is designed to facilitate management of communications in the most fail-safe manner to EROs. Telecommunications services are provided between the following locations in a redundant, diverse manner:

- CECC to State Emergency Management Agencies.
- CECC to the CRN Site.
- State Emergency Management Agencies to County Emergency Management Agencies.

In addition to the above listed emergency organizations, the JIC(s) and Field Coordination Center(s) are also equipped with public telephone lines. Finally, ENS and HPN (NRC FTS 2000 System) telephones provide communications from the TSC, Control Room, and the CECC to the NRC Headquarters and regional offices. CRN-EPIPs designate personnel who staff the ENS and HPN telephones. CRN-EPIPs also designate the interface with the NRC during TSC operation. TVA performs testing of these telephones on a monthly basis. In addition, ESP Plan Section 14.1.7, “Communication Drills,” states that communications drills are conducted at least once each calendar year at the CRN Site.

ESP Plan Section A.3, of Appendix A, states that the on-shift staff is continually present on a 24-hour basis, and ESP Plan Section 5.2 states that essential emergency positions are covered on a 24-hour-a-day basis by duty personnel. Organizational titles associated with communications are identified in ESP Plan Section 3.2, which states that the CRN Site is staffed on a continual 24-hour basis, and that emergency communications/notifications with State, local and Federal agencies, along with staffing instructions for the emergency response facilities, are specified in CRN-EPIPs. (The staff’s review of the onsite organization is included in Section 13.3.3.5.3 of this chapter.)

The staff’s review of CRN Site staffing is included in Sections 13.3.3.5.2 and 13.3.3.5.3 of this chapter. In addition, initial and follow-up notification is addressed in ESP Plan Section 5.0, and discussed in Section 13.3.3.5.6 of this chapter. Section A.8 of ESP Plan Appendix A lists the following CRN-EPIP topics associated with emergency staffing and emergency notifications:

- Notification Associated with Emergency Conditions,
- Emergency Communications,
- Activation of the Emergency Response Organization, and
- Staffing and Operation of Emergency Response Facilities.

In Section A.4.5.1, “Emergency Communications Equipment,” of ESP Plan Appendix A, the applicant stated that “[i]nformation regarding the CRN Site Emergency Communications Equipment [will be] addressed in the CRN Site COLA.” The staff understands from past new reactor licensing reviews that the design details associated with such equipment is usually dependent upon the specific reactor technology. As such, the staff identified the following COL Action Item to address the emergency communications equipment for the chosen SMR technology:

- <u>COL Action Item 13.3-6</u>: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the CRN Site Emergency Communications Equipment, including all required communications and data links, associated with the chosen SMR technology, consistent with the applicable regulations and guidance.

13.3.3.5.7.1 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG‑0654, Section II, Planning Standard F (NRC 1980-TN512). A COL or CP applicant will address COL Action Item 13.3-6. Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(6) (TN249) and 10 CFR Part 50, Appendix E, Section IV.E.9 (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.8 Public Education and Information

As reflected in NUREG‑0654, Section II, Planning Standard G, "Public Education and Information" (NRC 1980-TN512), 10 CFR 50.47(b)(7) (TN249) requires that information be made available periodically to the public concerning notification methods and initial actions the public should take in an emergency (e.g., listening to a local broadcast station and remaining indoors), that the principal points of contact with the news media for dissemination of information during an emergency (including the physical location or locations) be established in advance, and that procedures for coordinating dissemination of information to the public be established. In addition, 10 CFR Part 50, Appendix E, Section IV.D.2 (TN249) requires a description of provisions for yearly dissemination to the public within the PEP EPZ of basic EP information, such as methods for public notifications and protective actions planned if an accident occurs, general information about the nature and effects of radiation, and a list of local broadcast stations that will be used for dissemination of information during an emergency. Signs or other measures shall also be used to disseminate information to any transient population within the PEP (16 km [10 mi]) EPZ.

In ESP Plan Section 7.0, the applicant described the TVA emergency public information and education program. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG‑0654, Section II, Planning Standard G (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(7) (TN249).

ESP Plan Section 7.1, "Purpose," states that the purpose of the TVA emergency public information and education program is to ensure timely distribution of accurate information during an emergency, in accordance with applicable EPIPs. The program also provides for TVA to coordinate emergency information with non-TVA agencies that have a primary response role prior to its release to the public or news media. The program provides for a JIC to be established for use during an emergency. The purpose of the JIC is to provide a single location for TVA, local, State, and Federal agencies to coordinate public information activities. TVA and the State conduct coordinated annual orientations to acquaint the local area news media with the emergency plans, radiological information, and points of contact for release of information in an emergency. ESP Plan Section 8.4, "Joint Information Center," states that the CRN Site has a JIC established near the site to assist the news media in providing press coverage during an emergency, and that the location, function, and capabilities of the CRN Site JIC will be addressed in the CRN Site COLA. Consistent with the applicant's stated intention to identify the JIC in the COLA, the staff identified the following COL Action Item:

* COL Action Item 13.3-7: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location, function, and capabilities of the Joint Information Center (JIC), consistent with the applicable regulations and guidance.

ESP Plan Section 7.2, "Responsibilities," addresses the responsibilities of the offsite emergency organization performing public information functions. The CECC Director (or delegate) is responsible for approving written news statements after the CECC is activated. ESP Plan Section 9.2.1 lists CECC-EPIP-14, "Nuclear Emergency Public Information Organization and Operations." The JIC Spokesperson is responsible for representing TVA during news briefings, and coordinating information with other Federal, State, and local spokespersons prior to the briefings. The Director of Public Relations & Corporate Information is responsible for directing emergency public information activities of the agency, in accordance with approved procedures. ESP Plan Section A.8 of Appendix A lists a CRN-EPIP topic, entitled "Emergency Media Relations," which addresses the responsibility for coordinating with the CECC Director and non-TVA agencies, who would participate in JIC activities, and determining when to activate or deactivate the JIC. Finally, Operations Communications is responsible for the development, implementation, and maintenance of nuclear public information organizations and activities for an emergency, as well as those nuclear public information programs conducted on an annual basis.

ESP Plan Section 7.3, "Public Information Facilities," states that public information personnel are present at three locations with sufficient staff available to maintain operations on a 24-hour basis: (1) Operations Communications, which directs the activities of the emergency public news media present at the site; (2) the CECC in the Chattanooga Office Complex (COC), where staff develops news releases and coordinates the news releases with offsite agencies; and (3) the JIC, where staff coordinates with the offsite agencies in presenting emergency news briefings and respond to public telephone inquiries.

ESP Plan Section 7.4, "Coordination of Information," states that prior to activation of the CECC, coordination of public information with non-TVA primary response agencies is handled through Operations Communications, in accordance with emergency public information procedures. Upon activation and staffing of the CECC, the responsibility for coordination of public information with non-TVA agencies shifts to the CECC Information Staff. Upon JIC activation, the responsibility for coordination of public information shifts from the CECC to the JIC emergency response staff when, and if, offsite agencies are also operational at the JIC. The CECC Director continues to approve written news statements. Non-TVA primary response agencies are provided copies of written news statements until they are available to support coordination in the JIC.

Under ESP Plan Section 3.3, "Offsite Organization," TVA described the responsibilities of the JIC Liaison in ESP Plan Section 3.3.14, "JIC Liaison." The JIC Liaison contacts responding agencies, transmits information for coordination, and establishes and maintains an information flow from the JIC or Site Communications to the CECC. In addition, ESP Plan Section 3.3.13 lists the following overall responsibilities of the Public Information Manager.

* Coordinates the decision to activate the JIC with the CECC Director, Director – Public Relations & Corporate Information, and SEOC, if offsite officials elect to activate the SEOC.
* Ensures the JIC Spokesperson and the JIC Information Staff are provided information to inform the public and news media in response to an emergency.
* Informs the CECC Director of TVA public information activities, in response to an emergency.

- Coordinates news release drafts with the State and Federal agencies participating at the JIC, and secures approval of the CECC Director prior to making a release to the media.
- Coordinates the decision to establish the JIC with the SEOC.
- Directs the activities of support personnel who develop public information and maintain information flow into, and from, the JIC.

ESP Plan Section 7.5, “Public Education,” states that TVA coordinates development and distribution of public education materials and programs with the appropriate State agencies. In ESP Plan 5B, TVA described additional actions that will be taken with regard to the 2 mi PEP EPZ (TVA 2017-TN5442). Specifically, the public information and education program also provides education to the public located within the PEP EPZ about emergency plans. On an annual, non-emergency basis, the program provides that TVA, in coordination with the State, disseminates information to the public regarding emergency notification methods and actions. In addition, TVA will distribute within the 2 mi PEP EPZ, on an annual basis, public information about actions the permanent and transient populations should take in the event of an emergency. Mailing lists for the public in the PEP EPZ are updated annually to assure thorough and accurate distribution of the emergency information.

In ESP Plan Section 7.7, “Rumor Control/Public Information,” TVA described its coordinated arrangements for dealing with rumors. Specifically, teams in the JIC are responsible for emergency information. A trained media relations team responds to news media inquiries by telephone and media briefing, and a trained information team responds to citizen telephone inquiries. Also in the JIC, a trained media monitoring team monitors news media coverage. TVA coordinates information activities with offsite agencies at the JIC.

ESP Plan Section 7.6, “Employee Communications,” states that an information system that employees can access provides a method of informing TVA employees, who do not have emergency response assignments, about an emergency. Finally, ESP Plan Section 7.8, “Training,” states that TVA provides initial training and annual retraining to emergency public information staff to allow them to respond to an emergency.

13.3.3.5.8.1.1 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG-0654, Section II, Planning Standard G (NRC 1980-TN512). A COL or CP applicant will address COL Action Item 13.3-7. Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(7) (TN249) and 10 CFR Part 50, Appendix E, Section IV.D.2 (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.9 Emergency Facilities and Equipment

As reflected in NUREG-0654, Section II, Planning Standard H, “Emergency Facilities and Equipment” (NRC 1980-TN512), 10 CFR 50.47(b)(8) (TN249) requires that adequate emergency facilities and equipment to support the emergency response be provided and maintained. In addition, 10 CFR Part 50, Appendix E, Section IV.E.8 (TN249) requires that adequate provisions be made and described for emergency facilities and equipment, including a licensee’s onsite OSC and TSC, as well as an EOF from which effective direction can be given and effective control can be exercised during an emergency. 10 CFR Part 50, Appendix E, Section IV.E.8.b (TN249) addresses various requirements associated with an EOF located more

than 25 mi from a nuclear power reactor site. 10 CFR Part 50, Appendix E, Section IV.E.8.c (TN249) requires various EOF capabilities, which include supporting response to multiple reactors/sites and simultaneous events, as applicable. 10 CFR Part 50, Appendix E, Section IV.E.8.d (TN249) requires an alternative facility (for use when onsite emergency facilities cannot be safely accessed during hostile actions) that would be accessible and could function as a staging area for augmentation of emergency response staff. In addition, 10 CFR Part 50, Appendix E, Section IV.G (TN249) requires a description of provisions to be employed to ensure that the emergency plan, its implementing procedures, and emergency equipment and supplies are maintained up to date.

In the following ESP Plan sections, the applicant described the functions and locations of the emergency response facilities and equipment that will be used and maintained by TVA in coordinating and performing emergency response activities:

- ESP Plan Section 3.3, “Offsite Organization,”
- ESP Plan Section 6.0, “Communications,”
- ESP Plan Section 8.0, “Emergency Response Facilities, Equipment, and Supplies,”
- ESP Plan Section 9.0, “Accident Assessment,”
- ESP Plan Section 11.0, “Radiological Protection,”
- ESP Plan Section A.4, “Emergency Response Facilities, Equipment, and Supplies,” of Appendix A,
- ESP Plan Section A.8, “Emergency Plan Implementing Procedures,” of Appendix A, and
- ESP Plan Appendix A, Attachment 2, “Emergency Equipment and Supplies.”

The staff reviewed these sections, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff’s primary focus was to evaluate the emergency plan against NUREG-0654, Section II, Planning Standard H (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(8) (TN249).

ESP Plan Section A.4.4, “Onsite Monitoring Systems and Equipment,” of Appendix A briefly describes various area and process (radiological and nonradiological) monitoring systems and equipment, and states that information regarding onsite monitoring systems and equipment will be addressed in a COLA. In addition, ESP Plan Section A.4.4.2, “Radiological Monitors,” of Appendix A states that the installed Radiation Monitoring System consists of process monitors and area monitors, and that additional information regarding this system will be addressed in the CRN Site COLA. Radiological protection is addressed in ESP Plan Section 11.0 and discussed in Section 13.3.3.5.12 of this chapter. Consistent with the applicant’s stated intention to address the onsite monitoring systems and equipment in the COLA, the staff identified the following COL Action Item:

- <u>COL Action Item 13.3-8</u>: An applicant for a COL or CP that references this ESP should update the emergency plan to describe onsite monitoring systems and equipment, including the installed Radiation Monitoring System, consistent with the applicable regulations and guidance.

ESP Plan Section A.4.4.6, “Fire Protection,” of Appendix A states that the plant’s fire protection system provides extinguishing agents with the capability of extinguishing any single or probable combination of simultaneous fires that might occur, and that TVA controls the use of combustible materials.

ESP Plan Section A.4.4.1, “Natural Phenomena,” of Appendix A states that in the event an emergency is the result of a natural phenomenon, there is instrumentation to monitor its severity. The Environmental Data Station is located onsite and contains instruments capable of measuring wind direction, wind speed, and temperatures. ESP Plan Section 9.2.4, “Meteorological Information,” states that TVA has developed the meteorological measurements program to conform to the intent and guidance of RG 1.23, “Meteorological Monitoring Programs for Nuclear Power Plants” (NRC 2007-TN278), and provides a brief description of access to, and use of, meteorological data. In addition, the applicant stated that more specific information about the meteorological measurements program can be found in Section 2.3, “Meteorology,” of the CRN SSAR (i.e., ESPA Part 2) (TVA 2017-TN5387).

Seismic instrumentation is available in the plant to monitor acceleration levels of ground movement. Hydrological monitoring systems are installed to supply the flow and level information. Meteorological and seismic instrumentation have accessible readout in the Control Room. In the event of a failure of the onsite natural phenomena monitoring systems, TVA maintains access to backup data sources. These backup sources include telephone and web-based contact with Federal government data sources and alternate sources, including university and news media sources. Additional seismic and hydrological information can be obtained by the CECC from other TVA nuclear plants or the TVA water quality organization.

ESP Plan Section A.4.4.3, “Process Monitors (Non-radiological),” states that the Control Room provides a central, protected location for placement of the necessary instrumentation to assess plant systems status, including reactor coolant system pressure and temperature, containment pressure and temperature, liquid levels, flow rates, fire detection equipment, and meteorological instrumentation.

ESP Plan Section A.4.5, “Emergency Equipment,” of Appendix A states that the CRN Site maintains supplies of emergency equipment located in designated storage locations. The CRN Site implements site-specific procedures to ensure required calibrations are carried out on a routine basis. ESP Plan Appendix A, Attachment 2 provides additional information regarding emergency equipment and supplies, and indicates that TVA establishes and maintains inventories of emergency equipment and supplies for use by emergency response personnel in the emergency response facilities, and by TVA offsite field monitoring teams. (Onsite and offsite radiological monitoring systems, equipment, and teams are addressed in Sections 13.3.3.5.10 and 13.3.3.5.12 of this chapter.) The actual inventories are based on the activities that occur in, or are dispatched from, each individual facility, and are established in inventory lists in accordance with EPIPs. Section A.8 of ESP Plan Appendix A lists a supporting plant procedure entitled “Emergency Equipment and Communications Systems inventory and Operational Tests.” In addition, Section A.8 lists the following three CRN-EPIP topics associated with emergency facilities and equipment:

- Staffing and Operation of Emergency Response Facilities,
- Activation of the Emergency Response Organization, and
- Emergency Communications.

Finally, ESP Plan Section 8.1.5, “Equipment, Supplies, and Supplemental Data,” states that the CRN Site has sufficient equipment and supplies for the operation of the site emergency response facilities.

13.3.3.5.9.1 <u>*Control Room*</u>

As described in Section 1.2, “Control Room,” of NUREG‑0696 (NRC 1981-TN5966), the Control Room is the onsite location from which the NPP is operated. During abnormal operating conditions, the complexity of licensee responsibilities increases significantly, and the Control Room personnel must assume all of these responsibilities until additional onsite and offsite staff and facilities are activated to assume various emergency response actions. Additional Control Room responsibilities are described in NUREG‑0737, Supplement 1 (NRC 1983-TN5967).

While the ESP Plan does not include a separate section that addresses Control Room responsibilities and actions during an emergency at the CRN Site, the specific Control Room support of the overall site response, including interfaces with the other emergency response facilities and personnel, are addressed throughout the ESP Plan, and discussed in the respective sections of this chapter.

13.3.3.5.9.2 <u>*Technical Support Center*</u>

ESP Plan Section 8.1.1, “Technical Support Center,” states that the CRN Site has a TSC, which is dedicated for use during an emergency. Once activated, the TSC is the focal point of onsite activity, and is the primary source of communication from the site with offsite organizations during the event. The TSC has sufficient staff to provide management control of the site response to the event. Equipment is available to enable the TSC staff to communicate with onsite and offsite TVA emergency personnel. An area within the TSC is dedicated for NRC use, which includes commercial telephones and the NRC Federal Telecommunications System (FTS) 2000 System telephones. (Emergency communications are addressed in ESP Plan Section 6.0, and discussed in Section 13.3.3.5.7 of this chapter.) Sufficient plant parameter information is available to enable the TSC staff to assess the consequences of an event and assist the Control Room personnel in mitigating the emergency.

ESP Plan 5B further states that “[s]ufficient information is transmitted to the CECC to enable the CECC Director to make PARs to State authorities” (TVA 2017-TN5442). The TSC is activated during radiological emergencies, in accordance with CRN-EPIPs, which also describe the staffing and operation of the TSC. The degree of activation varies depending upon the emergency class. (The emergency classification system is addressed in ESP Plan Section 4.0, and discussed in Section 13.3.3.5.5 of this chapter.) Additional information regarding the TSC is provided in ESP Plan Appendix A.

ESP Plan Section A.4.1, “Technical Support Center,” of Appendix A states that the TSC is established consistent with NUREG‑0696 (NRC 1981-TN5966) and describes the following guidance associated with the TSC.

- <u>Function</u> – The TSC provides plant management and technical support personnel (including the appropriate number of NRC personnel) with a facility from which they can assist plant operating personnel located in the Control Room during an emergency. The SED and the NRC representative are located in the same general area to promote proper communications.

- Location – The TSC has the ability to retrieve plant data and displays available in the Control Room, and is equipped with sophisticated communications systems. This precludes the need for frequent face-to-face interchange between the TSC and Control Room personnel.
- Staffing and Training – The level of staffing and training is described in the Emergency Plan. The TSC accommodates the required personnel to support an emergency affecting the CRN Site. The level of staffing may vary according to the severity of the emergency condition.
- Size – The TSC provides working space, without crowding for the personnel assigned to the TSC at the maximum level of occupancy. The working space is sized for a minimum of 25 persons. The minimum size of working space is approximately 75 ft^2 per person.
- Structure – The TSC is designed in accordance with the Uniform Building Code to withstand earthquakes and high winds.
- Habitability – The ventilation system is operated in accordance with approved procedures, and is manually controlled from the TSC. In addition, portable radiation monitors are available to personnel in the TSC. Equipment and supplies are provided in accordance with the Emergency Plan. The ventilation system includes high-efficiency particulate air filters and charcoal filters. The ventilation system is designed to maintain exposures at or below 5 rem (0.05 Sv) TEDE, as defined in 10 CFR 50.2 (TN249), for the duration of an emergency. The TSC structure, shielding, and ventilation system are designed to protect the TSC personnel from radiological hazards.
- Communications – The TSC has reliable voice communications to the Control Room, the OSC, the CECC, and the NRC. Provisions for communications with State and local operations centers are also available in the TSC. The communications facilities include the means for reliable primary and backup communication. (Emergency communications is addressed in ESP Plan Section 6.0 and discussed in Section 13.3.3.5.7 of this chapter.)
- Instrumentation, Data System Equipment, and Power Supplies – The TSC is provided with reliable power and backup power supplies. Lighting is powered by the normal and backup electrical supply system. An emergency battery-operated lighting system is installed. Power for vital information systems is provided by reliable power supplies, including a battery-backed Uninterruptible Power Supply (UPS) system.
- Technical Data and Data System – Within the TSC, technical and operational data and information are available for each unit. Support facilities are located within the TSC to support long-term operation of the TSC. The TSC is equipped with a computer system, which provides source term and meteorological data, and technical data displays to allow TSC personnel to perform detailed analysis and diagnosis of abnormal plant conditions, including assessment of any significant release of radioactivity to the environment. Human factors engineering is incorporated into the design of the TSC, related to the display and availability of plant data.
- Records Availability and Management – The TSC has ready access to plant records. The documents maintained in the TSC include Technical Specifications; plant and emergency operating procedures; the FSAR; system piping and ventilation diagrams; heating, ventilation, and air-conditioning flow diagrams; piping area diagrams; and records needed to perform the functions of the CECC when it is not operational. All of these documents, as well as plant operating records and Plant Review Board records and reports, are available in CRN Site Document Control, and are updated, as necessary.

The staff reviewed this description of the TSC and determined that the ESPA does not address all of the relevant criteria in NUREG-0696 (NRC 1981-TN5966) and Supplement 1 to NUREG-0737 (NRC 1983-TN5967). Specifically, the applicant did not address the emergency classification requiring TSC activation, and the time frame for designated personnel to report to the TSC and achieve full functional operation. A partial TSC description is acceptable in a major features emergency plan because the applicant may request approval of only limited parts of one or more of the 16 standards in 10 CFR 50.47(b), pursuant to 10 CFR 52.17(b)(2)(i) and the definition of “major features” in 10 CFR 52.1. Therefore, the staff identified the following COL Action Item:

- COL Action Item 13.3-9: An applicant for a COL or CP that references this ESP should update the emergency plan to describe how the criteria in Section 2 of NUREG-0696 and Section 8 of Supplement 1 to NUREG-0737 are met for the TSC, including the emergency classification requiring activation and the time frame for designated personnel to report to the TSC and achieve full functional operation.

13.3.3.5.9.3 Operations Support Center

ESP Plan Section 8.1.2, “Operations Support Center,” states that the CRN Site has an OSC, which is a pre-designated area for the assembly of personnel to support the Control Room Operations crew during an emergency. The OSC area is under the control of the SED in the Control Room until the TSC is staffed, and will provide damage assessment, maintenance and repair services, and necessary technical services. Communications with the TSC are available. The OSC also establishes and maintains appropriate communications with any teams that may enter the plant for assessment or repair. Respiratory protective devices, protective clothing, portable lighting, other protective equipment and tools are available in the OSC, as needed. The OSC is activated during radiological emergencies, in accordance with CRN-EPIPs. Additional information regarding the OSC is provided in ESP Plan Appendix A.

ESP Plan Section A.4.2, “Operations Support Center,” of Appendix A states that designated plant support personnel assemble in the OSC to provide support to both the Control Room and TSC. The primary function of the OSC staff is to dispatch assessment, corrective action, and rescue personnel to locations in the plant, as directed by the TSC and Control Room. TVA provides for an OSC assembly area separate from the Control Room and the TSC. Personnel reporting to the OSC can be assigned duties in support of emergency operations. The OSC is not designed to remain habitable under all projected emergency conditions; however, implementing procedures make provisions for relocating the OSC, as needed, based on ongoing assessments of plant conditions and facility habitability. The SED directs relocation of the OSC, if required. CRN-EPIPs describe the staffing and operation of the OSC. The applicant did not identify the specific OSC location in the ESPA. Therefore, the staff identified the following COL Action Item:

- COL Action Item 13.3-10: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location of the Operations Support Center (OSC) and communications capabilities consistent with Section 3.3 of NUREG-0696.

13.3.3.5.9.4 Local Recovery Center

ESP Plan Section 8.1.3, “Local Recovery Center,” states that the CRN Site has a Local Recovery Center (LRC), which is a pre-designated facility dedicated for use by offsite TVA and NRC personnel that may be assigned to the CRN Site for recovery operations. The NRC has the capability to communicate offsite, and the LRC may be used by the NRC during the event as

an area near the site for assessment and assistance. Personnel in the LRC have access to necessary drawings and documents, including meteorological information. The LRC may serve as an alternate emergency response facility, as needed, and during an emergency it may be used as a staging location for personnel prior to dispatch to the CRN Site.

ESP Plan Appendix A, Section A.4.8, "Local Recovery Center," of Appendix A states that the LRC may be used by the NRC during an emergency event as an area near the site for assessment and assistance, and that it has the capability to communicate offsite. In addition, personnel in the LRC have access to necessary drawings, manuals, procedures and documents. Meteorological information and dose rate calculations are available in the LRC. The LRC has telephone communications capabilities to enable personnel to communicate with the CECC and the CRN Site TSC. The LRC is able to send and receive data, and document production/reproduction equipment is available. The location, function, and capabilities of the LRC will be addressed in the CRN Site COLA. Consistent with the applicant's stated intention for the LRC, the staff identified the following COL Action Item:

- COL Action Item 13.3-11: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location, function, and capabilities of the Local Recovery Center (LRC). In addition, the applicant should describe how the LRC meets the applicable requirements in Sections IV.E.8.b and IV.E.8.d of Appendix E to 10 CFR Part 50, and the criteria in Sections IV.D and IV.I of NSIR/DPR-ISG-01.

13.3.3.5.9.5 Central Emergency Control Center

ESP Plan Section 8.2, "Central Emergency Control Center," states that the purpose of the CECC and associated CECC staff is to provide the facilities and manpower for evaluating, coordinating, and directing the overall activities involved in coping with a radiological emergency. The specific response time for staffing the CECC will be determined as a result of evaluating the specific accident sequences and included in the COLA. ESP Plan Section 3.3 states that activation for the CECC is accomplished within a prescribed time following declaration of an Alert or higher emergency classification at the CRN Site, depending upon time of day, weather conditions, or immediate availability of personnel. The prescribed activation time for the CECC for an event at the CRN Site will be addressed in a COLA. (Emergency notification and activation of the emergency organization is addressed in ESP Plan Section 5.0, and discussed in Section 13.3.3.5.6 of this chapter.)

ESP Plan 5A, Section 8.2 states that during an emergency, the CECC Director and staff will review the response to the emergency by TVA to ensure an effective response (TVA 2017-TN5443). Additionally, the CECC Director and staff ensure that appropriate information is communicated to governmental officials. In contrast, ESP Plan 5B, Section 8.2 states that the CECC Director and staff will review the response to the emergency by TVA and the appropriate State agencies to ensure that an effective and cooperative effort is being made, and that the CECC Director is responsible for providing PARs to the appropriate State officials (TVA 2017-TN5442).

ESP Plan Section 8.2 states that the CECC staff coordinates with other TVA emergency response facilities to ensure an effective TVA effort in response to an emergency situation. The CECC staff also provides an accurate description of the emergency situation for TVA management and public information. In addition, the CECC coordinates with offsite Federal agencies, such as NRC and DOE, to ensure the availability of additional outside resources to TVA.

The CECC is located in the northeast corner of the sixth floor of Lookout Place in the TVA COC in Chattanooga, Tennessee. It is designed to house the CECC Director and staff during an emergency situation. Included in the CECC are areas for the plant systems assessment, radiological assessment, and public information staff. A floor plan for the CECC is provided in ESP Plan Figure 8-1, "Central Emergency Control Center," and access control is provided by security personnel. The CECC is designed to serve as the central point for information collection, assessment, and transfer during an emergency. The CECC is provided with direct communication links with State emergency response centers, other TVA EROs, other TVA nuclear plant sites, the JIC, and offsite Federal and State organizations.

The CECC is activated during radiological emergencies, in accordance with CRN-EPIPs. The degree of activation varies, depending upon the emergency classification. (ESP Plan Section 9.2.1 lists CECC-EPIP-1, "Central Emergency Control Center Operations," CECC-EPIP-11, "Security of Offsite Emergency Response Facilities," and CECC-EPIP-12, "Operational Readiness Check of the CECC and the Field Coordination Centers for SQN, BFN, WBN, & CRN and Joint Information Centers [JIC].") ESP Plan Attachment 1, "Justification for the Central Emergency Control Center", provides additional description of, and justification for, the location of the CECC.

ESP Plan Attachment 1 states that the CECC is used as the EOF for the CRN Site. The CECC serves as the EOF for the other TVA nuclear plants (i.e., Browns Ferry Nuclear Plant [BFN], Sequoyah Nuclear Plant [SQN], and Watts Bar Nuclear Plant [WBN]) (NRC 1981-TN5996, NRC 1981-TN5997, NRC 1981-TN5998). The CECC is located approximately 78 air mi from the CRN Site (i.e., more than 20 mi from the CRN Site TSC),[15] as is the case for BFN, SQN, and WBN, but does not alter the functions of the EOF, as described in NUREG–0696 (NRC 1981-TN5966).

Section IV.E.8.b of Appendix E to 10 CFR Part 50 (TN249) states that an EOF may serve more than one nuclear power reactor site. In addition, if a licensee desires to locate an EOF more than 25 mi from a nuclear power site, provisions must be made for locating NRC and offsite responders closer to the site so that NRC and offsite responders can interact face-to-face with emergency response personnel entering and leaving the site. Section IV.E.8.b lists the following requirements for this near-site facility, as addressed in Section IV.I of the associated guidance in NSIR/DPR-ISG-01 (NRC 2011-TN5969):[16]

- space for members of an NRC site team and Federal, State, and local responders;
- additional space for conducting briefings with emergency response personnel;

[15] In NUREG–0696, Table 2, "Relation of EOF Location to Habitability Criteria," an EOF location beyond 20 mi of the TSC requires specific NRC Commission approval (NRC 1981-TN5966). Pursuant to SRM to SECY-96-0170 (NRC 1996-TN5972), the criteria in Table 2 were modified to change the EOF distance requirement for Commission approval from 20 mi to 25 mi from the TSC. This change is reflected in Section IV.E.8.b of Appendix E, which was added by the November 23, 2011, Final Rule, "Enhancements to Emergency Preparedness Regulations" (76 FR 72560-TN5999), and addressed in the associated Interim Staff Guidance NSIR/DPR-ISG-01, Section IV.I, "Emergency Operations Facility – Performance-Based Approach" (NRC 2011-TN5969).

[16] In SECY-17-0050, "Duke Energy Proposal to Further Consolidate Duke Corporate Emergency Operations Facility" (April 14, 2017), the staff reviewed the concept of a consolidated or common EOF, which supports multiple nuclear power reactor sites and is located beyond 25 mi from the nuclear power reactor site (NRC 2017-TN6000, NRC 2017-TN6001, and NRC 2017-TN6002). The staff consideration of such requests is conducted on a case-by-case basis, with a focus on the adequacy of the consolidated EOF to support a declared emergency event at multiple sites.

- communication with other licensee and offsite emergency response facilities;
- access to plant data and radiological information; and
- access to copying equipment and office supplies.

In ESP Plan Section 8.1.3 and Section A.4.8 of Appendix A, the applicant identified the LRC (discussed above) as the near-site facility, and described how its capabilities meet the requirements of Section IV.E.8.b of Appendix E. ESP Plan Attachment 1 further states that the use of the CECC as the EOF for the CRN Site allows TVA to continue to operate a standardized program for corporate management and response to radiological emergencies at TVA nuclear facilities. The effectiveness of CECC operations has been demonstrated during numerous drills and exercises. Communications systems, data links, and staffing have been incorporated and tested. Using the CECC for the CRN Site also allows TVA to apply its corporate emergency response structure and experience to the CRN Site emergency plan.

In addition, ESP Plan Attachment 1 states that TVA has discussed this concept with TEMA. TEMA is familiar with the CECC because the facility is used for responding to radiological emergencies at SQN and WBN. Through the letter referenced in SSAR Section 13.3 of the CRN ESPA (TVA 2017-TN5387), TEMA confirms their support of the TVA emergency response program, including the use of the CECC in Chattanooga, Tennessee. (Contacts and arrangements with offsite agencies and organizations, including TEMA, are discussed in Section 13.3.3.2 of this chapter.)

TVA also included in ESP Plan Attachment 1 an evaluation of the CECC against the criteria provided in NUREG–0696 (NRC 1981-TN5966), which addresses the guidance associated with an EOF (described below). TVA concluded that the CECC meets the functional and design criteria provided in NUREG–0696 for an EOF, with the exception that it is located more than 20 mi from the CRN Site. ESP Plan Attachment 1 describes the TVA approach to assuring that these functional and design criteria are met and maintained. The consolidation of TVA corporate emergency response functions into a centralized facility provides a timely and effective response to a radiological emergency at the CRN Site, as described below.

- Evaluation Against NUREG–0696 (NRC 1981-TN5966) – The CECC is designed to provide for the effective and timely performance of the management of overall licensee emergency response, and coordination of radiological and environmental assessment. The primary role of the CECC is to relieve the plant staff of the functions of keeping the Federal, State, and county EROs informed; for directing dose assessment and field monitoring; for managing the informational needs of the media, interested industry groups, and elected officials; and for supporting the emergency assessment needs of the TSC staff. The NRC will have access to plant data through the CECC computer system and ERDS. The NRC also has telephones on the Emergency Telecommunications System (ETS) in Chattanooga, Tennessee.

  Equipment exists in the CECC for the acquisition, display, and evaluation of radiological meteorological, and plant system data. Because a similar set of data currently used for BFN, SQN, and WBN is required for the CRN Site, the plant and effluent data would be provided on as timely a basis at the CECC as it would be at a near-site location. Normal industrial security is already provided for the CECC, and processes are already established to upgrade the security of the facility during an activation.

- Location, Structure, and Habitability – The CECC is located in the northeast corner of the sixth floor of Lookout Place in the TVA COC in Chattanooga, Tennessee. The CECC has proven to be an effective facility for implementation of the TVA nuclear station emergency

plans. The CECC is used for existing TVA nuclear plants at the BFN, SQN, and WBN sites. The facility is more than 10 mi from any of the TVA nuclear stations; therefore, there are no specific habitability criteria.

- Staffing and Training – Incorporation of CRN emergency response functions into the CECC will not adversely affect the ability of TVA to staff the CECC in a timely manner. The CECC is staffed with experienced personnel from the TVA COC and personnel from one or more TVA nuclear plants. The CECC staff has demonstrated their ability to staff the CECC within required time frames following emergency declaration during previous staff augmentation drills. The CECC staff includes personnel to manage overall licensee emergency response, and coordinate radiological and environmental assessment.
- Size – The CECC size has proven to be adequate during drills and exercises for the existing TVA nuclear facilities. In addition, the NRC has workspace co-located with the decision-makers, radiological assessment, and emergency assessment personnel.
- Radiological Monitoring – The CECC is beyond 10 mi from any nuclear stations, and therefore does not require radiological monitoring equipment.
- Communications – The communications systems available in the CECC consist of central office trunks, tie-lines, digital services, privately owned/maintained microwave systems, NRC ETS phones, and EP radio system. The emergency communications systems at the CECC are designed to provide a reliable, timely flow of information between the parties that have an emergency response role. The single facility results in commonality of communications and interface with offsite officials and liaisons. The EP telephone system continues to be the primary means of communicating changes in event classification. This system operates on a combination of the TVA telecommunications network and leased circuits.

  The offsite communications network is used to communicate with Federal, State, and other supporting agencies. Access to these agencies is provided through several redundant, diverse routes. This diversity provides offsite routing through more than one type of facility. These facilities include, but are not limited to, commercial facilities such as central office trunks, tie-lines and digital services, plus privately owned and maintained microwave and fiber-optic systems. The offsite telecommunications network is designed to facilitate traffic in the most fail-safe manner to the EROs.

  The ENS and HPN (NRC FTS 2000 System) communication systems provide communications from each site TSC, Control Room, and the CECC to the NRC Headquarters and regional offices. These telephones are tested on a periodic basis, consistent with the CRN Site emergency plan. The EP radio system is a VHF mobile radio system which provides redundant radio coverage of the PEP EPZ, and provides radiological monitoring vehicles with mobile communications to other vehicle(s) and to the following locations: the Radiological Monitoring Control Center, TSC and Control Room at each TVA plant, and the CECC.
- Instrumentation, Data System Equipment, and Power Supplies – Various plant parameters are available to the CECC staff via a connection through the TVA CECC computer network. Data available at the CECC provide a snapshot of data from each unit's integrated set of plant data. These plant parameters are sufficient to perform emergency assessment and evaluate the potential environmental consequences of an emergency at the CRN Site. Detailed discussion of CRN Site plant-specific parameters is included in the emergency plan. The computers in the dose-assessment area are capable of running the dose-projection computer programs and accessing plant status data.

Hourly and 15-minute average meteorological data from the plant Environmental Data Station are available to the CECC, TSC, State, and LRC. The CECC computer system provides access to up to the most recent 168 hours of the data. A meteorologist in the CECC provides meteorological information to the CECC staff, in support of offsite dose projections.

The CECC draws its primary power from commercial power. A loss of commercial power should not impact any of the voice or data communications equipment located in the CECC. Common TVA telecommunications infrastructure that supports CECC functions, including, but not limited to fiber-optic transmission equipment, telephone switching equipment, and data network routers, is configured to operate from at least one (and usually multiple) backup power sources in the event of a loss of commercial power. These backup sources include generator, DC battery, and UPS systems.

- Technical Data and Data Systems – As discussed in the previous section, a variety of plant parameters are provided over the TVA communications network to the CECC.
- Reports Availability and Management – Hard copies of key reference materials for the CRN Site are maintained in the CECC. In addition, station design documentation, plant drawings, procedures, etc. are available via Local Area Network connection from the Business Support Library. Information available at the CECC for the CRN Site includes plant technical specifications, plant and emergency operating procedures, final safety analysis report, and up-to-date licensee, State, and local emergency response plans.

The staff reviewed the applicant's description of the CECC against the EOF guidance in NUREG-0696 (NRC 1981-TN5966) and Supplement 1 to NUREG–0737 (NRC 1983-TN5967), as supplemented by NSIR/DPR-ISG-01 (NRC 2011-TN5969), and determined that the application does not fully describe CECC size, or identify the specific technical data systems and plant parameters that are available in the CECC. In addition, the applicant did not address the capability of the CECC to support response to events occurring simultaneously at the CRN Site, and at one or more of TVA's other nuclear power reactor sites that are also served by the CECC.[17] Finally, the applicant did not address the need for prior Commission approval to locate an EOF (i.e., the CECC) beyond 25 mi of the CRN Site. A partial EOF description is acceptable in a major features emergency plan because the applicant may request approval of only limited parts of one or more of the 16 standards in 10 CFR 50.47(b), pursuant to 10 CFR 52.17(b)(2)(i) and the definition of "major features" in 10 CFR 52.1. Therefore, the staff identified the following COL Action Item to address these issues (in some cases supplementing the CECC description in the ESPA); including the CECC activation time, and response time for staffing the CECC (identified above):

- COL Action Item 13.3-12: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the capability of the Central Emergency Control Center (CECC) to support response to events occurring simultaneously at the CRN Site and at one or more of the other TVA nuclear power reactor sites that are served by the CECC. The CECC description should address, as a minimum, the following considerations, consistent with the applicable regulations and guidance.

  a. The facility's location and size.
  b. The prescribed activation time for the facility.
  c. Whether the facility would be able to fulfill its intended required emergency response functions.

[17] *Id.*

d. The anticipated staffing (including response time) and training of licensee emergency response personnel at the facility.
e. The facility's communication capabilities and data systems.
f. The availability in the facility of the radiation monitoring system and Safety Parameter Display System (SPDS) plant parameter variables, including those identified in NRC RG 1.97, Revision 4, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants" (or other applicable guidance).
g. The facility's capacity for accommodating a multi-site event.
h. Impact on the NRC and/or State and local response organizations.

13.3.3.5.9.6 <u>Radiological Monitoring Control Center</u>

ESP Plan Section 8.3, "Radiological Monitoring Control Center," states that the Radiological Monitoring Control Center (RMCC) is located in the TEMA East facility (TEMA East) in Knoxville, Tennessee. ESP Plan 5B, Section 8.3 states that the RMCC is staffed by the TVA Field Coordinator and personnel from the State (TVA 2017-TN5442). In contrast, ESP Plan 5A, Section 8.3 (TVA 2017-TN5443) states the following:

> If it is deemed necessary by TEMA East for an emergency at the CRN Site, the RMCC will be staffed by the TVA Field Coordinator and personnel from the State in an ad hoc manner, consistent with the CEMP approach. TVA will be co-located in the RMCC, and coordination of TVA and State monitoring teams will be conducted form that point. Finally, environmental monitoring data will be shared between the State and TVA.

ESP Plan Section 8.3 further states that these personnel cooperate in providing direction and control of the monitoring teams. Monitoring teams have maps of the area, and are directed to selected monitoring points or locations to collect data. These data are transmitted to the RMCC and CECC for analysis. Facilities at the RMCC include radio and telephone communications, and necessary desks, tables, and chairs. ESP Plan 5B, Section 8.3 further states that maps of the PEP EPZ and the ingestion exposure pathway EPZ for the CRN Site are located at the RMCC (TVA 2017-TN5442).

13.3.3.5.9.7 <u>Conclusion</u>

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG-0654, Section II, Planning Standard H (NRC 1980-TN512). A COL or CP applicant will address COL Action Items 13.3-8, 13.3-9, 13.3-10, 13.3-11, and 13.3-12. Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(8) (TN249) and 10 CFR Part 50, Appendix E, Sections IV.E.8, IV.G, and VI.1 (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.10 Accident Assessment

As reflected in NUREG-0654, Section II, Planning Standard I, "Accident Assessment" (NRC 1980-TN512), 10 CFR 50.47(b)(9) (TN249) requires the use of adequate methods, systems, and equipment for assessing and monitoring the actual or potential offsite consequences of a radiological emergency condition. In addition, 10 CFR Part 50, Appendix E, Section IV.A.4 (TN249) requires the identification of persons within the licensee organization who will be responsible for making offsite dose projections, and describing how these projections will be

made and the results transmitted to State and local authorities, the NRC, and other appropriate governmental entities. In addition, 10 CFR Part 50, Appendix E, Section IV.B (TN249) requires a description of the means to be used for determining the magnitude of, and for continually assessing the impact of, the release of radioactive materials. In addition, 10 CFR Part 50, Appendix E, Section IV.E.2 (TN249) requires that adequate provisions shall be made and described for emergency facilities and equipment, including equipment for determining the magnitude of, and for continuously assessing the impact of, the release of radioactive materials to the environment.

In ESP Plan Section 9.0, the applicant described the methods, systems, and equipment available for assessing and monitoring the actual or potential consequences of a radiological emergency. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG–0654, Section II, Planning Standard I (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(9) (TN249).

ESP Plan Section 9.1, "Onsite," states that in-plant accident assessment actions are carried out by the plant emergency staff in order to properly characterize and classify the emergency, determine the actual or potential radioactivity releases, and determine the effect on plant personnel and (for ESP Plan 5B [TVA 2017-TN5442] only) the public. The assessment methodology consists of actions carried out through plant operating procedures, as well as CRN-EPIPs. ESP Plan Section A.8 of Appendix A lists a CRN-EPIP, entitled "Core Damage Assessment." At the onset of an emergency, plant operating procedures (normal, abnormal, and emergency) assist the plant operator and SED in identifying the cause of the emergency, actions necessary to control the emergency, radioactivity release rate (if any), and in-plant radiation levels. The CRN-EPIPs assist the SED in (1) identifying and reassessing emergency classification; (2) determining the need for plant area evacuation; (3) initiating activation of onsite and (for ESP Plan 5B [TVA 2017-TN5442] only) offsite emergency organizations; (4) directing the use of needed medical and/or decontamination facilities; (5) implementing predetermined security and access control plans; and (for ESP Plan 5B [TVA 2017-TN5442] only) (6) determining the need for offsite protective actions.

Each of the above-mentioned activities is described in the plant operating procedures or CRN-EPIPs, as applicable, for a given situation. The distinct breakdown of assessment actions into operating procedures and implementing procedures is necessary because some assessment actions are necessarily carried out prior to identification or classification of an emergency. The procedures to ensure that emergencies are properly evaluated, timely notifications are made, and assessment and protective actions are performed, are compiled in the CRN-EPIPs. These procedures are summarized by topic in Appendix A, Attachment 1. Under severe emergency conditions, and as required by the plant emergency operating procedures, the onsite emergency organization is responsible for recognition of severe emergency conditions, transition to, and implementation of the Severe Accident Management Guidelines.

In ESP Plan Section 9.2, "Offsite," the implementation of protective actions includes various differences between ESP Plan 5A (with a site boundary PEP EPZ) (TVA 2017-TN5443), and ESP Plan 5B (with a 2 mi PEP EPZ) (TVA 2017-TN5442). Specifically, ESP Plan 5A states that TVA maintains the capability to assess the consequences of potential or actual releases of radioactivity offsite, and if determined appropriate by State and local agencies, protective actions for the protection of the public may be implemented using a CEMP (or *all hazards*

approach) to EP (TVA 2017-TN5443). In contrast, ESP Plan 5B (TVA 2017-TN5442) states the following:

> TVA and State agencies are prepared to assess the consequences of potential or actual releases of radioactivity offsite. State and local agencies implement protective actions for the public. Written messages have been prepared which give the public instructions with regard to specific protective actions to be taken by occupants of affected areas. These messages are included in the State Plan referenced in Appendix A, Attachment 1.

Implementing procedures have been developed for the CECC to ensure that emergencies are properly evaluated, timely notifications are made, and assessment and onsite protective actions are performed. Once an SMR technology is selected, the details about accident progression rates and radiological release pathways will be known, and can then be reflected in a set of EPIPs and dose-assessment modeling, similar to the CECC-EPIP list in ESP Plan Section 9.2.1. (See Section 13.3.3.5.17 of this chapter.) ESP Plan Section 9.2.1 lists the following CECC-EPIPs associated with CECC accident assessment activities that support the CRN Site:

- CECC-EPIP-6, "CECC Plant Assessment Staff Procedure for Alert, Site Area Emergency, and General Emergency,"
- CECC-EPIP-7, "CECC Radiological Assessment Staff Procedure for Alert, Site Area Emergency, and General Emergency,"
- CECC-EPIP-8, "Dose Assessment Staff Activities During Nuclear Plant Radiological Emergencies,"
- CECC-EPIP-9, "Environmental Radiological Monitoring Procedures," and
- CECC-EPIP-15, "EP Field Support Staff Radiological Emergency Procedure."

Pursuant to 10 CFR 50.47(b)(9) (TN249), and Sections IV.B and IV.E.2 of Appendix E to 10 CFR Part 50 (TN249), the emergency plan must include a description of the means to be used for determining the magnitude of, and for continually assessing the impact of, the release of radioactive materials to the environment. Such means may include a description of methods, systems, and equipment that identify plant system and effluent parameter values characteristic of a spectrum of off-normal conditions and accidents (see Section II.I, Evaluation Criterion 1, of NUREG–0654 [NRC 1980-TN512]) (NRC 1981-TN5966, NRC 1983-TN5967, NRC 2007/2018-TN5898). While the specific details may be reflected in a set of EPIPs, the emergency plan must also include an overview description. Consistent with the applicant's intention to identify the details about accident progression rates when an SMR technology is selected, the staff identified the following COL Action Item to address the description of radiation monitoring and other systems and equipment associated with the chosen SMR technology that support accident assessment activities, as well as specific monitoring and dose-assessment and dose-projection modeling capabilities.

- <u>COL Action Item 13.3-13</u>: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the radiation monitoring and other systems and equipment, including potential major release points from the plant, associated with the chosen SMR technology that support accident assessment activities. The emergency plan should also identify the specific monitoring capability for the radiological parameters identified in NRC RG 1.97, Revision 4 (or other applicable guidance), and the dose assessment and projection modeling system.

Section 13.3.3.5.9 of this chapter also discusses the availability of plant parameter and meteorological variables in the TSC.

ESP Plan Section 9.2.2, “Sampling Team,” states that TVA has vehicles equipped to monitor the environment for radioactivity. Each vehicle has an air sampler, radiation measurement equipment, a generator, radio, and other assorted equipment. A detailed list of the minimum required equipment is available in the CECC-EPIPs. These vehicles are dispatched for environmental monitoring upon declaration of a Site Area Emergency and General Emergency. TVA may deploy these vehicles for an NOUE and Alert declaration, if warranted. One or more vehicles are stationed at the CRN Site. Each sampling team has the capacity to do the following:

- Obtain environmental samples for analysis.
- Make direct radiation readings.
- Collect air samples and analyze them for gross beta-gamma radioactivity over a range of energies.
- Collect air samples and analyze them for radioiodine in the field, to concentrations as low as 10^{-7} microcuries/cc (μCi/cc).

CRN-EPIPs describe the composition and activation of sampling teams. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP entitled “Plume Tracking and Assessment of Radiological Conditions.”) For the Site Area Emergency and General Emergency classifications, sampling teams are dispatched from the nearest location. If necessary, TVA can coordinate team transport via helicopter or fixed-wing aircraft. The TSC Radiation Protection Manager or CECC Environs Assessor can request assistance from a neighboring plant for environmental monitoring, if deemed necessary. TVA has aquatic monitoring teams located at Chattanooga and Knoxville, Tennessee. These teams have boats that can be deployed to obtain samples from the river for subsequent analysis for radioactivity in the laboratories. ESP Plan 5B, Section 9.2.2 (TVA 2017-TN5442) includes the following additional description:

> State agencies have the responsibility to coordinate and evaluate offsite assessment actions. Environmental monitoring activities are coordinated through the RMCC. State environmental monitoring capabilities and the RMCC operations are referenced in Appendix A, Attachment 1. TVA personnel are co-located in the RMCC, which provides for coordination of TVA and State monitoring teams. TVA and the State share environmental monitoring data.
>
> Additional environmental monitoring assistance is available from the DOE offices at Oak Ridge, Tennessee, or Aiken, South Carolina. The EPA in Montgomery, Alabama [AL], can also provide assistance. Available support includes environmental monitoring teams and mobile radioanalytical laboratories. The State agencies usually request and coordinate these services.

The RMCC is described in Section 13.3.3.5.9 of this chapter. ESP Plan Section 9.2.3, “Analyzing Environmental Samples,” states that the sampling teams may send samples to the Western Area Radiological Laboratory (WARL) for analysis. The WARL is a TVA laboratory located in Muscle Shoals, Alabama, that has the capability to perform further quantitative and qualitative analysis (i.e., analyze environmental samples for radioactive content). The WARL is available, as needed, and can be operated 24 hours per day. The WARL can establish a central point for receipt of samples when needed. ESP Plan Section A.8 of Appendix A lists a

CRN-EPIP entitled "Obtaining and Analyzing High Activity Samples Under Emergency Conditions."

ESP Plan Section 9.2.4 states that TVA has developed the meteorological program to conform to the intent and guidance of RG 1.23 (NRC 2007-TN278). Wind direction, wind speed, and air temperature are measured at two levels. The temperature difference is used to estimate the Pasquill stability class. Precipitation and dew point temperature are also measured. Hourly and 15-minute average meteorological data from the plant Environmental Data Station are available to the CECC, TSC, State, and LRC. More specific information about the meteorological measurements program can be found in Section 2.3, "Meteorology," of the CRN SSAR (i.e., ESPA Part 2, "Site Safety Analysis Report" [TVA 2017-TN5387]). TVA has prepared objective backup procedures to provide estimates for missing or garbled data needed to perform dose calculations and to determine transport estimates. They incorporate available onsite and offsite data. Each procedure has an accompanying statement of reliability.

In SSAR Section 2.3.3, "Onsite Meteorological Measurements Program" (TVA 2017-TN5387), the applicant described the historical meteorological monitoring that has been performed at the CRN Site, the meteorological monitoring program used for the ESPA, and the proposed operational monitoring program. The applicant stated that the primary meteorological facility for the ESPA consisted of a 110 m tower with wind, temperature, and dew point measurements at the two lowest levels (i.e., 10 and 60 m); a ground-based instrument for rainfall measurements; and an Environmental Data Station, which housed the data processing and recording equipment. This facility was located approximately 830 m south-southeast of the expected plant site, and had a base elevation of 7 m below plant grade. The applicant further stated that the primary 110 m tower used for collecting data for the ESPA has been removed, and that a new tower will be installed to collect data during the CRN Site operational phase. The meteorological program will be implemented during operation of the CRN SMR, consistent with the guidance in NRC RG 1.23 (NRC 2007-TN278). The new tower, and the associated instrumentation, will be designed to meet the requirements of RG 1.23 (NRC 2007-TN278), and meteorological data will be collected and retained for the life of the facility at the CRN Site. Consistent with the applicant's stated intention to install a new meteorological tower and implement a meteorological monitoring program, the NRC staff identified the following COL Action Item:

- COL Action Item 13.3-14: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the new meteorological tower and meteorological monitoring program at the CRN Site, in accordance with NRC RG 1.23, Revision 1, "Meteorological Monitoring Programs for Nuclear Power Plants." The emergency plan should also describe the specific design, instrumentation, and capabilities to provide required meteorological information in support of the new reactor(s) at the CRN Site.

ESP Plan Section 9.2.4 further states that the CECC Meteorologist has the responsibility for providing meteorological information to CECC staff, and the dose assessors use this information to project doses. ESP Plan 5B, Section 9.2.4.3, "Real Time and Forecast Meteorological Data," adds that the dose assessors project offsite doses, and that plume positions are plotted on a site area map (TVA 2017-TN5442). The meteorological support actions and projection of doses are discussed in detail in CECC-EPIPs. Meteorological support may be provided in the CECC or from a remote location. Access of up to the most recent 168 hours of 15-minute and hourly meteorological data is available to authorized users through the CECC computer. The remote access system gathers data from the CRN Site, performs unit conversion, reformats data, and

flags questionable values. ESP Plan Section 9.2.1 lists CECC-EPIP-17, "Central Emergency Control Center Meteorologist Procedures."

ESP Plan Section 9.2.5, "Dose Assessment," states that on-shift dose-assessment capability is maintained at the CRN Site, and can be implemented if needed during the initial phase of an emergency until the CECC is activated and assumes the dose-assessment function. Doses from emergency-related releases of radioactivity are estimated using a combination of calculations, field measurements, and laboratory analyses of environmental samples. ESP Plan 5A includes the estimation of offsite doses, and further states that "[d]ata on meteorological conditions are used in determining offsite dispersion factors" (TVA 2017-TN5443).

ESP Plan Section 9.2.5 continues by stating that using plant operational data, field measurements, and effluent monitor readings, actual or potential releases of radioactivity are analyzed by the plant staff, the Radiological Assessment staff, or the CECC Plant Assessment Team to generate or modify a source term for use in the dose assessment. With this information, the CECC Dose Assessment Team can predict offsite doses through the use of several models and/or methods described in the CECC-EPIPs. These models provide a means of estimating public exposures throughout the emergency and recovery period. Environs measurements are used, to the extent possible, to confirm doses projected by modeling.

A preliminary dose projection is performed following receipt of measured effluent release data (the source term) and meteorological data. The preliminary dose projection is followed up by a more detailed assessment using computerized dose models. Manual dose-assessment methods are available for use in the event that the computer is unavailable. Input to the detailed calculations includes measured source terms, projected future releases, near real time and forecast meteorological data, field measurements of exposure rates and/or airborne radioactivity in the environs around the plant, or a combination thereof. Field measurements are used to estimate doses, and (especially in the case of an unmonitored release) source terms, and to verify doses projected using models. After termination of emergency-related releases to the atmosphere, integrated doses are calculated to assist in recovery/reentry operations. ESP Plan 5B, Section 9.2.5 (TVA 2017-TN5442) adds the following description regarding determinations of radiological impact:

> A combination of inputs including results from modeling field exposure rate and air concentration measurements and laboratory analyses of soil, vegetation, and water samples are used to assess doses. Recommendations are made regarding evacuation area clearance and reentry based on doses calculated for exposure from ground contamination, inhalation of re-suspended radioactivity, and ingestion of radioactivity in vegetables and milk.

13.3.3.5.10.1.1 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG–0654, Section II, Planning Standard I (NRC 1980-TN512). A COL or CP applicant will address COL Action Items 13.3-13 and 13.3-14. Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(9) (TN249) and 10 CFR Part 50, Appendix E, Sections IV.A.4, IV.B, and IV.E.2 (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.11 Protective Response

As reflected in NUREG-0654, Section II, Planning Standard J, "Protective Response" (NRC 1980-TN512), 10 CFR 50.47(b)(10) (TN249) requires that a range of protective actions has been developed for the PEP EPZ for emergency workers and the public. In developing this range of actions, consideration has been given to evacuation, sheltering, and as a supplement to these, the prophylactic use of potassium iodide (KI). ETEs have been developed by applicants and licensees, and licensees shall update the ETEs on a periodic basis. Guidelines for the choice of protective actions during an emergency are developed and in place, and protective actions for the ingestion exposure pathway EPZ appropriate to the locale have been developed. In 10 CFR Part 50, Appendix E, Section IV.I (TN249) requires the development of a range of protective actions to protect onsite personnel during hostile action to ensure the continued ability of the licensee to safely shut down the reactor and perform the functions of the emergency plan.

In ESP Plan Sections 10.0, "Protective Response," and 11.0, "Radiological Protection," the applicant described the range of protective actions that have been developed for TVA emergency workers and the general public in the PEP EPZ. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG-0654, Section II, Planning Standard J (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(10) (TN249).

ESP Plan Section 10.1, "Onsite Protective Actions for Radiological Events," states that in the event of an unplanned significant release of radioactivity or sudden increase in radiation levels, it is the responsibility of the SED to make the decision concerning the necessity for building and area evacuation. In arriving at this decision, the primary consideration is personnel safety. The SED may use various radiation and airborne radioactivity monitors placed throughout the plant, with readout in the Control Room, to assess the extent of the radiological hazards and to determine the extent of evacuation necessary.

ESP Plan Section A.4.7, "Assembly/Accountability Alarm," of Appendix A states that TVA maintains warning signals to alert onsite personnel of hazards and the need for assembly or evacuation. ESP Plan Section 10.1 further states that the assembly/accountability alarm is used to initiate the assembly of site personnel. The public address system is used if only specific areas are to be evacuated. Nuclear Security Services personnel patrol the area between the security boundary described in the Physical Security Plan and the site boundary, and evacuate any nonessential personnel.

Upon hearing the emergency alarm, persons in the plant areas proceed to pre-assigned assembly areas to be accounted for, and await further instructions from the SED. Predetermined assembly areas are identified in approved procedures. The capability exists to determine the number of unaccounted individuals within approximately 30 minutes for persons within the security area, as defined in the Physical Security Plan. If only a particular area is cleared, personnel in that area evacuate to a safe area. An accountability report is provided to the SED from Security. Further details of evacuation procedures are described in CRN-EPIPs. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP topic, entitled "Onsite Protective Action Recommendations.")

If radiation levels or airborne radioactivity levels at an assembly point are significantly higher than those in alternative assembly areas, or the SED deems it necessary, the SED orders relocation to a safe assembly point. Employees are released from this assembly point when the SED determines it is suitable to do so. Procedures require that potentially contaminated people and vehicles pass through a Rad Protection check-point for survey prior to being released. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP topic entitled “Personnel Monitoring.”)

In the event of the evacuation of nonessential site personnel, the SED notifies the CECC Director. If the personnel require transportation and sheltering, the CECC Director coordinates arrangements with the appropriate State agency. If the evacuees require radiological decontamination, they are informed of transportation, sheltering, and decontamination arrangements prior to leaving the plant site. An alternate decontamination facility is specified in a CRN-EPIP. Before being released by TVA, contaminated personnel are decontaminated to the limits specified in the CRN Site Radiological Control Instructions by methods described in the instructions. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP topic entitled “Decontamination.”)

Procedures also specify the actions to be taken by, and the accountability of, personnel having an emergency assignment. Essential plant personnel remaining onsite are protected by plant systems designed to provide a habitable environment. In addition, precautionary measures may include the use of respiratory protective equipment and protective clothing. Personnel doses are controlled in accordance with ESP Plan Section 11.0.

ESP Plan Section 10.2 states that a range of protective actions to protect onsite personnel during a hostile action event are developed to ensure the continued ability to safely shut down the reactor(s) and perform the functions of the emergency plan. This range of protective actions is contained in the CRN Site abnormal procedures, which are classified as security sensitive.

ESP Plan 5A, Section 10.3, “Offsite,” states that, if determined appropriate, government officials may use a CEMP approach to EP to implement ad hoc protective actions to protect the public (TVA 2017-TN5443). This is addressed in FEMA’s Comprehensive Preparedness Guide 101, “Developing and Maintaining Emergency Operations Plans” (CPG-101) (FEMA 2010-TN5985). In contrast, ESP Plan 5B, Section 10.3 (TVA 2017-TN5442) states the following:

> Should an event be initially classified as a General Emergency, the SED has the responsibility to determine an initial protective action for recommendation to State and local government agencies. CRN-EPIPs provide a logic diagram as a decisional aid to facilitate this recommendation.
>
> After the CECC is staffed, the responsibility for PARs is transferred to the CECC Director. The CECC Plant Assessment Manager provides an assessment of actual and projected plant conditions. The RAM [Radiological Assessment Manager] provides an assessment of actual and/or projected radiological conditions offsite. The RAM also provides a recommendation for a specific protective action. The CECC Director evaluates the recommendation from staff and make[s] a recommendation to the State. The logic diagram for PEP recommendations is provided in the CECC-EPIPs as a decisional aid to facilitate the recommendation.
>
> The State and local agencies are responsible for implementing actions to protect the health and safety of the public offsite. Although TVA may recommend

protective actions to these agencies, the State and local governments are responsible for deciding if any actions are needed and what they should be. The CECC will discuss and provide ingestion exposure pathway recommendations (i.e., agricultural) and recommendations for liquid release (i.e., closing of public water supplies) with the State as appropriate.

The decision to implement one or more of the above actions is based upon some or all of the following considerations:

- Projected offsite integrated doses,
- Actual measured dose rates,
- Present and future weather conditions,
- Projected improvement or deterioration of plant conditions,
- State PAGs,
- Levels of airborne radioactivity,
- Levels of waterborne radioactivity,
- Concentrations of radioactivity in items for human consumption, and
- Evacuation time estimate.

In NUREG-0654, Section II, Planning Standard J, Evaluation Criteria II.J.8, II.J.10.a, and II.J.10.b (NRC 1980-TN512) address the need for the emergency plan to contain time estimates for evacuation within the plume exposure EPZ, which include maps showing population distribution around the nuclear facility, evacuation areas and routes, relocation centers, and preselected radiological sampling and monitoring points. The applicant included as part of ESP Plan 5B (TVA 2017-TN5442), a CRN Site ETE Report associated with the 2 mi PEP EPZ, which is discussed in Section 13.3.3.5.18 of this chapter.

13.3.3.5.11.1 <u>Conclusion</u>

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG-0654, Section II, Planning Standard J (NRC 1980-TN512). Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(10) (TN249), 10 CFR 50.47(c)(2) (TN249), and 10 CFR Part 50, Appendix E, Sections I and IV.I (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.12 Radiological Exposure Control

As reflected in NUREG-0654, Section II, Planning Standard K, "Radiological Exposure Control" (NRC 1980-TN512), 10 CFR 50.47(b)(11) (TN249) requires that the means for controlling radiological exposures in an emergency be established for emergency workers. The means for controlling radiological exposures shall include exposure guidelines consistent with the EPA PAG Manual (EPA 2017-TN5977). In addition, 10 CFR Part 50, Appendix E, Section IV.E.3 (TN249) requires that adequate provisions shall be made and described for emergency facilities and equipment, including facilities and supplies at the site for decontamination of onsite individuals.

In ESP Plan Section 11.0, the applicant described the means to control emergency workers' radiological exposures during an emergency, including measures to provide assistance to persons injured by or exposed to radioactive materials. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to

the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG-0654, Section II, Planning Standard K (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(11) (TN249).

ESP Plan Section 11.0 states that the Radiological Protection Section at the CRN Site is responsible for radiological protection activities onsite. Its function is to develop instructions to implement the requirements of 10 CFR Part 20, "Standards for Protection Against Radiation" (TN283), and other required standards, as well as the requirements and policies in TVA Radiological Control Procedures. The Radiological Protection Section provides surveillance during normal operation and emergency situations, and advises key plant personnel on radiological matters for routine and emergency conditions.

The limiting doses to occupational workers during routine plant operations would be found in TVA Radiological Control Procedures. If possible, TVA maintains these limits during emergency operations. If these standards cannot be met during emergencies, TVA implements the dose guidance described in ESP Plan Table 11-1, "Emergency Worker Dose Guidance." A CRN-EPIP describes the methods for authorizing and using the emergency worker doses in ESP Plan Table 11-1. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP, entitled "Radiation Protection Under Emergency Conditions.") ESP Plan Table 11-2, "Health Effects of Radiation Doses Greater than 25 RAD," describes the health effects of radiation doses greater than 25 rad.[18] Authorizations for emergency dose limits for onsite personnel are provided by the SED. ESP Plan 5B, Section 11.0 further states that "authorization for offsite personnel is provided by the CECC Radiological Assessment Manager" (TVA 2017-TN5442).

For individuals entering radiation work permit areas, electronic dosimeters and primary dosimeters are issued and read in accordance with the site TVA Radiological Control Procedures. (ESP Plan Section A8 lists a CRN-EPIP, entitled "Personnel Monitoring.") The electronic dosimeters can be read at any time. Primary dosimetry processing and evaluation is performed by an organization currently accredited by the National Voluntary Laboratory Accreditation Program of the National Institute of Standards and Technology for the type(s) of radiation that most closely approximates the type of radiation(s) for which the individual wearing the dosimeter is monitored. Dose records are maintained for each individual by computer.

TVA Radiological Control Procedures contain the criteria used to establish contamination zones, and for the release of personnel, equipment, and clothing. Onsite facilities are available to decontaminate equipment and personnel. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP, entitled "Decontamination.") Procedures for using individual respiratory protection and protective clothing are provided in specific plant operating procedures, and procedures for use of radioprotective drugs are provided in the EPIPs. Drinking water and eating controls are established by Radiation Protection. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP, entitled "Respiratory Protection and Distribution of Radioprotective Drugs.")

ESP Plan Section 8.1.4, "Site Decontamination Facilities," states that the CRN Site has facilities for the decontamination of personnel, including those with injuries, and that information about these facilities is provided in ESP Plan Appendix A. ESP Plan Section A.4.5.2.1, "Decontamination Facilities," of Appendix A states that the site maintains supplies and

[18] 10 CFR 20.1004, "Units of radiation dose" (TN283), defines "rad" as the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram, or 0.01 joule/kilogram (0.01 gray).

equipment as needed to establish a temporary decontamination area for the purpose of gross radiological decontamination and injured person evaluation and stabilization. Equipment and materials for decontamination and first aid, including a stretcher, are available. (Arrangements for medical services for contaminated and injured personnel at the CRN Site are addressed in ESP Plan Section 12.0 and discussed in Section 13.3.3.5.13 of this chapter.) The ESPA did not identify the location of the site decontamination facility. Therefore, the staff identified the following COL Action Item:

- COL Action Item 13.3-15: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location of the onsite personnel decontamination facility.

ESP Plan Section 11.0 further states that TVA implements adequate protective measures so that dose, considering both internal and external pathways, is maintained As Low As Reasonably Achievable (ALARA). Internal dose is minimized by the use of respiratory protection equipment, consistent with maintaining the TEDE ALARA, and protective clothing is used to minimize personnel contamination. If a projected dose to a plant worker's thyroid is expected to exceed 10 rem during a radiological emergency, KI is issued, in accordance with applicable implementing procedures.

Receipt of emergency exposures in excess of 10 CFR 20.1201 (TN283) limits shall be on a voluntary basis. Personnel receiving emergency exposures shall be informed of the risks involved, including the numerical levels of dose at which acute effects of radiation will be incurred, and numerical estimates of the risk of delayed effects. ESP Plan Table 11-2 provides information that is consistent with "Environmental Protection Agency Protective Action Guides and Planning Guidance for Radiological Incidents (EPA PAG Manual [EPA 2013-TN5978]), Draft for Interim Use and Public Comment, dated March 2013."[19]

Personnel shall not enter any area where dose rates are unknown or unmeasurable with either instruments or available dosimetry. Any personnel dose in excess of 5 rem TEDE shall be handled in accordance with the TVA Nuclear Radiological Protection Plan. Personnel receiving emergency doses should be restricted for further occupational exposure, pending the outcome of exposure evaluations and medical surveillance, if necessary.

13.3.3.5.12.1 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG-0654, Section II, Planning Standard K (NRC 1980-TN512). A COL or CP applicant will address COL Action Item 13.3-15. Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(11) (TN249) and 10 CFR Part 50, Appendix E, Section IV.E.3 (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.13 Medical and Public Health Support

As reflected in NUREG-0654, Section II, Planning Standard L, "Medical and Public Health Support" (NRC 1980-TN512), 10 CFR 50.47(b)(12) (TN249) requires that arrangements be made for medical services for contaminated injured individuals. In addition, 10 CFR Part 50, Appendix E, Section IV.E (TN249) requires facilities and medical supplies at the site for

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[19] The March 2013 EPA PAG Manual (Draft for Interim Use [EPA 2013-TN5978]) was in effect when the NRC docketed the ESPA on December 30, 2016 (Docket No. 52-047).

appropriate emergency first aid treatment, and arrangements for medical service providers qualified to handle radiation emergencies onsite. Arrangements are also required for transportation of contaminated injured individuals from the site to specifically identified treatment facilities outside the site boundary.

In ESP Plan Section 12.0, the applicant described the arrangements for medical services for contaminated injured personnel at the CRN Site. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG-0654, Section II, Planning Standard L (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(12) (TN249).

ESP Plan Section 12.0 states that facilities, equipment, medical supplies, and trained personnel are available for first aid/emergency medical treatment of ill or injured persons onsite, including those who have been overexposed to radiation, or are known to be or are suspected of being contaminated. (Radiological emergency response training is addressed in ESP Plan Section 15.0, "Training," and discussed in Section 13.3.3.5.16 of this chapter.) Immediate lifesaving and disability limiting procedures take precedence over non-critical decontamination and dosimetry assessment measures. Guidance for medical assistance is found in a CRN-EPIP. When activated, the CECC coordinates the care, disposition, and reporting of injuries known or suspected to be associated with excess levels of radiation exposure or contamination. The purpose of the Medical Emergency Response Team (MERT) (team composition specified in a CRN Site procedure) is to do the following:

- Provide first aid/emergency medical treatment for ill or injured persons onsite, including those who may have been exposed to or contaminated with radioactive material.
- Minimize injury during the rescue treatment, and transport of injured persons, while minimizing radiological hazards and exposure to the victim.
- Advise and protect attending personnel from unacceptable and unnecessary radiological hazards and exposures.
- Identify, document, and control radiation exposure and contamination hazards associated with the emergency.

Section A.4.5.2.2, "First Aid Stations and Supplies," of ESP Plan Appendix A states that Emergency Medical Technicians (EMTs) provide first aid for injured individuals, and that first aid treatment is available 24 hours a day. Emergency medical equipment is strategically located throughout the plant, including trauma kits and other specified equipment available for use by the MERT. In addition, radiation protection stores and controls KI tablets for onsite personnel. CRN-EPIPs provide usage information, including information addressing authorization for use and dispersal of KI. (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP topic, entitled "Respiratory Protection and Distribution of Radioprotective Drugs.")

ESP Plan Section 12.3, "Transportation of Injured Personnel," states that the decision to transport a patient offsite is the responsibility of the emergency medical care provider performing patient assessment (i.e., EMT or Registered Nurse). When ambulance transportation is indicated, transport may be provided by either the site Fire Protection EMTs (using a TVA ambulance), or by an agreement ambulance service. ESP Plan Section 16.5 states that agreements are maintained with ambulance services for 24-hour availability of EMT-

staffed ambulances for the transport of irradiated/contaminated patients. (ESP Plan Section 6.8 states that "[t]he plant ambulance has a radio used for communication with the local hospitals and the plant" (see Section 13.3.3.5.7, "Emergency Communications," of this chapter).) The MERT Leader coordinates requests for offsite ambulance assistance through the SM, who performs initial requests and notifications for assistance.

TVA maintains arrangements for one or more agreement ambulance services for the CRN Site with trained personnel to transport patients, including those who may have been exposed to, or contaminated with, radioactive material. These services are designated in a CRN-EPIP, and letters of agreement for response are maintained. (ESP Plan Section A.8 of Appendix A lists CRN-EPIP topics entitled "Radiation Protection Under Emergency Conditions," "Personnel Monitoring," and "Decontamination.") (See ESP Plan Section 16.5.)

ESP Plan Section 12.4 states that TVA maintains arrangements with REAC/TS[20] as the CRN Site receiving hospital. REAC/TS, which is in close proximity to the CRN Site, is a DOE-sponsored facility operated by Oak Ridge Associated Universities Medical and Health Sciences Division, in cooperation with the Oak Ridge Methodist Medical Center in Oak Ridge, Tennessee. The University of Tennessee Medical Center in Knoxville serves as a backup to REAC/TS. Specialized facilities and expert personnel are available at both medical facilities for definitive care for radiation emergency victims. Letters of agreement for services are maintained. (See ESP Plan Section 16.5.)

13.3.3.5.13.1 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG‑0654, Section II, Planning Standard L (NRC 1980-TN512). Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(12) (TN249) and 10 CFR Part 50, Appendix E, Section IV.E (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.14 Recovery and Reentry Planning and Post-Accident Operations

As reflected in NUREG‑0654, Section II, Planning Standard M, "Recovery and Reentry Planning and Post-Accident Operations" (NRC 1980-TN512), 10 CFR 50.47(b)(13) (TN249) requires that general plans for recovery and reentry be developed. In addition, 10 CFR Part 50, Appendix E, Section IV.H (TN249) requires a description of criteria to be used to determine when, following an accident, reentry of the facility would be appropriate or when operation could be resumed.

In ESP Plan Section 13.0 the applicant described activities for reentry into the areas of the plant that have been evacuated as a result of an accident, as well as the recovery organization and its concepts of operation. The staff reviewed this section, as well as other relevant portions, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency

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[20] U.S. Department of Energy REAC/TS staff is available 24 hours a day, 7 days a week, to deploy and provide emergency medical consultation for incidents involving radiation anywhere in the world. REAC/TS provides direct support for the National Nuclear Security Administration's Office of Emergency Response and the Federal Radiological Monitoring and Assessment Center. Source: https://orise.orau.gov/reacts/, visited April 13, 2017.

plan against NUREG–0654, Section II, Planning Standard M (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(13) (TN249).

ESP Plan Section 13.1, “Termination,” states that in the event of an incident requiring activation of onsite and offsite emergency centers, the SED is responsible for the decision to terminate an event, and coordinates the decision to terminate the event with the CECC Director after consultation with the plant technical and operations staffs. The CECC Director, after consultation with the State, the SED, and discussion with the NRC (if appropriate), announces that the emergency has terminated and the recovery phase is to be initiated, if appropriate. TVA then develops procedures and plans to implement the most expeditious recovery sequence to return the plant to normal operations. The State has the authority and responsibility for offsite recovery efforts, and TVA will provide requested assistance through the recovery organization shown in Figure 13-1, “TVA Recovery Organization,” which lists functions that must be addressed for recovery. State representatives are responsible for decisions to relax protective measures for the public that may have been implemented.

ESP Plan Section 13.2, “Recovery Organization,” describes the positions/titles and responsibilities of individuals who will fill key positions in the facility recovery organization. ESP Plan Section 13.3, “Onsite Recovery,” states that most post-emergency onsite recovery measures are performed in accordance with written procedures (ESP Plan Section A.8 of Appendix A lists a CRN-EPIP topic, entitled “Recovery and Reentry”), and that additional procedures may be developed following an emergency to address the following activities:

- the first auxiliary/reactor building entry,
- the first containment building entry,
- damage evaluation,
- decontamination,
- disassembly,
- repair,
- disposal, and
- test and startup of restored facilities.

In addition, appropriate personnel protective measures are taken on initial entries and throughout assessment and recovery operations to limit exposures to those outlined in ESP Plan Section 11.0. (ESP Plan Section A.8 of Appendix A lists CRN-EPIP topics entitled “Radiation Protection Under Emergency Conditions,” “Respiratory Protection and Distribution of Radioprotective Drugs,” “Personnel Monitoring,” and “Decontamination.”) Reentry and recovery individual and population dose estimates are obtained using dose rate measurements or calculations and population distribution, as described in ESP Plan Section 9.2.5, for which the methodology is contained in CECC-EPIPs. Section A.8 of ESP Plan Appendix A lists a CRN-EPIP topic, entitled “Plume Tracking and Assessment of Radiological Conditions.” In addition, ESP Plan Section 9.2.1 lists CECC-EPIP-16, “Termination and Recovery,” and CECC-EPIP-19, “Post Emergency Fuel Damage Assessment.”

ESP Plan Section 13.4, “Local Recovery Center,” describes the LRC, which provides a facility for TVA recovery management, NRC emergency response personnel, and other emergency and/or recovery personnel. The LRC provides adequate space for TVA and others who may locate there to support the site if additional office space near the site becomes necessary during the recovery phase. The LRC provides dedicated space for NRC personnel and contains

adequate supplies, communications, and data necessary for them to carry out appropriate functions. Section A.4.8, "Local Recovery Center," of ESP Plan Appendix A, provides a more detailed description of the LRC, and states that the location, function, and capabilities of the LRC are addressed in the CRN Site COLA.

With regard to actions that are taken offsite, ESP Plan 5A (TVA 2017-TN5443) and ESP Plan 5B (TVA 2017-TN5442) provide the following different descriptions in their respective ESP Plan Section 13.5, "Offsite Recovery:"

- ESP Plan 5A (Site Boundary EPZ), Section 13.5 (TVA 2017-TN5443)

  > As addressed in the FEMA Comprehensive Preparedness Guide 101, "Developing and Maintaining Emergency Operations Plans" (CPG-101), if determined appropriate, government officials may utilize a CEMP approach to emergency planning to implement ad hoc protective actions to protect the public.

- ESP Plan 5B (2 mi EPZ), Section 13.5 (TVA 2017-TN5442)

  > The State has the authority for actions taken offsite; however, TVA serves as an important source of technical and analytic assistance for the State in offsite monitoring and sampling needed to determine the extent and methods of offsite recovery. The Chief Nuclear Officer, or designee, serve as the State's contact for coordination of TVA efforts in offsite monitoring, sampling, and recovery.

13.3.3.5.14.1 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG-0654, Section II, Planning Standard M (NRC 1980-TN512). Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(13) (TN249) and 10 CFR Part 50, Appendix E, Section IV.H (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.15 Exercises and Drills

As reflected in NUREG-0654, Section II, Planning Standard N, "Exercises and Drills" (NRC 1980-TN512), 10 CFR 50.47(b)(14) (TN249) requires that periodic exercises be conducted to evaluate major portions of emergency response capabilities, periodic drills be conducted to develop and maintain key skills, and that deficiencies identified as a result of exercises or drills be corrected. In addition, 10 CFR Part 50, Appendix E, Section IV.F (TN249) requires a description of the program that provides for training of employees, exercising by periodic drills, and participation by other assisting persons. The exercises, including hostile action exercises of the onsite and offsite emergency plans, shall test the adequacy of timing and content of implementing procedures and methods, test emergency equipment and communications networks, test the public ANS, and ensure that emergency organization personnel are familiar with their duties. Title 10 CFR Part 50, Appendix E, Section IV.F (TN249) further describes the full participation exercise (including timing), participation by each offsite authority that has a role under the radiological response plan, deficiencies identified during the exercise, remedial exercises, exercise scenarios, and 8-year exercise cycle.

In ESP Plan Section 14.0, the applicant described the program for drills and exercises conducted to practice, test, and evaluate the adequacy of the emergency preparedness

program, including facilities, equipment, procedures, communication links, actions of ERO personnel, and coordination between TVA and OROs. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG-0654, Section II, Planning Standard N (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(14) (TN249).

ESP Plan Section A.7.2, "Drills and Exercises," of Appendix A states that TVA conducts drills and exercises to develop and maintain the key skills that are required for emergency response, and that TVA may conduct the drills identified in ESP Plan Section 14.0. (ESP Plan Section A.8 of Appendix A lists a supporting plant procedure, entitled "Conduct of Emergency Drills and Exercises.") ESP Plan Section 14.2, "Exercises," states that exercises are scheduled and conducted such that a biennial exercise will be conducted for the CRN Site to test the REP every 2 calendar years. ESP Plan 5B, Section 14.2 further states that State of Tennessee participation in other TVA exercises within the State determines if there will be full or partial participation by the State during CRN Site exercises (TVA 2017-TN5442).

ESP Plan Section 14.2 further states that the CRN Site ensures that adequate emergency response capabilities are maintained during the interval between biennial exercises by conducting drills, including at least one drill involving a combination of some of the principal functional areas of the onsite emergency response capabilities. The principal functional areas of emergency response include activities such as management and coordination of emergency response, emergency assessment, plant system repair and corrective actions, and (for ESP Plan 5B [TVA 2017-TN5442] only) protective action decision-making.[21] During these drills supervised instruction is permitted, and activation of all of the emergency response facilities is not necessary. Sites have the opportunity to consider emergency management strategies, operating staff have the opportunity to resolve problems (success paths) rather than have controllers intervene, and the drills can focus on onsite training objectives. Sites shall enable the state and local authorities to participate in such drills when requested.

In ESP Plan 5A, Section 14.2, the applicant stated that TVA offers State and local authorities and support organizations the opportunity to participate in drills and exercises to the extent their assistance would be expected during an emergency at the CRN Site; however, participation is not required (TVA 2017-TN5443). In contrast, ESP Plan 5B, Section 14.2 (TVA 2017-TN5442) adds the following:

> An exercise is conducted for the CRN Site, with full participation by State and local authorities, every two years. (Where a State has more than one site it shall participate fully every two years at some site and partially participate at the other sites offsite exercises.)
>
> An exercise is conducted for the CRN Site such that the State may exercise emergency plans related to ingestion exposure pathway measures every eight

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[21] See Section 13.3.4.4.3.14 of this report, related to TVA's exemption request associated with Section IV.F.2.b of Appendix E to 10 CFR Part 50 (TN249) for the site boundary PEP EPZ (i.e., ESP Plan 5A [TVA 2017-TN5443]), which addresses the need to include the functional areas of PAR development and decision-making for onsite response.

years. (Where a State has more than one site, this participation should be rotated between sites.)

ESP Plan Section 14.2 further states that major elements of the emergency plans and organizations are tested within an 8-year period, and that the CRN Site initiates an exercise between 6:00 p.m. and 4:00 a.m. at least once every 8 years (where the exact time of the exercise is unannounced).

ESP Plan Section 14.1, “Drills,” states that drills are conducted to develop and maintain key skills required for emergency response, and that these drills may be conducted individually or as part of an REP exercise. The following are required drills:

- Medical Emergency Drills – A medical emergency drill involving a simulated contaminated/injured individual, with participation by a TVA or agreement ambulance and each agreement hospital (see ESP Plan Section 16.5) is conducted each calendar year for the CRN Site. Scenario development, drill activities, and evaluations will be jointly conducted and critiqued by EP and the site.
- Radiological Monitoring Drills – Environmental monitoring vehicle drills are conducted each calendar year for the CRN Site. These drills include collection and analyses of sample media (i.e., water, air, grass, and/or soil as may be required by the scenario), direct radiation measurements, operation of vehicles, communication equipment, sampling equipment, and recordkeeping. The scenario is developed and the drills are conducted and critiqued by the site or EP.
- Rad Protection Drills – Rad Protection drills are conducted twice each calendar year for the CRN Site. These drills involve response to, and analysis of, simulated elevated airborne samples and direct radiation readings in the plant. The scenario is developed and the drills are conducted and critiqued by the site.
- Radio Chemistry Drills – Radiochemistry drills are conducted each calendar year at the CRN Site. These drills involve collecting and analyzing in-plant liquid and gaseous samples containing actual or simulated elevated levels, including use or simulated use of the post-emergency sampling system. The scenario is developed and the drills are conducted and critiqued by the site.
- Radiological Dose Assessment – Radiological dose-assessment drills are conducted at least twice each calendar year to test the procedures, calculation techniques, computer codes, and environmental assessment abilities of the CECC staff and support groups. These scenarios are developed and the drills are conducted and critiqued by EP.
- Fire Drills – Fire drills are conducted at the CRN Site in accordance with, and as required by, specific procedural requirements.
- Communications Drills – Communications drills are conducted at least once each calendar year at the CRN Site.

The frequency of communications drills is not consistent with the evaluation criteria in Section II.N.2.a of NUREG‑0654 (NRC 1980-TN512), because it does not include monthly and quarterly testing. In addition, as described above, Section IV.F of Appendix E to 10 CFR Part 50 (TN249) requires exercising by periodic drills, including hostile action exercises. A partial drill description is acceptable in a major features emergency plan because the applicant may request approval of only limited parts of one or more of the 16 standards in 10 CFR 50.47(b), pursuant to 10 CFR 52.17(b)(2)(i) and the definition of “major features” in 10 CFR 52.1.

Because ESP Plan Section 14.0 does not reflect the relevant communications testing guidance, and does not address hostile action exercises and drills for the CRN Site, the staff identified the following COL Action Item:

- COL Action Item 13.3-16: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the frequency for communications testing, and for the conduct of hostile action exercises, consistent with the applicable regulations and guidance.

ESP Plan Section 14.3, “Scenarios,” states that drills and exercises are conducted in accordance with scenarios that have been properly planned, research, and developed. The drill and exercise scenarios include, but are not limited to, the following:

- the basic objectives of each drill or exercise;
- the date(s), time period, place(s), and participating organizations;
- the simulated events;
- a time schedule of real and simulated initiating events; and
- a narrative summary describing the conduct of the exercises or drill, including simulated casualties, offsite fire department assistance, rescue of personnel, use of protective clothing, deployment of radiological monitoring teams, and public information activities.

Drill scenario development and implementation are the responsibility of the organization responsible for the specific drill. Exercise scenario development and implementation is the responsibility of EP, and scenario specifics are not released by those representatives prior to the exercise. ESP Plan 5A, Section 14.3 adds that “[e]xercise scenario planning and development is coordinated with representatives of appropriate organizations and State agencies” (TVA 2017-TN5443).

ESP Plan Section 14.3 further states that exercise scenarios will be developed to thoroughly test the REP on an 8-year cycle. The exact time of an exercise is not released, but a time span within which the exercise is to occur may be supplied to appropriate organizations and the news media, so that the exercise is not confused with an actual emergency. If a remedial exercise is required, a scenario is developed to demonstrate that corrective measures have been taken regarding the described deficiencies.

ESP Plan Section 14.4, “Critiques,” states that representatives of Quality Assurance, INPO, NRC, DHS, State/local agencies, and others may observe the exercise. Additional evaluators may be requested from other organizations, as necessary. Evaluators are provided with sufficient material and a briefing prior to the exercise to become familiar with the Emergency Plan and exercise scenario.

At the conclusion of each exercise/drill, a critique is conducted during which the exercise/drill and its participants are evaluated for their effectiveness, procedural compliance, and good practices. The Emergency Preparedness Department evaluates critique comments, develops a formal written report, coordinates corrective actions for deficiencies or items needing improvement, and follows up to ensure completion of corrective actions. Drill critiques, critique reports, coordination of corrective action and followup to ensure completion are the responsibility of the organization administering the drill.

13.3.3.5.15.1 <u>Conclusion</u>

For the reasons given above, and as discussed in Section 13.3.3.4.4.3.16 of this chapter, with the resolution of Confirmatory Item 13.3-1 (TVA 2019-TN5856) to retain requirements associated with exercising the ingestion pathway, the staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG‑0654, Section II, Planning Standard N (NRC 1980-TN512). A COL or CP applicant will address COL Action Item 13.3-16. Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(14) (TN249) and 10 CFR Part 50, Appendix E, Section IV.F (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.16 Radiological Emergency Response Training

As reflected in NUREG‑0654, Section II, Planning Standard O, "Radiological Emergency Response Training" (NRC 1980-TN512), 10 CFR 50.47(b)(15) (TN249), requires that radiological emergency response training be provided to those who may be called on to assist in an emergency. In addition, 10 CFR Part 50, Appendix E, Section IV.F.1 (TN249) requires a description of the program that provides for training of employees, exercising the emergency plan by periodic drills, and participation by other assisting persons.

In ESP Plan Section 15.0, the applicant described the radiological emergency response training program that ensures the training, qualification, and requalification of individuals who will be required to provide assistance during an emergency at the CRN Site. The staff reviewed this section, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff's primary focus was to evaluate the emergency plan against NUREG‑0654, Section II, *Planning Standard O (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the emergency plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(15) (TN249).

ESP Plan Section A.7.1, "Training Personnel," of Appendix A states that personnel with specific duties and responsibilities in the CRN Site REP Program receive instruction in the performance of their duties and responsibilities, in accordance with CRN Site training procedures, and as required in ESP Plan 5A/5B Section 15.0. ESP Plan Section 15.0 states that TVA ensures that personnel with specific duties and responsibilities in the NP-REP receive instruction in the performance of these duties and responsibilities. ESP Plan Section 15.1, "Onsite," states that Site Nuclear Training/line organizations/site EP provide training in emergency procedures to permanent plant personnel and applicable non-plant personnel, in accordance with plant training procedures. (ESP Plan Section A.8 of Appendix A lists a supporting plant procedure entitled "Emergency Plan Training.")

For personnel with specific duties involving the NP-REP, this training consists of initial training classes and annual retraining to maintain familiarity with the features of the NP-REP.[22] Participation in drills, while not a requirement for all personnel with specific duties involving the NP-REP, does augment the training of those personnel who do participate. Key site responders are required to participate in drills on a periodic basis. The site EP group provides training to

[22] ESP Plan Section 17.0, "Definitions and Acronyms," states that the NP-REP provides the policies and the actions to be used to minimize the impact on personnel, public, and the environment from an emergency at a TVA nuclear plant.

key site responders in the TSC, OSC, and SED, in accordance with applicable procedures. Training for plant access is conducted in accordance with applicable CRN Site security procedures.

ESP Plan Section 15.1 further states that the Safety and Emergency Response Training Academy provides emergency medical care training to medical personnel and selected Nuclear Power personnel stationed at the CRN Site. Successful completion of training commensurate with their duties allows personnel to fulfill the role of medical care provider on the site MERT.

ESP Plan Section 15.2, “Offsite,” states that CECC personnel have current fitness for duty training. The Emergency Preparedness Department is responsible for ensuring that lesson plans are developed and training is conducted for CECC personnel. Training provided under the ESP Plan is documented on an annual basis. Such documentation includes the date of the training, the names of those trained, and the training administered. Training and annual retraining are provided to local plant support agencies (security, fire, ambulance, and hospital personnel) that may be involved with direct support of the site during an emergency.

Nuclear Support Services is responsible for providing agreement hospital and ambulance support training. (Emergency first aid team qualifications and treatment are addressed in ESP Plan Section 12.0 and discussed in Section 13.3.3.5.13 of this chapter.) The CRN Site is responsible for providing fire support training, with assistance from Nuclear Support Services, as needed. The CRN Site is responsible for providing local law enforcement (security) training. Training includes procedures for notification, basic radiation protection, expected roles, and site access procedures (as applicable).

ESP Plan Section 15.3, “Professional Development Training,” states that full-time EP staff members are afforded formal professional development training or activities commensurate with their duties and experience. (EP staff members responsible for maintaining CRN Site emergency preparedness are addressed in ESP Plan Section A.5, “Maintaining Emergency Preparedness,” and discussed in Section 13.3.3.5.17 of this chapter.)

13.3.3.5.16.1 <u>Conclusion</u>

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG‑0654, Section II, Planning Standard O (NRC 1980-TN512). Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(15) (TN249) and 10 CFR Part 50, Appendix E, Section IV.F.1 (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.17 Responsibility for the Planning Effort: Development, Periodic Review and Distribution of Emergency Plans

As reflected in NUREG‑0654, Section II, Planning Standard P, “Responsibility for the Planning Effort: Development, Periodic Review and Distribution of Emergency Plans” (NRC 1980-TN512), 10 CFR 50.47(b)(16) (TN249) requires that responsibilities for plan development and review and for distribution of emergency plans are established and that planners are properly trained. In addition, 10 CFR Part 50, Appendix E, Section IV.G (TN249) requires a description of provisions to be employed to ensure that the emergency plan, its implementing procedures, and emergency equipment and supplies are maintained up to date.

In the following ESP Plan sections, the applicant described the responsibilities associated with maintaining the emergency preparedness program, including the development, review, and distribution of the emergency plan:

- ESP Plan Section 9.2.1, “General Information,”
- ESP Plan Section 15.3, “Professional Development Training,”
- ESP Plan Section 16.0, “Plan Maintenance,”
- ESP Plan Section A.5, “Maintaining Emergency Preparedness,” of Appendix A,
- ESP Plan Section A.7.1, “Training Personnel,” of Appendix A,
- ESP Plan Section A.8, “Emergency Plan Implementing Procedures,” of Appendix A, and
- ESP Plan Appendix A, Attachment 1, “State Multijurisdictional Radiological Emergency Response Plan.”

The staff reviewed these sections, as well as other relevant portions of the application, to determine whether the application conforms to the applicable guidance and complies with the pertinent regulatory requirements. The staff’s primary focus was to evaluate the emergency plan compared to NUREG–0654, Planning Standard P (NRC 1980-TN512), which provides the detailed evaluation criteria that the staff should consider when determining whether the ESP Plan meets the applicable regulatory requirements in 10 CFR 50.47(b)(16) (TN249).

ESP Plan Section A.5.1 of Appendix A states that the Site Vice President maintains overall authority and responsibility for radiological emergency response planning. The Director of Emergency Preparedness is assigned responsibility for coordinating emergency preparedness efforts, including activities related to the development of emergency plans and procedures, and coordinating the plans and procedures with supporting organizations to ensure the overall effectiveness of the program.

ESP Plan Section A.7.1 of Appendix A states that personnel with specific duties and responsibilities in the CRN Site REP Program receive instruction in the performance of their duties and responsibilities in accordance with CRN Site training procedures, and as required in ESP Plan Section 15.0. In addition, ESP Plan Section 15.3 states that full-time EP staff members are afforded formal professional development training, or activities commensurate with their duties and experience. (The TVA radiological emergency response training program is addressed in ESP Plan Section 15.0, and discussed in Section 13.3.3.5.165 of this chapter.)

ESP Plan Section 16.0 describes how TVA maintains the ESP Plan. Specifically, the CRN NP-REP and the appendices are reviewed by CRN Site and EP staff annually for accuracy, completeness, operational readiness, and compliance with existing regulations and established policy. Revision to the CRN NP-REP may result from these periodic reviews, drills, exercises, or changes in regulations. Revisions are made as expeditiously as possible, and are not necessarily held for submittal with an annual review. Each (CRN NP-REP) line affected by a particular revision is marked in the margin, and changes in a revision are stated in the revision log (which includes a brief explanation of the pages affected).

The Plant Operations Review Committee approves CRN NP-REP revisions to ESP Plan Appendix A prior to their implementation. Changes to the CRN EP-REP are approved by the General Manager, Support Services, or designee. Changes are made and distributed according to ESP Plan Figure 16.1, “Update Procedure for NP-REP and Appendices.” To provide REP

holders with assurance that the Emergency Plan is up to date, cover pages and revision logs are distributed with each revision or addition. The revision log lists the latest revision number, the date revised, pages revised, and the reason for the revision.

ESP Plan Section A.5.2, "Procedures," states that the CRN Site maintains a range of CRN-EPIPs that provide instructions for implementing the emergency response measures described in the ESP Plan. ESP Plan Section 16.0 provides a description of the CRN-EPIP document control, approval, and revision processes. ESP Plan Section 16.2, "EPIPs," describes how the EPIPs are controlled and reviewed, including how changes are made and distributed (in accordance with ESP Plan Figure 16-2, "Update Procedure for EPIPs").

ESP Plan Section A.5.3, "Independent Reviews of Emergency Preparedness," of Appendix A states that TVA's independent Quality Assurance organization performs, or oversees the performance of, periodic independent audits of the emergency preparedness program, consistent with the requirements of 10 CFR 50.54(t) (TN249). The audits include, at a minimum, the following:

- the emergency plan,
- EPIPs and practices,
- the emergency preparedness training program,
- readiness testing (e.g., drills and exercises),
- emergency response facilities, equipment, and supplies,
- interfaces with State and local government agencies, and
- required records and documentation.

TVA's independent Quality Assurance organization documents audit results and improvement recommendations, and reports these results to the CRN Site and TVA management. TVA establishes and maintains the frequency of the periodic audits based on an assessment of performance compared to performance indicators; however, the audit frequency is not less than once every 24 months. In addition, TVA conducts a program audit as soon as reasonably practicable after a change occurs in personnel, procedures, equipment, or facilities that potentially could adversely affect emergency preparedness; but no longer than 12 months after the change. TVA makes those portions of the audits that address the adequacy of interfaces with State and local governments available to the affected governments. In addition, ESP Plan Section 16.4, "Audits," states that Quality Assurance is also responsible for offering recommendations on overall emergency plan improvement, and retaining the audit results in the files for a period of 5 years.

ESP Plan Section 9.2.1 states that EPIPs have been developed for the CECC to ensure that emergencies are properly evaluated, timely notifications are made, and assessment and protective actions are performed (ESP Plan 5A [TVA 2017-TN5443] is limited to onsite protective actions). Section 9.2.1 includes a list of CECC-EPIPs, and ESP Plan Section A.8 includes a list of CRN Site EPIPs and additional plant procedures that support the ongoing maintenance of the EP program. (ESP Plan Section A.8 of Appendix A lists a supporting plant procedure entitled "Maintaining Emergency Preparedness.") In addition, ESP Plan Appendix A, Attachment 1, "State Multijurisdictional Radiological Emergency Response Plan," states that the State of Tennessee Multijurisdictional Radiological Emergency Response Plan is maintained in the CECC and the CRN Site TSC.

Finally, the applicant included ESP Plan tables of contents, with cross-references to NUREG-0654 evaluation criteria (NRC 1980-TN512), in (1) ESP Plan "Table of Contents;" (2)

ESP Plan Appendix A, “Table of Contents;” and (3) ESP Plan Appendix A, Attachment 3, “Cross-Reference to Regulations and Guidance.”

13.3.3.5.17.1 Conclusion

The staff concludes that the information provided in the ESPA is consistent with the guidelines in NUREG–0654, Section II, Planning Standard P (NRC 1980-TN512). Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(16) (TN249) and 10 CFR Part 50, Appendix E, Section IV.G (TN249), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.3.5.18 Evacuation Time Estimate Analysis

10 CFR 50.47(b)(10) (TN249) requires, in part, that ETEs have been developed by applicants and licensees, and that licensees shall update the ETEs on a periodic basis. In addition, 10 CFR Part 50, Appendix E, Section IV (TN249) requires that the applicant provide an analysis of the time required to evacuate various sectors and distances within the PEP EPZ for transient and permanent populations, using the most recent U.S. Census Bureau data as of the application submission date. These requirements also apply to ESP applicants that propose complete and integrated emergency plans pursuant to 10 CFR 52.17(b)(2)(ii) (TN251), and may be addressed by ESP applicants that propose major features of the emergency plans pursuant to 10 CFR 52.17(b)(2)(i) (TN251).

NUREG/CR-7002 (Jones et al. 2011-TN5968) contains the detailed guidance to be used by the staff when determining whether the ETE Report (TVA 2016-TN5955) meets the applicable regulatory requirements in 10 CFR Part 50, Appendix E (TN249). ETEs are part of the required EP basis and provide TVA and State and local governments with site-specific information needed for protective action decision-making.

SSAR Section 13.3.4, “Evacuation Time Estimates” (TVA 2017-TN5387), states that an independent ETE study has been performed to provide estimates of the time required to evacuate permanent resident and transient resident populations from the CRN Site PEP (2 mi) EPZ for various times of the day, week, and year under favorable and adverse weather conditions. For the emergency plan in ESPA Part 5B (i.e., ESP Plan 5B [TVA 2017-TN5442]), the ETE for evacuation of an approximately 2 mi PEP EPZ is detailed in the ETE Report (TVA 2016-TN5955) provided in ESP Plan 5B (TVA 2017-TN5442). The analyses were conducted in accordance with the guidance provided in NUREG/CR-7002 (Jones et al. 2011-TN5968). For the emergency plan in ESPA Part 5A (i.e., ESP Plan 5A [TVA 2017-TN5443]), an ETE study was not performed because the plan does not require the establishment of a PEP EPZ beyond the site boundary and development of offsite REP plans.

The staff evaluated the ETE Report (TVA 2016-TN5955) against the criteria set forth in the latest guidance contained in NUREG/CR-7002 (Jones et al. 2011-TN5968). The evaluation included checking the ETE Report (TVA 2016-TN5955) for internal consistency, consistency with other parts of the emergency plan, and consistency with other parts of the ESPA, including the SSAR (TVA 2017-TN5387). The following discussion reflects information contained in the ETE Report (TVA 2016-TN5955), including the staff’s evaluation and RAIs.

The CRN Site is a proposed SMR project on 1,200 ac of land adjacent to the Clinch River arm of the Watts Bar Reservoir, south of the DOE ORR, within the city limits of Oak Ridge, in Roane

County, Tennessee. For the proposed CRN Site, the PEP EPZ is an area encompassing an approximate 2 mi radius around the proposed reactor center point location. Figure 1.1, "CRN Site Vicinity Map," shows the proposed CRN Site, surrounding communities, political boundaries, and major highways and geographic features. The mapping provided in Section 3, "Roadway Capacity" shows details that include intersections, as well as collectors, arterials, and Interstate highways. Major roads out of the EPZ are illustrated in Figure 2.5, "Roadway Network in the Vicinity of the CRN Site."

This ETE Report includes a discussion of the traffic simulation model INTEGRATION, which was used in performing the ETE analysis (TVA 2016-TN5955). The CRN Site was modeled using the INTEGRATION system, which reflected demographic and field survey information for the defined evacuation region, and applied the procedures specified in the 2010 Highway Capacity Manual. Additional details regarding the traffic simulation model are included in Section 4.2, "Evacuation Time Estimate Modeling."

As described in ETE Report Section 1.1, "Approach," TVA conducted a detailed field survey of the roadway network and traffic conditions within the EPZ to validate existing mapping and obtain characteristics of the primary roadways (TVA 2016-TN5955). The evacuation network used in the analysis is illustrated on mapping provided in Section 3, "Roadway Capacity," and the types and capacities of each roadway segment are listed by unique link numbers in Table A.2, "Link Input File." Field survey data were used to adjust roadway characteristics to reflect actual conditions, such as roadway capacity and intersection control.

The ETE is used as an information tool; therefore, no limit on evacuation time must be achieved. The guidance under Evaluation Criterion J.10 of NUREG-0654, Section II (NRC 1980-TN512), provides additional information regarding the use of ETE results, in support of protective response within the EPZ. For purposes of the ESPA, the ETE also serves to satisfy the requirements in 10 CFR 52.17(b)(1) (TN251), which states that the SSAR must identify the physical characteristics of the proposed site, such as egress limitations from the area surrounding the site, that could pose a significant impediment to the development of emergency plans. The Executive Summary of the ETE Report states that the ETE did not identify physical characteristics of the proposed site that could pose a significant impediment to the development of emergency plans (TVA 2016-TN5955) (see also, Section 13.3.3.1 of this chapter).

The ETEs are calculations of the time necessary to evacuate the 2 mi PEP EPZ. The exact size and configuration of the PEP EPZ surrounding the CRN Site was developed in relation to local emergency response needs and capabilities, because they are affected by conditions such as demography, topography, land characteristics, access routes and jurisdictional boundaries. Of particular interest in the development of CRN Site 2 mi PEP EPZ is the overlapping EPZ for the DOE ORR. The ETEs are primarily used by OROs to inform protective action decision-making; and they may also be used in the development of traffic management plans to support an evacuation. The Preface of the ETE Report (TVA 2016-TN5955) summarizes the ETE contents, as follows:

- Section 1: Provides an introduction to the ETE, describes the characteristics of the EPZ, establishes general assumptions, and identifies the evacuation scenarios evaluated in this analysis.
- Section 2: Provides details considered in developing demand estimates for permanent residents and transients, transit-dependent populations, special facilities, schools, special events, and quantifying a shadow evacuation.

- Section 3: Describes the approach for evaluating the roadway capacity and establishes values for use in adverse weather calculations.
- Section 4: Discusses the process for developing trip generation times and provides details about information included in traffic simulation modeling.
- Section 5: Identifies other considerations, including the need for development of a traffic control plan, potential enhancements to the ETE, and State and local review.
- Appendix A: Provides characteristics for the roadways in the roadway network.
- Appendix B: Includes ETE review criteria contained in Appendix B of NUREG/CR-7002 (Jones et al. 2011-TN5968).

The ETE Report (TVA 2016-TN5955) was prepared based on guidance provided in NUREG/CR-7002 (Jones et al. 2011-TN5968). Consistent with this guidance, the ETE provides the time to evacuate 90 percent and 100 percent of the total population of the EPZ. The 90 percent ETEs provides the evacuation times that would typically be used to support PARs and decision-making. As described in ETE Report Section 1.4, "Emergency Response Planning Areas" (TVA 2016-TN5955), and consistent with NUREG-0654, Supplement 3, "Guidance for Protective Action Strategies" (NRC 1980-TN512), PARs would be implemented consistently throughout the 2 mi PEP EPZ.

The ETE Report includes an analysis of permanent residents and transient populations, transit-dependent permanent residents (ambulatory and nonambulatory), special facility residents, and schools (TVA 2016-TN5955). The PEP EPZ is sparsely populated and has no major commercial facilities (except for the two major employers, identified below), schools, correctional facilities, licensed day care facilities, nursing home facilities, or major retail facilities located in the PEP EPZ. The ETE Report also provides details about the development of the evacuation demand considered in the ETE (described above), preparation activities associated with development of the ETE, and the use of traffic simulation modeling (TVA 2016-TN5955).

As described in Section 2.1, "Permanent Residents and Transient Population," the 856 permanent residents within the PEP EPZ are based on the 2010 U.S. Census[23] (projected to 2015). In addition to the demand estimates for resident and transient populations, demand estimates were also considered for people who work in the PEP EPZ. Section 2.5, "Other Demand Estimate Considerations," provides estimate of the number of employees and evacuating vehicles for major employers (i.e., those with 50 or more employees) identified in the vicinity of the CRN Site. Considerations included in the ETE analysis are as follows:

- A shadow evacuation extending to 15 mi from the CRN Site assumes that 20 percent of the public outside the boundary of the PEP EPZ to a distance of 15 mi for the CRN Site would spontaneously evacuate.
- Lack of existing emergency preparedness programs and evacuation plans, including the absence of existing registration programs for people with disabilities and those with access and functional needs who do not reside in special facilities, and the absence of existing evacuation routes and traffic control plans.
- Verification of the future commitment of resources, such as buses and ambulances.

[23] 2010 U.S. Census ("Census 2010") (https://www.census.gov/2010census/, visited December 28, 2017).

- Consideration of the evacuation tail.
- Future ETE updates related to a COLA.[24]

The Soaring Eagle Campground is the only facility in the PEP EPZ that attracts transients, and is located approximately 1 mi south of the proposed CRN Site. No hotels or motels were identified within the PEP EPZ. An estimate of the transient population is provided in Section 2.1.2, "Transient Population," and the peak transient population of 197 (requiring 116 evacuating vehicles) is presented in Table 2.4, "Peak Transient Population and Evacuating Vehicles." This estimate assumes the facility operates at capacity during the summer.

Section 2.3, "Special Facility Residents" describes one special facility within the PEP EPZ—the Kingston Academy. The Kingston Academy is a psychiatric residential treatment facility with living quarters and a capacity for 52 children. Table 2.6 indicates that the 47 residents (90%) of the Kingston Academy are transported using three facility vans, and Table 4.12, "ETEs for Special Facility Populations," provides an ETE for the Kingston Academy of 1:19 (hour:minute). The Kingston Academy is further described in Section 4.1.3, "Special Facilities."

The special event evaluated in the analysis was new plant (SMR) construction. Table 2.8, "Total Population Considered for Each Scenario," identifies the peak construction year as 2024, and explains that the permanent resident and shadow populations were extrapolated to this year to determine the ETE. During the peak construction period the workforce estimate is 2,700 construction workers. The existing roadway system was used for this scenario and no roadway improvements were considered. However, because a site plan detailing road access to the site has not been finalized, it was assumed that driveway access to and from the site would be along Bear Creek Road.

Ten evacuation scenarios are described in Table 1.3, "Evacuation Scenarios," which includes the ETEs associated with summer, winter, midweek, weekend, daytime, evening, normal and adverse weather, roadway impact, and a special event consisting of peak construction. For the 10 evacuation scenarios, Table 4.13, "ETEs for Evacuation of the General Public (90% of the Affected Population)," and Table 4.14, "ETEs for Evacuation of the General Public (100% of the Affected Population)," provide the ETEs for the evacuation of the general public, which range from 1:40 (hour:minute) to 2:17 for the 90th percentile general population (excluding the peak construction scenario). The maximum ETE for the 100th percentile is 4:07 for evacuation during peak construction of the new (SMR) plant. Separate ETEs were developed for the transit-dependent and special facility populations. Table 2.6, "Summary of Transit Dependent Residents," indicates that there are a total of 82 transit dependent individual in the EPZ, and Table 4.11, "Evacuation of Transit Dependent Individuals," provides the associated ETEs, which range from 2:10 to 2:36.

ETE Section 5.3, "State and Local Review," states that State and local authorities were involved in the development of the ETE (TVA 2016-TN5955). Interactions began with a kick-off meeting in Knoxville, Tennessee, in January 2014, during which the regulatory requirements, the process used to develop the ETE, and the associated data and information needs were discussed. The meeting was attended by representatives of the following State and local agencies and private sector support organizations:

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[24] If the site boundary EPZ (reflected in ESP Plan 5A [TVA 2017-TN5443]) is selected for the CRN Site, TVA has proposed an exemption from the requirements to perform an ETE, and an update to the (ESP Plan 5B) ETE will not be necessary.

- TEMA
- Tennessee Highway Patrol
- Roane County Office of Emergency Services and Homeland Security
- Anderson County Office of Emergency Management and Homeland Security
- Loudon County Mayor
- Loudon County Homeland Security and Emergency Management Agency
- Loudon County Sheriff's Office
- Knox County Emergency Management Agency
- Knox County Sheriff's Office
- Knox County Engineering
- City of Oak Ridge Fire Department
- Kingston Police Department
- Lenoir City Fire Department
- Rural/Metro of East Tennessee
- American Red Cross of East Tennessee.

After the kick-off meeting, a telephone survey instrument was prepared and provided to the TEMA for review and comment, resulting in several modifications. Each agency approved the instrument prior to initiating the telephone survey. TEMA and Roane County provided assistance with completing data collection related to the permanent resident and transient populations, schools, major employers, transportation resources, transit-dependent residents, and hotels, motels and campgrounds in the PEP EPZ. Site-specific telephone survey results were used to establish demographic characteristics and auto occupancy information, including the population without access to a vehicle or who are dependent on help to evacuate. Specific assumptions supporting the demand estimation, vehicle usage, and trip generation times are based on the results of a site-specific telephone survey, which was not included in the report.

In an e-mail dated August 21, 2017, NRC provided TVA with eRAI-9029 (NRC 2017-TN6003), which requested that the applicant address various areas of the ETE Report (TVA 2016-TN5955), including (1) the methodology used to project population growth from 2010 to 2015, (2) identification of major employers within the 2 mi PEP EPZ, (3) PEP EPZ population and evacuation network modeling, and (4) various ETE inconsistencies.

In a September 15, 2017, response to eRAI-9029 (TVA 2017-TN6004), the applicant addressed the staff's questions. The staff reviewed the applicant's responses to eRAI-9029, and found the responses acceptable because they (1) stated that the methodology used to project the 2015 transient, permanent, and shadow evacuation populations used in the ETE Report (TVA 2016-TN5955) is the same methodology described in ESPA Part 2, and provided additional methodology description. In addition, the applicant (2) described the major employers within the 2 mi PEP EPZ—Energy Solutions (previously referred to as Duratek), VW Group of America, and HT Hackney facility—and the applicant included specific descriptions of each employer. (Table 2.7, "Major Employers in the EPZ," of the ETE also identified Kingston Academy as a major employer within the 2 mi PEP EPZ.) The applicant also (3) provided a detailed description of PEP EPZ population and evacuation network modeling, and (4) resolved the various ETE inconsistencies that the staff identified. Therefore, the staff considers eRAI-9029 resolved.

As described above, the staff finds that the applicant has developed adequate ETEs for the PEP EPZ for transient and permanent populations using the most recent U.S. Census Bureau data

as of the application submission date, and that the ETEs are consistent with the guidance in NUREG/CR-7002 (Jones et al. 2011-TN5968).

13.3.3.5.18.1 Conclusion

The staff concludes that Revision 1 of the ETE Report (TVA 2016-TN5955) is consistent with the guidelines in NUREG/CR-7002 (Jones et al. 2011-TN5968). Therefore, the staff finds that the information is acceptable and meets the relevant requirements of 10 CFR 50.47(b)(10) (TN249); 10 CFR Part 50, Appendix E, Section IV (TN249); and 10 CFR 52.17(b)(2)(ii) (TN251), insofar as the information describes the essential elements of advanced planning and the provisions made to cope with emergency situations.

13.3.4 Conclusions Regarding Emergency Planning

The staff reviewed the TVA ESPA, including the major features emergency plans, for the proposed new unit(s) at the CRN Site against the relevant requirements and guidance identified above in Section 13.3.3 of this chapter. Pursuant to 10 CFR 52.17 (TN251) and 10 CFR 52.18 (TN251), and in consultation with FEMA, the staff concludes that (1) there are no physical characteristics unique to the CRN Site that could pose a significant impediment to the development of emergency plans; (2) TVA has provided an adequate description of contacts and arrangements made with Federal, State, and local governmental agencies that have EP responsibilities; and (3) except for the emergency classification system described above in Section 13.3.3.5.5, the proposed major features of the emergency plans meet the pertinent standards of 10 CFR 50.47 (TN249) and the requirements of Appendix E to 10 CFR Part 50 (TN249), insofar as the plans address a limited description of the major features as proposed in the ESPA. Pursuant to 10 CFR 52.17(b)(2)(i) and the definition of a major features emergency plan in 10 CFR 52.1, an ESP applicant submitting major features emergency plans may request approval of only limited parts of one or more of the 16 standards in 10 CFR 50.47(b).

In addition, the staff concludes that the proposed methodology (described in SSAR Section 13.3 [TVA 2017-TN5387]) for preparing an analysis, as the technical basis to support the PEP EPZ size determination in a subsequent CRN Site COLA or CP application, is reasonable, consistent with Commission considerations for SMR EPZ size determinations, and consistent with the analyses that form the technical basis for the current regulatory requirement of a PEP EPZ about 10 mi in radius for LLWRs.

The staff evaluation of and findings related to the exemption requests with respect to the Commission regulations on exemptions are provided above in Sections 13.3.3.4.2 and 13.3.3.4.3.

The CRN Site ESP, if granted, is subject to the following COL Action Items and Permit Conditions:

- COL Action Item 13.3-1: An applicant for a COL or CP that references this ESP should identify the chosen SMR technology for the CRN Site, including the applicable ESP major features emergency plan, or, if appropriate, a new emergency plan for NRC review. In addition, if the accident dose consequences of the chosen SMR technology support the site boundary plume exposure pathway (PEP) EPZ, the applicant will inform the offsite response organizations regarding establishment of the PEP EPZ at the site boundary. The applicant should update the major features emergency plan to reflect the chosen SMR technology, and incorporate it into a complete and integrated emergency plan. In addition, the applicant should provide detailed information that shows the ability of the chosen SMR technology to

meet the applicable PEP EPZ, as described in ESPA, Part 2, Section 13.3.3, "Emergency Planning Zones." (See Section 13.3.3.4 of this chapter.)

- COL Action Item 13.3-2 An applicant for a COL or CP that references this ESP should submit to the NRC up-to-date letters of agreement or memoranda of understanding with offsite support organizations, which address the concept of operations in support of their respective emergency response roles associated with the chosen plant design, including hostile actions at the CRN Site, consistent with applicable requirements and guidance, including 10 CFR 52.79(a)(22)(i) and (ii) and 10 CFR 50.47(b), (c). (See Section 13.3.3.5.2 of this chapter.)
- COL Action Item 13.3-3: An applicant for a COL or CP that references this ESP should update the emergency plan to describe on-shift emergency response organization staffing in support of the chosen SMR technology for the CRN Site, including the capability for Tennessee Valley Authority's (TVA's) onsite and offsite emergency response organization positions to be staffed and emergency response facilities activated, consistent with the applicable requirements and guidance. (See Section 13.3.3.5.3 of this chapter.)
- COL Action Item 13.3-4: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the emergency classification and action level scheme applicable to the chosen SMR technology for the CRN Site, consistent with the applicable requirements and guidance. (See Section 13.3.3.5.5 of this chapter.)
- COL Action Item 13.3-5. An applicant for a COL or CP that references this ESP, including the Part 5B Emergency Plan (2-Mile Emergency Planning Zone [EPZ]), should update the emergency plan to describe the chosen Alert and Notification System (ANS) network(s), which reflects the assessment of the various technologies by TVA and the affected State and local agencies, and meets the applicable requirements and guidance. (See Section 13.3.3.5.6 of this chapter.)
- COL Action Item 13.3-6: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the CRN Site Emergency Communications Equipment, including all required communications and data links, associated with the chosen SMR technology, consistent with the applicable regulations and guidance. (See Section 13.3.3.5.7 of this chapter.)
- COL Action Item 13.3-7: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location, function, and capabilities of the Joint Information Center (JIC), consistent with the applicable regulations and guidance. (See Section 13.3.3.5.8 of this chapter.)
- COL Action Item 13.3-8: An applicant for a COL or CP that references this ESP should update the emergency plan to describe onsite monitoring systems and equipment, including the installed Radiation Monitoring System, consistent with the applicable regulations and guidance. (See Section 13.3.3.5.9 of this chapter.)
- COL Action Item 13.3-9: An applicant for a COL or CP that references this ESP should update the emergency plan to describe how the criteria in Section 2 of NUREG-0696 and Section 8 of Supplement 1 to NUREG-0737 are met for the TSC, including the emergency classification requiring activation and the time frame for designated personnel to report to the TSC and achieve full functional operation. (See Section 13.3.3.5.9 of this chapter.)
- COL Action Item 13.3-10: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location of the Operations Support Center (OSC)

and communications capabilities consistent with Section 3.3 of NUREG‑0696. (See Section 13.3.3.5.9 of this chapter.)

- COL Action Item 13.3-11: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location, function, and capabilities of the Local Recovery Center (LRC). In addition, the applicant should describe how the LRC meets the applicable requirements in Sections IV.E.8.b and IV.E.8.d of Appendix E to 10 CFR Part 50, and the criteria in Sections IV.D and IV.I of NSIR/DPR-ISG-01. (See Section 13.3.3.5.9 of this chapter.)

- COL Action Item 13.3-12: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the capability of the Central Emergency Control Center (CECC) to support response to events occurring simultaneously at the CRN Site and at one or more of the other TVA nuclear power reactor sites that are served by the CECC. The CECC description should address, as a minimum, the following considerations, consistent with the applicable regulations and guidance:

  a. The facility's location and size.
  b. The prescribed activation time for the facility.
  c. Whether the facility would be able to fulfill its intended required emergency response functions.
  d. The anticipated staffing (including response time) and training of licensee emergency response personnel at the facility.
  e. The facility's communication capabilities and data systems.
  f. The availability in the facility of the radiation monitoring system and Safety Parameter Display System (SPDS) plant parameter variables, including those identified in NRC RG 1.97, Revision 4, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants" (or other applicable guidance).
  g. The facility's capacity for accommodating a multi-site event.
  h. Impact on the NRC and/or State and local response organizations.

  (See Section 13.3.3.5.9 of this chapter.)

- COL Action Item 13.3-13: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the radiation monitoring and other systems and equipment, including potential major release points from the plant, associated with the chosen SMR technology that support accident assessment activities. The emergency plan should also identify the specific monitoring capability for the radiological parameters identified in NRC RG 1.97, Revision 4 (or other applicable guidance), and the dose assessment and projection modeling system. (See Section 13.3.3.5.10 of this chapter.)

- COL Action Item 13.3-14: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the new meteorological tower and meteorological monitoring program at the CRN Site, in accordance with NRC Regulatory Guide 1.23, Revision 1, "Meteorological Monitoring Programs for Nuclear Power Plants." The emergency plan should also describe the specific design, instrumentation, and capabilities to provide required meteorological information in support of the new reactor(s) at the CRN Site. (See Section 13.3.3.5.10 of this chapter.)

- COL Action Item 13.3-15: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location of the onsite personnel decontamination facility. (See Section 13.3.3.5.12 of this chapter.)

- COL Action Item 13.3-16: An applicant for a COL or CP that references this ESP should update the emergency plan to describe the frequency for communications testing, and for the conduct of hostile action exercises, consistent with the applicable regulations and guidance. (See Section 13.3.3.5.15 of this chapter.)
- Permit Conditions 13.3-1 and 13.3-2 (Permit Conditions 5 and 6):
  1. An applicant for a COL or CP that references this ESP shall provide detailed information in the COL or CP application that demonstrates that the accident release source term information for the selected small modular reactor (SMR) design used in analyses to support the determination of the plume exposure pathway emergency planning zone (EPZ) size is bounded by the non-design-specific plant parameter source term information below in Table 13.3-1, "Plant Parameter Accident Releases for Determining Emergency Planning Zone (EPZ) Size in Support of Emergency Planning Exemptions." (See Section 13.3.3.3.3 of this chapter.)
  2. An applicant for a COL or CP that references this ESP shall update the emergency plan to describe the on-shift personnel assigned to emergency plan implementing functions based on the chosen SMR technology and the number of proposed reactor units.

     (i) In addition, if a COL applicant references this ESP, the COL applicant shall propose a license condition for the COL holder to perform the following: No later than 18 months before the latest date set forth in the schedule submitted in accordance with 10 CFR 52.99(a) for completing the inspections, tests, and analyses in the Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC), the licensee shall have performed a detailed staffing analysis, in accordance with the latest NRC-endorsed revision of Nuclear Energy Institute (NEI) 10-05, "Assessment of On-Shift Emergency Response Organization Staffing and Capabilities."

     (ii) No later than 180 days before the date scheduled for initial fuel loading set forth in the notification submitted in accordance with 10 CFR 52.103(a), the licensee shall have revised the emergency plan to incorporate any changes identified in the staffing analysis that are needed to bring staffing to the required levels.

     If a CP applicant references this ESP, the CP applicant shall propose a permit condition for the operating license applicant to:

     (i) Perform a detailed staffing analysis, in accordance with the latest NRC-endorsed revision of Nuclear Energy Institute (NEI) 10-05, "Assessment of On-Shift Emergency Response Organization Staffing and Capabilities."

     (ii) Revise the emergency plan to incorporate any changes identified in the staffing analysis that are needed to bring staffing to the required levels.

(See Section 13.3.3.5.3 of this chapter.)

Table 13.3-1 Plant Parameter Accident Releases for Determining Emergency Planning Zone (EPZ) Size in Support of Emergency Planning Exemptions

Nuclide	4-Day Total Activity (Ci)	Nuclide	4-Day Total Activity (Ci)
Kr-85	3.29E+03	Ru-106	2.68E+00
Kr-85m	1.94E+03	Rh-103m	4.11E+00
Kr-87	1.10E+03	Rh-106	2.70E+00
Kr-88	3.04E+03	Nb-95	6.45E+01
Xe-133	1.74E+05	Co-58	7.88E-05
Xe-135	1.49E+04	Co-60	8.74E-04
Xe-135m	6.95E+02	Mo-99	6.16E+01
Cs-134	1.26E+02	Tc-99m	5.80E+01
Cs-136	2.82E+01	Nb-97	3.95E+00
Cs-137	8.88E+01	Nb-97m	4.61E-01
Rb-86	9.92E-01	Ce-141	1.31E+00
Rb-88	2.59E+03	Ce-143	1.09E+00
Ba-139	1.22E+01	Ce-144	1.10E+00
Ba-140	4.82E+01	Np-239	1.10E+01
Sr-89	2.20E+01	Pu-238	7.75E-03
Sr-90	7.46E+00	Pu-239	3.21E-04
Sr-91	2.05E+01	Pu-240	6.48E-04
Sr-92	1.27E+01	Pu-241	1.60E-01
Ba-137m	8.00E+01	Zr-95	6.34E-01
I-131	6.79E+02	Zr-97	5.64E-01
I-132	4.35E+02	Am-241	1.06E-04
I-133	9.72E+02	Cm-242	2.61E-02
I-134	2.08E+02	Cm-244	1.09E-02
I-135	6.59E+02	La-140	4.75E+00
Sb-127	1.51E+01	La-141	2.45E-02
Sb-129	1.23E+01	La-142	8.65E-01
Te-127	1.60E+01	Nd-147	6.82E+00
Te-127m	2.86E+00	Pr-143	3.10E-01
Te-129	1.75E+01	Y-90	5.05E-01
Te-129m	8.15E+00	Y-91	2.74E-01
Te-131m	2.22E+01	Y-92	7.46E+00
Te-132	1.78E+02	Y-93	2.90E-01
Te-131	1.09E+01	Y-91m	9.90E+00
Rh-105	2.90E+00	Pr-144	9.65E-01
Ru-103	4.13E+00	Pr-144m	1.72E-02
Ru-105	1.55E+00		

13.6 Physical Security

The ESPA for the CRN Site, submitted by TVA, describes the site characteristics applicable to security and provides information to demonstrate that security plans and measures can be developed in accordance with the applicable requirements of 10 CFR 73.55, “Requirements for physical protection of licensed activities in nuclear power reactors against radiological sabotage” (TN423), and 10 CFR 100.21(f) (TN282). In SSAR Chapter 1, “Introduction and General Description of the Plant”; Chapter 2, “Site Characteristics”; Chapter 3, “Design of Structures, Systems, Components, and Equipment”; and Chapter 13, “Conduct of Operations,” Section 13.6, “Physical Security,” (contained in ESPA Part 2), the applicant describes the characteristics of the proposed the CRN Site and the bounding parameters that establish the PPE within which a reactor design will be selected before applying for a COL for construction and operation of two or more SMRs (TVA 2017-TN5387).

The CRN Site is a tract of land adjacent to the Clinch River arm of the Watts Bar Reservoir, located west of the ORR, within the city of Oak Ridge, Tennessee. The CRN Site is approximately 935 ac within a 1,200 ac property owned by the United States of America and managed by the TVA. Part 2, Chapter 1, of the ESPA provides a detailed description of the CRN Site.

13.6.1 Summary of Application

SSAR Chapters 1 and 2 provide information about the site’s specific location, description, and PPE and contain various site maps and the CRN Site aerial photographs that depict the site topography (TVA 2017-TN5387). The ESPA also includes descriptions and depictions of the locations of existing industrial facilities, sewage treatment plants, pipelines, waterways, mining operations, highways, railroads, airports, airways, nearby power plants, and military facilities. In addition, the ESPA provides descriptions and evaluations of potential hazards within the vicinity of the site (explosions, flammable vapor clouds, toxic chemicals, fires, liquid spills, radiological hazards, dam failures, etc.), including natural hazards, such as floods, ice, and seismic activity. SSAR Section 13.6 describes site characteristics necessary to meet the applicable regulatory requirements for the CRN Site so that adequate security plans and measures can be developed for the site (TVA 2017-TN5387).

SSAR Chapter 2 provides CRN Site coordinates including a center-point reference location inside a 935 ac area of land at U.S. North American Datum 1983 (decimal degrees); longitude: 35.890889 North; latitude: 84.380927 West and at Universal Transverse Mercator Zone 16 North, North American Datum 1983 (meters); 3,974,815.26 Northing and 736,407.14 Easting (TVA 2017-TN5387). SSAR Figure 1.2-1, “Clinch River Site Location,” and Figure 2.1-1, “Site Map,” also depict a proposed EAB of 1,200 ac owned by the United States and managed by TVA that encompasses the CRN Site (TVA 2017-TN5387). The CRN Site is located in Oak Ridge, Tennessee, and is situated on the former site of the CRBRP (cancelled in 1983) within the EAB. Because TVA only evaluated a number of SMR designs, as discussed in SSAR Section 1.11 (TVA 2017-TN5387), the power block area center-point location has not specifically been identified; only a proposed area location on a 28 ac site within the 94 ac area of land has been allocated for the plant area. SSAR Figure 1.2-2, “Clinch River Nuclear Site Plant Areas,” depicts the site location that includes the power block area in relation to the overall plant area. SSAR Chapter 2 (TVA 2017-TN5387) and the Environmental Report (ER) (TVA 2017-TN4921) describe other manmade features such as a barge slip and intake structures.

13.6.2 Regulatory Basis

The provisions of 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants,” Subpart A, “Early Site Permits” (TN251) establish the requirements and procedures applicable to the NRC issuance of an ESP for approval of a site for one or more nuclear power facilities separate from the filing of an application for a construction permit or a COL for the facility.

Provisions in 10 CFR 52.17, “Contents of applications; technical information” (TN251), sets forth the requirements for the contents and technical information to be submitted in applications under the following subpart:

- 10 CFR 52.17(a)(1)(x) (TN251), as it relates to the requirement for submission of information to demonstrate that the site characteristics are such that adequate security plans and measures can be developed.

The provisions in 10 CFR 73.55 (TN423) set forth the requirements for power reactor licensees and applicants to establish and maintain a physical protection program, including a security organization, whose objective is to provide high assurance that activities involving special nuclear material are not harmful to the common defense and security and do not constitute an unreasonable risk to public health and safety.

The provisions in 10 CFR 100.21, “Non-seismic siting criteria” (TN282), set forth the requirements regarding non-seismic siting criteria for proposed commercial power reactor sites in the following subpart:

- 10 CFR 100.21(f) (TN282), as it relates to the requirement that site characteristics to be such that adequate security plans and measures can be developed.

Acceptance criteria adequate for meeting the above requirements include those set forth in the following:

- Regulatory Guide (RG) 4.7, “General Site Suitability Criteria for Nuclear Power Stations,” Revision 2, April 1998 (NRC 1998-TN1008), as it relates to the suitability criteria for a proposed site.
- NUREG–0800, “Standard Review Plan (SRP) for the Review of Safety Analysis Reports for Nuclear Power Plants,” Chapter 13, Section 13.6.3, “Physical Security – Early Site Permit,” Revision 1, October 2010, as it relates to the review of physical security aspects of a permit application for a proposed site (NRC 2007/2018-TN5898). The staff recently updated SRP Section 13.6.3 and published the guidance document in October 2016. The staff expects that the COL applicants will use the most updated regulatory guidance to provide the necessary updates in the COLA.

13.6.3 Technical Evaluation

In conducting the technical evaluation of the information contained in SSAR Chapter 13, Section 13.6, the staff also reviewed the pertinent information and figures contained in the following SSAR chapters and sections (TVA 2017-TN5387):

- Chapter 1, “Introduction and General Description of the Plant”; Section 1.1, “Introduction,” Section 1.2, “General Plant Description”;

- Chapter 2, “Site Characteristics,” Section 2.0, “Plant Parameter Envelope”; Section 2.1, “Geography and Demography,” Section 2.2, “Nearby Industrial, Transportation, and Military Facilities,” and Section 2.4, “Hydrologic Engineering”; and
- Chapter 3, “Design of Structures, Systems, Components, and Equipment.”

In addition, the staff reviewed pertinent information and figures contained in ER Chapters 1 and 2 to confirm the consistency of site characteristics information applicable to the review of physical security between the SSAR (TVA 2017-TN5387) and the ER (TVA 2017-TN4921).

The staff review focused on (1) whether the information in the ESPA meets the requirements stated in 10 CFR 52.17(a)(1)(x) (TN251) to demonstrate that the site is such that security plans and measures can be developed; (2) that the applicant has considered the applicable physical protection requirements stated in 10 CFR 73.55 (TN423) in the selection of the site and its proposed layout; and (3) that the ESPA information related to the site characteristics and potential hazards provide a sufficient technical basis to demonstrate that the site characteristics and potential hazards do not present impediments that would preclude the development of adequate security plans and measures consistent with 10 CFR 100.21(f) (TN282).

13.6.3.1 Security Boundaries

In SSAR Section 13.6, the applicant states that the CRN Site is sufficiently large to implement the requirements of 10 CFR 73.55 (TN423), including adequate distances between safety-related structures and the required security boundaries and consideration of land-based and waterborne vehicle bombs (TVA 2017-TN5387). Spatial separation is not limited by the natural topography of the CRN Site and planned structures for the site would not limit spatial separation.

Based on the information contained in ESPA Part 2, Sections 1.2, 2.1, and 13.6, the applicant identified a 94 ac area of land, which includes a proposed location of the power block area within the 935 ac proposed for the CRN Site’s owner-controlled area (OCA). The applicant concluded that the CRN area of land is sufficiently large enough to allow for the establishment of the security boundaries of the OCA, protected area (PA), vital area (VA), and PA perimeter isolation zones, with sufficient distance between these security boundaries and VAs, for the implementation of a physical protection program consistent with the requirements of 10 CFR 73.55 (TN423). The applicant also stated in ESPA Chapter 2 that the actual design information selected for the CRN Site would be reviewed as part of a COLA to demonstrate that the design is bounded by the PPE.

The staff issued RAI 13.06.03-1 (NRC 2017-TN5922), requesting that TVA confirm that once the specific design has been identified, a COL applicant would demonstrate that the chosen design is bounded by plant parameters identified in Chapter 2, Table 2.0-1, ”Site Characteristics.” The staff considers the power block area specific coordinates as part of the ESPA review. Once the specific SMR design is identified, the staff will review the selected design as part of the COLA to ensure that the power block is bounded by the PPE as indicated in Chapter 2, Table 2.0-1.

In a letter (TVA 2017-TN5923), TVA indicated that if TVA applies for a COL referencing the ESP, the actual design selected would be reviewed as part of the COLA to demonstrate that the design would be bounded by the PPE, and differences would be reviewed to confirm that the design selected would not invalidate the proposed location of the power block area. TVA further

confirmed that the area of land corresponding to the selection of any specific reactor design technology discussed in Chapter 2 of the CRN ESP would be sufficiently large to allow for the establishment of the security boundaries of the OCA, PA, VA, and PA perimeter isolation zones, and include sufficient distance between these security boundaries and VAs for the implementation of a physical protection program consistent with the requirements of 10 CFR 73.55 (TN423) (see also 10 CFR 52.17 [TN251]).

Based on the above response, the staff finds that the information contained in the application is consistent with the requirements of 10 CFR 52.17(a)(1)(x) (TN251) and provides a sufficient basis to conclude that site characteristics regarding the establishment of security boundaries are such that adequate security plans and measures can be developed.

13.6.3.2 Site Characteristics

In SSAR Chapters 1 and 2, the applicant describes and depicts the site characteristics and potential nearby hazards (TVA 2017-TN5387). Specifically, SSAR Figure 1.2-1 depicts and identifies features of the overall layout of the site, the proposed EAB as well as existing facilities, structures, and other manmade features, such as a barge-unloading facility, intake structures, and the existing 500 kV power line corridor and 161 kV power line corridor, which will be relocated away from the plant area. In addition, SSAR Chapter 2 provides the CRN Site coordinates, including a center-point reference location inside a 935 ac land mass at U.S. North American Datum 1983 (decimal degrees); longitude: 35.890889 North; latitude: 84.380927 West and at Universal Transverse Mercator Zone 16 North, North American Datum 1983 (meters); 3,974,815.26 Northing and 736,407.14 Easting. SSAR Figure 1.2-1 and Figure 2.1-1 also depict a proposed EAB of 1,200 ac owned by the United States and managed by TVA that encompasses the CRN Site (TVA 2017-TN5387). Along with the proposed power block location, SSAR Figure 3.1-2 depicts several large permanent and temporary cleared areas, including switchyard and cooling-tower areas, that could support the construction activities (TVA 2017-TN5387). A designated area for a future independent spent fuel storage installation facility is also identified.

In SSAR Section 13.6 (TVA 2017-TN5387), the applicant states that the characteristics of the new plant footprint meet the applicable requirements of 10 CFR 100.21(f) (TN282) and 10 CFR 73.55 (TN423). The applicant also indicates that a COL applicant will address site-specific design features of the selected SMR technology that details site-specific security, engineering designed features and monitoring equipment, and security methods for screening station operating personnel.

The staff issued RAI 13.06.03-4 (NRC 2017-TN5922), requesting that the applicant confirm that subsequent COL applicant(s) who select any specific reactor design technology, as discussed in Chapter 2 of the SSAR, will meet the PPE parameters and follow the requirements of 10 CFR 73.55 (TN423) and 10 CFR 100.21(f) (TN282). The following sources provide criteria for meeting the regulations that address physical protection of licensed activities in nuclear power reactors relative to radiological sabotage:

- NRC RG 4.7, “General Site Suitability Criteria for Nuclear Stations”(NRC 1998-TN1008)
- U.S. Nuclear Energy Institute 03-12, “Template for Security Plan and Training and Qualification Plan” (NEI 2007-TN6037)

- EA-03-086, Revised Design Basis Threat Order for site-specific security, engineering designed features and monitoring equipment, and security methods for screening station operating personnel (NRC 2003-TN5924).

In a letter (TVA 2017-TN5923), TVA indicated that if TVA applies for a COL referencing the ESP, TVA would review the actual design selected for the CRN Site COLA to demonstrate that the design would be bounded by the PPE, and differences would be reviewed for acceptability in the COLA. This review would confirm that selection of any specific reactor design technology discussed in Chapter 2 would not impact the development of the security plan to address site-specific security, engineering designed features and monitoring equipment, and security methods for screening station operating personnel.

Based on the above response, the staff finds:

- The information contained in the application is consistent with the requirements stated in 10 CFR 52.17(a)(1)(x) (TN251) and, along with the applicant's response to the staff RAI, provides sufficient basis to conclude that site characteristics regarding the installation of physical protection equipment and the implementation of a physical protection program are such that adequate security plans and measures can be developed.
- The site characteristics and topographical features would not be an impediment to the implementation of a physical protection program. The proposed power block location within the 94 ac land area is of sufficient size for the installation of intrusion-detection and assessment equipment, physical barriers, vehicle checkpoints and search areas (sally ports), and will accommodate the implementation of a physical protection program consistent with the requirements of 10 CFR 73.55 (TN423) and 10 CFR 100.21(f) (TN282).

13.6.3.3 Approaches

In SSAR Section 2.2, "Nearby Industrial, Transportation, and Military Facilities," the applicant describes hazardous materials, railways, highways and routes, airports, nearby power plants, pipelines information, and waterways that could impact the facilities and activities within the 5 mi vicinity of the CRN Site (TVA 2017-TN5387). These characteristics were analyzed to confirm that they meet the guidance in the SRP (NRC 2007/2018-TN5898).

13.6.3.3.1 Locations and Routes

The approximately 935 ac CRN Site is located within the city limits of Oak Ridge, Tennessee. The southern portion of the site, containing the power block area, is located on a peninsula bounded by the Clinch River arm of the Watts Bar Reservoir on the western, southern, and eastern sides.

The northern portion of the CRN Site is bounded on the north by the Grassy Creek Habitat Protection Area and on the east by the U.S. Department of Energy's Oak Ridge Reservation and Management Area. The applicant evaluated potential hazard facilities and routes within the 5 mi vicinity of the CRN Site, and airports within 10 mi of the site along with significant facilities at a greater distance in accordance with RG 1.206, "Combined License Applications for Nuclear Power Plant LWR Edition" (NRC 2007-TN3035); RG 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants" (NRC 2013-TN5899), RG 4.7; "General Site Suitability Criteria for Nuclear Power Stations" (NRC 1998-TN1008); RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a

Postulated Hazardous Chemical Release" (NRC 2001-TN5897); and relevant sections of 10 CFR Parts 50 (TN249), 52 (TN251), and 100 (TN282).

The evaluation performed by the applicant identified five industrial facilities, the Clinch River arm of Watts Bar Reservoir, one major highway, four major roads, the Heritage Railroad Corporation Railway, and two natural gas pipelines that are significant enough to be considered. The facilities include the following:

- Industrial Facilities
  - Oak Ridge National Laboratory
  - TVA Kingston Fossil Plant
  - Oak Ridge Water Treatment Plant (WTP)
  - TVA Bull Run Fossil Plant
  - Hallsdale Powell Utility District Melton Hill WTP
- Transport Routes
  - Clinch River arm of Watts Bar Reservoir
  - Highways I-40, Tennessee State Route (TN) 1/US 11-70, and TN 58, TN 95, and TN 327
  - Heritage Railroad Corporation Railway
  - East Tennessee Natural Gas Pipeline 1 (East) and Pipeline 2 (North).

13.6.3.3.2 SSAR – Nearby Transportation Routes/Pipelines

The staff evaluation below focuses on the impacts of industrial facilities, transport routes and airways, as well as chemical hazards. SSAR Section 2.2.3.1.1.3, "Nearby Transportation Routes/Pipelines," indicates that there are two natural gas transmission pipelines within the vicinity of the CRN Site (TVA 2017-TN5387). The closest approach from the nearest natural gas transmission pipeline—the East Tennessee Natural Gas Pipeline 1 (6 in.)—to the edge of the CRN Site power block area is approximately 1.1 mi (5,800 ft) and the closest approach from the East Tennessee Natural Gas Pipeline 2 (22 in.) to the edge of the power block area is approximately 3 mi (15,800 ft). The applicant indicated that a natural gas pipeline explosion occurring in the vicinity of the release point would be in an unconfined environment. The worst-case scenario had considered the immediate detonation of natural gas content in the pipeline to be capable of supporting an explosion. The scenario assumed that the pipe had burst open, leaving the full cross-sectional area of the pipe completely exposed to the air. It was also assumed that the ignition source existed at the break point. The safe distance to 1 psi overpressure was calculated by determining the mass of natural gas released using the TNT mass equivalent methodology as described in SSAR Section 2.2.3.1.1 (TVA 2017-TN5387). Due to the nature of a high-pressure release through a pipeline, upon a complete pipeline rupture, the initial release rate of the gas (lb/s) will be very large and quickly drop to a fraction of the initial release rate in an unconfined environment. As a result, detonation of natural gas in an unconfined environment would not have an adverse impact on structures beyond the safe distance and therefore would not be credible. However, ignition of a natural gas release near the release point could result in a less damaging deflagration explosion or jet fire.

The staff issued RAI 13.06.03-2 (NRC 2017-TN5922), requesting that the applicant discuss how such an event, specifically the pressure induced by an explosion and the heat flux induced by a jet fire, was considered for the future development of the security plan.

In a letter (TVA 2017-TN5923), TVA indicated that SSAR Section 2.2.2.3 and Table 2.2-4 provide a description of the pipelines, sizes, age, operating pressure, depth of burial, and product carried. SSAR Section 2.2.2.3 identifies various isolation valves located along the pipeline route, which can be reached and operated within 1 hour of notification (TVA 2017-TN5387). The worst-case scenarios, which considered the delayed ignition (detonation) of the released natural gas, with a 1-hour maximum release, were presented in SSAR Sections 2.2.3.1.2.3, 2.2.3.1.3.3, and 2.2.3.1.4.

TVA indicated that the largest calculated safe distance of flammable vapor clouds (delayed ignition), deflagration and detonation, and jet fire for East Tennessee Natural Gas Pipeline 1 is 1,575 ft, which is less than the distance to the CRN Site power block area of 5,800 ft; and the largest calculated safe distance for East Tennessee Natural Gas Pipeline 2 is 4,572 ft, which is less than the distance to the CRN Site power block area of 15,800 ft (Table 2.2-10). Based on the maximum safe distance information, the ability to access and operate the isolation valves provided by TVA, and a review of SSAR reference sections and tables, the staff concludes that gas pipeline explosions would not impact safety-related structures, or prohibit the development of site security plans and measures in accordance with 10 CFR 52.17(a)(1)(x) (TN251), 10 CFR 100.21(f) (TN282), and the requirements of 10 CFR 73.55 (TN423).

The staff also issued RAI 13.06.03-3 (NRC 2017-TN5922), requesting that the applicant discuss transportation routes for ORNL, an assessment of products and materials being transported along the I-40 corridor, and the potential impact on the development of a site-specific security plan.

In responding to the staff RAI, TVA indicated that SSAR Section 2.2.2.5 identified I-40 as a bounding transport route in the vicinity of the CRN Site (NRC 2017-TN5922). The I-40 corridor, located approximately 1 mi from the site power block area, is the most significant and closest highway to the CRN Site. The route is evaluated as a potential transport route for supplies shipped to ORNL and for the potential effects of chemical accidents as part of design basis events for plant design parameters. The route used for shipping and receiving supplies at the plant may vary, and unless a material is prohibited on a route, there are no restrictions that would prevent delivery vehicles from taking another nearby available route.

The chemicals stored at ORNL are listed in Table 2.2-2 of the SSAR. The disposition of hazards associated with these chemicals is summarized in Table 2.2-5 and the subsequent analysis of these chemicals is addressed in SSAR Section 2.2.3 (TVA 2017-TN5387). Analysis of accidents involving chemicals, liquid fuels, and gaseous fuels were considered for facilities and activities within the vicinity of the CRN Site, where such materials are processed, stored, used, or transported in quantity. The effects of explosions were analyzed for structural response to blast pressures. The effects of blast pressure from explosions located at nearby facilities and transportation routes to the CRN Site power block area boundary were included in SSAR Section 2.2.3 (TVA 2017-TN5387), which addressed whether the explosion would have an adverse effect on safety-related plant structures located within the CRN Site power block area that could affect plant operation or prevent safe shutdown of the plant.

In a letter (TVA 2017-TN5923), TVA indicated that it had provided additional clarifying discussion of the transportation routes in SSAR Section 2.2.2.2.2. These clarifications were, subsequently, incorporated in Revision 1 of the CRN ESPA (TVA 2017-TN5883). Based on additional information provided by the applicant and the review of relevant SSAR sections, the staff finds that potential accidents involving explosions and flammable vapor clouds from materials

transported along the I-40 route would not adversely affect the safe operation or shutdown of units located within the CRN Site, or impact the development of the site security plan.

13.6.3.3.3 SSAR – Airports, Aircraft, and Airway Hazards

Section 2.2.2.7, "Airports, Aircraft, and Airway Hazards," indicates that there are five small privately owned airports (Big T, Wolf Creek, Cox Farm, Will A Hildreth Farm, and Riley Creek) located between 5 and 10 statute mi of the CRN Site. These airports have no Federal Aviation Administration (FAA) Terminal Area Forecast (TAF) data available due to their size and low number of operations; however, their projected number of operations, based on locally available data, is less than the significance factor (i.e., the allowable annual number of operations) as specified in Criterion 1 of SRP Section 3.5.1.6 of (NRC 2007/2018-TN5898), in which the probability of aircraft accidents resulting in radiological consequences greater than the 10 CFR Part 100 (TN282) exposure guidelines is less than an order of magnitude of 10^{-7} per year.

The applicant also indicated that two small privately owned airports—Oliver Springs and Fergusons Flying Circus—are within 10 to 15 statute mi of the CRN Site. No FAA TAF data were available due to their size and low number of operations. However, based on locally available data for these airports, the projected number of operations for each airport is less than the significance factor (i.e., the allowable annual number of operations) as specified in Criterion 1 of SRP Section 3.5.1.6 (NRC 2007/2018-TN5898). Airports located at distances greater than 15 statute mi from the CRN Site were also evaluated to ensure that they meet the significance factor specified in Criterion 1 of SRP Section 3.5.1.6 (NRC 2007/2018-TN5898). SSAR Table 2.2-7 documents the proximity screening results for these airports (TVA 2017-TN5387).

The applicant also evaluated the probability of aircraft accidents at the CRN Site to determine whether the site met proximity screening Criterion 2, as specified in SRP Section 3.5.1.6 (NRC 2007/2018-TN5898). The applicant identified that the CRN Site is located about 19.2 statute mi from the centerline of the closest military training route. The closest military operation area (MOA) is the Snowbird MOA located approximately 36 mi from the CRN Site. The primary users of the Snowbird MOA were Air National Guard units, which have since been relocated or converted from fighter aircraft to other missions due to high terrain for the eastern part of the country and altitude allocated to accommodate civil overflights, which limit the area's flexibility and utility for military operations. Given this separation distance between the CRN Site and the nearest military training route (greater than 5 mi from the nearest edge of a military training route), along with the distance to the nearest MOA, the applicant concluded that Criterion 2 of SRP Section 3.5.1.6 (NRC 2007/2018-TN5898) was met.

There are two Federal airways (V16 and J46) whose nearest edge is located within 2 statute mi of the CRN Site. As required by SRP Section 3.5.1.6 (NRC 2007/2018-TN5898), the applicant conducted a detailed review of aircraft hazards to determine the accident probability rate. The analysis result is detailed in SSAR Section 2.2.2.7, and shown to be on the order of a magnitude of 10^{-6} per year and the realistic probability has been shown to be lower (TVA 2017-TN5387). The applicant discussed aircraft hazards and assessment results in SSAR Section 3, "Design of Structures, Systems, Components, and Equipment," and concluded that the risk to plant safety from aircraft hazards is sufficiently low (TVA 2017-TN5387). Detailed discussion of aircraft impacts and staff regulatory assessment is discussed in Section 3.5.1.6 of this FSER.

Based on the above discussion, the staff finds that the information contained in the application is consistent with the requirements of 10 CFR 52.17(a)(1)(x) (TN251) and provides a sufficient basis for concluding that site characteristics regarding the establishment of security boundaries are such that adequate security plans and measures can be developed.

13.6.4 Conclusion

As described above and based on its review of additional clarification of referenced SSAR sections and tables, and response to staff RAIs, the staff concludes that the applicant provided sufficient technical basis to demonstrate that the site characteristics and potential hazards do not present impediments that would preclude the development of adequate security plans and measures. The staff also concludes that the CRN Site is such that adequate security plans and measures can be developed consistent with the requirements in 10 CFR 52.17(a)(1)(x) (TN251) and 10 CFR 100.21(f) (TN282).

15.0 ACCIDENT ANALYSIS

This chapter of the final safety evaluation report (FSER) describes the U.S. Nuclear Regulatory Commission (NRC) staff's evaluation of the information provided in Chapter 15, "Accident Analysis," of the Site Safety Analysis Report (SSAR), contained in Part 2 of the Clinch River Nuclear (CRN) Site early site permit (ESP) application (TVA 2017-TN5387). The information in Chapter 15 describes the radiological consequences of design basis accidents (DBAs). The description uses information based on four conceptual small modular reactor (SMR) designs under consideration for the site as included in the plant parameter envelope (PPE). The intention is to demonstrate that two or more new SMR unit(s) with a maximum rated thermal power for a single unit of 800 MWt (reactor core) could be sited at the proposed CRN Site without posing an undue risk to the health and safety of the public, in compliance with the requirements in Title 10 of the *Code of Federal Regulations* (10 CFR), 52.17 (TN251), "Contents of Applications," and 10 CFR Part 100 (TN282), "Reactor Site Criteria."

15.0.3 Summary of Application

The four conceptual SMRs considered in the development of a surrogate plant for the PPE are described in SSAR Section 1.11, "Overview of Reactor Types," (TVA 2017-TN5387). Each of the designs is a pressurized-water reactor (PWR) and all four of the designs are of an integral PWR type. All four designs are described as being passively safe designs with minimal or no reliance on offsite power, offsite water, or operator action for safety. The four designs and associated vendors are as follows:

- BWXT mPower™ (Generation mPower, LLC);
- NuScale (NuScale Power, LLC);
- SMR-160 (Holtec SMR, LLC); and
- Westinghouse SMR (Westinghouse Electric Company, LLC).

SSAR Chapter 15 describes the applicant's assessment of the offsite radiological consequences of DBAs for a surrogate plant, as bounded by the PPE (TVA 2017-TN5387). The U.S. Nuclear Energy Institute 10-01, "Industry Guidance for Developing a Plant Parameter Envelope in Support of an Early Site Permit," notes that accident analyses model the time-dependent transport of radionuclides out of the reactor core through several pathways, each with different time-dependent removal mechanisms for radionuclides (NEI 2010-TN5866). As the applicant notes in SSAR Section 15.1, "Accident Selection," different reactor designs have different release pathways, and each pathway has different release rates and different radionuclide removal mechanisms (TVA 2017-TN5387). Given these differences, the applicant chose to use the DBA radiological consequence analyses from the design that resulted in the highest post-accident offsite doses in its assessment of the radiological consequences of DBAs at the CRN Site.

The applicant's DBA radiological consequence analysis used, as input, the site characteristic short-term accident atmospheric dispersion (χ/Q s) factors at the exclusion area boundary (EAB) and the low-population zone (LPZ) boundary provided in SSAR Section 2.3.4 (TVA 2017-TN5387). In SSAR Table 2.0-3, the applicant provided the bounding DBA source term (release rates of radioactive materials to the environment). The applicant also presented the DBA dose assessment results at the proposed EAB and the LPZ outer boundary in SSAR Table 15-1, which demonstrates that the potential doses would be within the radiological consequence evaluation factors set forth in 10 CFR 50.34(a)(1) (TN249) and 10 CFR 52.17(a)(1) (TN251).

Because the reactor design technology is not selected and the orientations of plant structures on the site are not known, the detailed accident analyses and resulting post-accident doses for control room habitability and the Technical Support Center would be performed at the combined license application (COLA) stage, consistent with guidance provided in NUREG–0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Light-Water Reactor (LWR) Edition”(SRP) and revisions (NRC 2007/2018-TN5898, Chapter 2.0, Table 1).

15.0.3.1 Regulatory Basis

The applicable NRC regulatory requirements for the radiological dose consequences analyses of DBAs include the following:

- 10 CFR 52.17, “Contents of applications; technical information” (TN251), as it relates to the assessment that must contain analysis and evaluation of the major structures, systems, and components of the facility that bear significantly on the acceptability of the site under the radiological consequence evaluation factors identified in paragraphs (a)(1)(ix)(A) and (a)(1)(ix)(B) of this section;
- 10 CFR Part 100, “Reactor Site Criteria” (TN282), as it relates to considering evaluation factors for stationary power reactor site applications on or after January 10, 1997, to demonstrate that the radiological dose consequences of postulated accidents shall meet the criteria set forth in 10 CFR 50.34(a)(1) (TN249) for the type of facility proposed to be located at the CRN Site; and
- 10 CFR 50.34, “Contents of applications; technical information” (TN249), as it relates to a description and safety assessment of the site and safety assessment of facility.

The acceptance criteria for meeting the above requirements are located in the following guidance and reference documents:

- Review Standard (RS)-002, “Processing Applications for Early Site Permits” (NRC 2004-TN2219), as it relates to providing guidance on the staff’s process for reviewing an ESP application (ESPA) and developing the FSER with specific technical and format guidance; and
- NUREG–0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Light-Water Reactor (LWR) Edition” (SRP; NRC 2007/2018-TN5898 and revisions), as it relates to providing guidance to staff to perform safety reviews of applications to construct or operate nuclear power plants and the review of applications to approve standard designs and sites for nuclear power plants, to assure the quality and uniformity of the staff safety review.

As required in 10 CFR 52.17(a)(1) (TN251), ESPAs must contain an analysis and evaluation of the major systems, structures, and components of the facility that bear significantly on the acceptability of the site under the radiological consequence evaluation factors identified in the requirements of 10 CFR 52.17(a)(1)(ix) (TN251). In addition, the ESP site characteristics must comply with the requirements of 10 CFR 100.21, “Non-Seismic Siting Criteria” (TN282), which states that radiological dose consequences of postulated accidents shall meet the criteria set forth in 10 CFR 50.34(a)(1) (TN249). The radiological dose reference values in 10 CFR 50.34(a)(1) (TN249) and 10 CFR 52.17(a)(1) (TN251) for a postulated fission product release based on a major accident are as follows:

- An individual located at any point on the boundary of the exclusion area for any 2-hour period following the onset of the postulated fission product release would not receive a radiation dose in excess of 25 roentgen equivalent man (rem) total effective dose equivalent (TEDE).
- An individual located at any point on the outer boundary of the LPZ who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a radiation dose in excess of 25 rem TEDE.

15.0.3.2 Technical Evaluation

Using the guidance listed above, the staff reviewed SSAR Chapter 15 (TVA 2017-TN5387) for compliance with the applicable regulations. Although the applicant is using the PPE approach, for the DBA radiological consequence analysis, the loss of coolant accident (LOCA) source term is selected based upon vendor information, and presents the design with the highest resulting dose at the EAB and the LPZ outer boundary from four SMR designs under consideration. The applicant evaluated the suitability of the site using the bounding LOCA DBA source term and radiological consequences, as well as site characteristic χ/Q factor values.

15.0.3.2.1 Selection of Design Basis Accidents and Source Term

The applicant assessed the LOCA DBA in the design control document for an SMR with vendor-provided PPE source terms. The DBA is addressed in SSAR Sections 15.1 and 15.2 (TVA 2017-TN5387). The staff independently analyzed the information provided by the applicant and finds that the applicant-selected DBA is consistent with the DBAs listed in SRP Chapter 15 (NRC 2007/2018-TN5898) for large LWRs.

Each of the four small modular PWR designs under consideration for the CRN Site is expected to include advanced features that would further minimize accident consequences, as addressed in SSAR Section 1.11 (TVA 2017-TN5387). As such, the Tennessee Valley Authority (TVA) anticipates that the consequences of a LOCA would be less than those for large PWR designs and that no events of greater consequence would be identified.

Thus, the analysis of postulated DBAs other than a LOCA is not necessary for this ESPA, because the maximum potential offsite doses have been evaluated, demonstrating the ability of the site to comply with the dose limits in 10 CFR 52.17 (TN251). In accordance with 10 CFR 52.79(b)(1) (TN251), the COLA would verify that the accident doses provided in the ESPA are bounding or would provide an evaluation of accident radiological consequences. The staff finds this applicant's approach reasonable and acceptable.

The staff's experience with other PWR designs, as documented in other ESPAs to date (examples provided by applicant in SSAR Section 15.1 [TVA 2017-TN5387]), has shown that offsite doses due to a postulated LOCAs are expected to more closely approach 10 CFR 52.17 (TN251) dose criteria than other DBAs that may have greater probability of occurrence but a lesser magnitude of activity release.

The LOCA source term (radionuclide activity released to the environment) selected for inclusion in the PPE is based upon vendor input and represents the design that has the highest resulting dose at the EAB and the LPZ outer boundary from the four SMR designs under consideration. Key parameters associated with the accident source term in the PPE have been evaluated by the applicant to assess their reasonableness for and representativeness of SMR designs.

The PPE LOCA source term is based on a design that uses standard LWR fuel, which is representative of the SMR designs under consideration, and assumes a core power level for a single module at 800 MWt (reactor core). For comparison, for the other three SMR designs considered in the PPE, the values for the rated core thermal power per single unit are 160, 525, and 530 MWt. TVA anticipates that comparable methodologies and techniques that are used for the development of the source terms for large LWRs also would be used in the development of the SMR accident source terms to be presented in SMR design documents.

The source terms developed for the surrogate SMR plant (the design parameters represented by the PPE in lieu of a specific reactor design) are representative of the potential SMR designs that consider core power and average burnup. The maximum average burnup for the surrogate SMR is 51 gigawatt-day/metric-ton of uranium (GWD/MTU), while for the remaining SMRs it is less than 41 GWD/MTU. Although it is recognized that core power and burnup would not necessarily result in one-to-one ratios to activity releases, it is anticipated the larger core power and burnup would result in larger activity releases than those associated with the remaining designs. The bounding DBA LOCA source term is provided in SSAR Table 2.0-3 (TVA 2017-TN5387).

To assess reasonableness, the applicant also provided a comparison of the PPE LOCA source term to that of the Westinghouse Advanced Passive 1000 (AP1000) reactor design, and scaled the source term by a factor of 0.235 (800 MWt/3400 MWt [reactor core]) to account for the smaller core thermal power of the SMR designs being considered for the CRN Site. The worst 2-hour EAB associated activity is approximately 25 percent greater for the scaled AP1000 design than that for the surrogate plant (as provided in the PPE). The applicant considers this difference reasonable given that SMR designs contain additional safety features that are expected to result in reduced accident releases compared to the AP1000 design. The applicant acknowledged approximately 25 percent greater total activity release for the scaled-down AP1000 source term than that for the surrogate plant (as provided in the PPE) for the worst 2-hour period. However, an independent staff evaluation resulted in higher activity release using the same 0.235 scaled-down ratio for all radionuclides for all time periods except for noble gases. This higher release may be attributed to the staff-determined source term that is reduced from the known large LWR release source term by a megawatt ratio that may have not been exactly representative because of unaccounted for fuel and core design differences between the large (AP1000 core) and small (SMR core) fission product inventories. In addition, the bounding SMR source terms used as the basis for the PPE LOCA source term may reflect the SMR design enhanced removal mechanisms and advanced engineering features for larger retention times that are not accounted for in the assumption that the accident release source terms from a large LWR can be reduced in direct relationship to the reduction of the core power. Therefore, the staff's assessment potentially overestimates the potential source term for any specific SMR rated at a reactor core power of 800 MWt. However, this evaluation only ensures that the applicant's PPE LOCA source term is representative and not unreasonable. Moreover, regarding the LOCA source term for the selected SMR for the COLA, the applicant is required (10 CFR 52.79 (a)(1) [TN251]) to demonstrate that the selected SMR LOCA source term is bounded by the PPE LOCA source term. If this is not demonstrated, the applicant shall opt for a variance and demonstrate NRC regulatory compliance with radiological dose criteria for site suitability. Therefore, the staff finds the applicant's bounding source term based on the ratio is not unreasonable, and the bounding vendor-provided SMR source term is also not unreasonable.

Therefore, based on its evaluation of the applicant's information and its own independent analysis to scope the PPE source term, the staff finds the CRN Site SSAR DBA source terms to

be not unreasonable as part of the PPE for showing compliance with requirements of 10 CFR 52.17(a)(1)(ix) (TN251). However, it should be noted that if the bounding DBA source term provided by the applicant does not bound the actual source term for a design selected for the CRN Site, then the radiological consequences of DBAs for the combined license (COL) may exceed the dose results determined in the SSAR (TVA 2017-TN5387). They may also potentially exceed the regulatory dose reference values in 10 CFR 50.34(a)(1) (TN249) and 10 CFR 52.79(a)(1) (TN251). Therefore, the applicant's PPE source term information in SSAR Table 2.0-3 (TVA 2017-TN5387) shall be compared with the COL DBA source term for the design that may be selected for the CRN Site at the time of COL review in accordance with 10 CFR 52.79(b)(1) (TN251). Also, the applicant shall ensure that the radionuclide releases of the PPE bounds the SMR design selected for the CRN Site in meeting the regulatory requirements of 10 CFR 52.79(c)(1) and (d)(1) (TN251).

15.0.3.2.2 Site Characteristic Short-Term Atmospheric Dispersion Factors

Site characteristic short-term (accident) χ/Q values are used in the radiological consequences analyses to characterize the effect of the site-specific meteorological conditions, topography, and distance to either the EAB or LPZ outer boundary on dose at the offsite receptors for purposes of siting. The applicant calculated accident χ/Q factors using RG 1.145 methodology (NRC 1983-TN279) and site-specific meteorological data. The staff's evaluation of the site characteristic short-term χ/Q values is described in Section 2.3.4 of this report. The site characteristic accident χ/Q values calculated by the applicant are given in SSAR Table 2.0-1 (TVA 2017-TN5387).

15.0.3.2.3 Radiological Consequences

Doses for LOCAs are evaluated at the EAB and LPZ outer boundary using site characteristic short-term (accident) χ/Q values for the CRN Site. Site-specific dose results were calculated by the applicant by adjusting the vendor-provided dose results for each time period by the ratio of the site characteristic χ/Q values to the vendor-provided χ/Q values, then adding the dose results for each time period to get a resulting total dose. The CRN Site site-specific doses are presented in SSAR Table 15-1 (TVA 2017-TN5387).

For the LOCA radiological consequence analysis referenced by the CRN Site ESP applicant, the vendor's analyses used the design-specific source term assumptions and inputs and reference site parameter values for the accident χ/Q s in lieu of site-specific values. The χ/Q values are the only input to the DBA radiological consequences analysis that are affected by the site characteristics. The estimated DBA dose calculated for a particular site is affected by the site characteristics through the calculated χ/Q input to the analysis; therefore, the resulting dose would be different than that calculated generically by the vendor with assumed reference χ/Q s. Smaller χ/Q values are associated with greater dilution capability, resulting in lower radiological doses. The applicant also stated that all other inputs and assumptions in the radiological consequences analysis remain the same as in the vendor-provided analysis.

To determine the potential doses resulting from a DBA at the proposed site, the applicant used the site characteristic χ/Q values in conjunction with the DBA doses calculated using site parameter χ/Q values (based on PPE) that were provided by the vendor for the plant design used in the bounding analysis. The estimated site characteristic χ/Q values for the proposed site are higher for the EAB and lower for the LPZ outer boundary than the corresponding site parameter χ/Q values, as summarized below in Table 15.0.3-1.

Table 15.0.3-1 Site Parameter Short-Term χ/Q Values for Vendor Design Site Parameter and Comparison to Site Characteristic χ/Q Values

Location	Release Time (hr)	Site Characteristic χ/Q (sec/m^3)	Vendor Design Site Parameter χ/Q (sec/m^3)	χ/Q Ratio Characteristic/ Parameter	Dose (rem TEDE) Vendor	Dose (rem TEDE) Site
EAB	0-2	4.96 x 10^{-3}	1.0 x 10^{-3}	4.96	4.35	21.6
LPZ	0-8	3.10 x 10^{-4}	5.0 x 10^{-4}	0.620	4.44	2.75
	8-24	2.26 x 10^{-4}	3.0 x 10^{-4}	0.753	0.20	0.15
	24-96	1.14 x 10^{-4}	1.5 x 10^{-4}	0.760	0.05	0.038
	96-720	4.30 x 10^{-5}	8.0 x 10^{-5}	0.538	0.06	0.032
LPZ_{total}	-	-	-	-	-	2.97

The radiological consequence results of a LOCA at the CRN Site, using the PPE and site characteristic accident χ/Q values are 21.6 rem TEDE at the EAB and 2.97 rem TEDE total at the LPZ outer boundary. The calculated radiological consequences at the proposed site are within the regulatory dose criteria of 25 rem TEDE for the maximum 2-hour period at the EAB and 25 rem TEDE at the outer boundary of the LPZ for the duration of the accident release,

Based on its evaluation of the applicant's DBA radiological consequences analysis methodology and the inputs to that analysis, the staff finds that the applicant correctly concluded that the radiological consequences for the considered PPE design technology comply with the radiological dose reference values set forth in 10 CFR 50.34(a)(1) (TN249) and 10 CFR 52.17(a)(1) (TN251).

15.0.3.3 Conclusion

As set forth above, the applicant presented the radiological consequence analysis using PPE values for source terms for the standard design and site characteristic χ/Q values; the applicant concluded that the proposed site meets the radiological dose reference values identified in 10 CFR 50.34(a)(1) (TN249) and 10 CFR 52.17(a)(1) (TN251) for the vendor-provided PPE source terms and site parameter χ/Q values. Based on the technical evaluation presented in Section 15.0.3 of this report, the staff finds that the applicant's PPE values for source terms are not unreasonable. Furthermore, the staff finds the applicant's dose consequence evaluation methodology acceptable. In accordance with 10 CFR 52.79(b)(1) (TN251), a COL applicant referencing the ESP for the CRN Site, if granted, must either include or incorporate by reference the ESP SSAR (TVA 2017-TN5387), and the COLA must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified with respect to radionuclide releases and site characteristics provided in the ESP, if granted.

The staff further concludes that the applicant-determined site characteristic distances to the EAB and the LPZ outer (i.e., outermost) boundary of the proposed CRN Site in SSAR Table 2.0-1 (TVA 2017-TN5387), in conjunction with the PPE design parameter source terms, are adequate to provide reasonable assurance that the radiological consequences of postulated DBAs for a SMR design similar to those used as a basis for the PPE would be within the radiological dose reference values set forth in 10 CFR 50.34(a)(1) (TN249) and 10 CFR 52.17(a)(1) (TN251).

17.0 QUALITY ASSURANCE

17.5 Quality Assurance Program Description – Design Certification, Early Site Permit, and New License Applicants

In a letter to the U.S. Nuclear Regulatory Commission (NRC) dated May 12, 2016 (TVA 2016-TN5002), the Tennessee Valley Authority (TVA) submitted an application for an early site permit (ESP) at the Clinch River Nuclear (CRN) Site in accordance with the requirements contained in Title 10 of the *Code of Federal Regulations* Part 52, "Licenses, Certifications and Approvals for the Nuclear Power Plants" (10 CFR Part 52-TN251). The application was composed of several documents, including Part 8, "Enclosures" (TVA 2016-TN6129). The enclosures included the TVA Nuclear Quality Assurance Plan (NQAP), Revision 32 (TVA 2016-TN5870). The NRC staff reviewed and evaluated TVA's NQAP in accordance with the requirements of 10 CFR 52.17(a)(1)(xi) and (xii) (TN251); Appendix B to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" (TN249).

17.5.1 Summary of Application

TVA ESP Site Safety Analysis Report (SSAR), Revision 1, Section 17.5, "Quality Assurance Program Description – Design Certification, Early Site Permit and New License Applicants" (TVA 2017-TN5387) stated that the NQAP was implemented during the development of the ESP application (ESPA). NQAP Revision 32 is a top-level policy document that defines the quality assurance (QA) policy and assigns major functional responsibilities (TVA 2016-TN5870). The NQAP controls TVA activities that affect the quality of the safety-related structures, systems, and components (SSCs) of the proposed small modular reactors (SMRs) at the CRN Site. The NQAP applies to safety-related SSCs as well as to selected elements of non-safety-related SSCs that are important to plant safety. The NQAP is included in Part 8 of the ESPA (TVA 2016-TN6129).

The TVA NQAP references TVA nuclear personnel and organizations performing activities that affect quality-related SSCs at TVA's nuclear plants and independent spent fuel storage installations (TVA 2016-TN5870). The NQAP is formatted in a manner that identifies documents in the TVA Nuclear Procedure System that were developed to implement the requirements.

During the course of the application review, the staff issued one request for additional information (RAI) comprising eight questions, dated March 9, 2018 (NRC 2018-TN5868). By letter dated April 9, 2018, the applicant responded to the staff's questions (TVA 2018-TN5869). Following an April 16– 20, 2018 QA inspection, which is a standard aspect of NRC's ESP review process, TVA issued NQAP Revision 36 (TVA 2018-TN5867), on May 8, 2018. The staff used Revision 36 of the NQAP as the basis for its review of the QAP for the Clinch River ESPA.

17.5.2 Regulatory Basis

10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants" (TN249), establishes the NRC QA requirements for the design, fabrication, construction, and testing of the facility SSCs. These requirements apply to all activities affecting the safety-related functions of those SSCs. This includes, but is not limited to, designing, procuring, handling, testing, siting, inspecting, storing, training, and shipping.

The technical information requirements for ESPs are set forth in 10 CFR 52.17, “Contents of Applications; Technical Information” (TN251). 10 CFR 52.17(a)(1)(xi) requires that ESPAs provide a description of the QAP applied to site-related activities for the future design, fabrication, construction, and testing of the SSCs of a facility or facilities that may be constructed on the site.

10 CFR 52.17(a)(1)(xii), “Licenses, Certifications and Approvals for the Nuclear Power Plants” (TN251), requires that applications for ESPs include an evaluation of the site against the applicable sections of NUREG–0800, “Standard Review Plan for the Review of Safety Analysis Report for Nuclear Power Plants (LWR Edition),” Revision 1, dated August 2015 (hereafter SRP, NRC 2015-TN5871), that are in effect 6 months prior to the docket date of the application.

17.5.3 Technical Evaluation

The staff used SRP Section 17.5, “Quality Assurance Program Description – Design Certification, Early Site Permit and New License Applicants,” of the SRP (NRC 2015-TN5871), to evaluate the applicant’s QAP. As part of the guidance in SRP Section 17.5, the staff used the American Society of Mechanical Engineers (ASME) Nuclear Quality Assurance (NQA) Standard NQA-1-2008 (ASME 2008-TN6095) and NQA-1a-2009 Addenda (ASME 2009-TN6096), “Quality Assurance Program Requirements for Nuclear Facility Applications,” as supplemented by other regulatory and industry guidance for nuclear operating facilities.

TVA submitted its ESPA in accordance with the requirements of 10 CFR Part 52 (TN251). TVA stated in the application that the site suitability QAP for the Clinch River ESP is carried out in accordance with TVA’s NQAP, which commits to meeting Regulatory Guide (RG) 1.28, “Quality Assurance Program Criteria (Design and Construction),” Revision 3 (which endorses NQA-1-1983 [ASME 1983-TN6097]) (NRC 1985-TN5873). Guidance in the latest revision (Revision 1) of SRP Section 17.5 (NRC 2015-TN5871) is aligned with RG 1.28 Revision 4 (NRC 2010-TN5872), and ASME NQA-1-2008/2009a. Revision 1 of SRP Section 17.5 (NRC 2015-TN5871), which is aligned with RG 1.28 Revision 4 (NRC 2010-TN5872), was in effect more than 6 months prior to submittal of the ESPA, and it extends the scope of the NRC’s endorsement to include Part II of ASME NQA-1 (ASME 2008-TN6095). Part II contains amplifying QA criteria for certain site-specific work activities occurring at various stages of a facility’s life. These work activities include, but are not limited to, management, planning, site investigation, design, computer software use, commercial-grade dedication, procurement, fabrication, installation, inspection, and testing.

The staff conducted a QA implementation inspection of TVA’s ESP activities for a proposed SMR at the CRN Site from April 16 through April 20, 2018. The inspection was complementary to the staff’s safety review of the SSAR QAP programmatic description, because the inspection evaluated the implementation (versus description) of TVA’s QAP for the CRN Site ESPA. The areas inspected included 10 CFR Part 21 (TN5874); corrective actions; QA records; the QAP; internal audits; QA organization; design control; procurement document control; control of purchased material, equipment, and services; and external audits. As described in Inspection Report 05200047/2018-201 (NRC 2018-TN5878), no findings of significance were identified during the inspection.

17.5.3.1 Organization

The staff reviewed the applicant’s NQAP against Criterion I, “Organization” of 10 CFR Part 50, Appendix B (TN249), and guidance of SRP Section 17.5, Paragraph II.A (NRC 2015-TN5871).

Upon the staff's initial review, the NQAP did not meet organizational QA requirements and acceptance criteria described above in Section 17.5.3. For this reason, the staff issued eRAI-8798 (RAI no. 12) (NRC 2018-TN5868), Questions 17.5-01, 17.5-02, and 17.5-03, requesting the applicant to provide a gap analysis and discuss how their QAP addresses differences between RG 1.28 Revision 3 (NRC 1985-TN5873) and Revision 4 (NRC 2010-TN5872). In addition, the staff requested that the applicant address the applicability of 10 CFR Part 52 (TN251), "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants," to the NQAP because the NQAP did not reference 10 CFR Part 52 or provide an indication the NQAP commits to meeting 10 CFR Part 52 requirements. The staff was concerned about organizational elements under the cognizance of the QAP, specifically the SMR activities described in the ESPA. The applicant did not address the authority and duties of persons and organizations associated with Section 4.1.8 "Small Modular Reactor," and the organization chart of Appendix I in NQAP Revision 32 (TVA 2016-TN5870).

The applicant responded in the April 9, 2018 letter (TVA 2018-TN5869) that it would revise the NQAP to address several gaps in the QA requirements between 10 CFR Part 52 (TN251) and the applicant's submitted NQAP. Also, the applicant proposed additional alternatives for addressing the gaps between RG 1.28 Revisions 3 and 4 (NRC 1985-TN5873, NRC 2010-TN5872).

After reviewing TVA's responses (TVA 2018-TN5869) to eRAI-8798 (RAI no. 12), Questions 17.5-01, 17.5-02, 17.5-03, and NQAP Revision 36, the staff determined the applicant addressed the QA requirements of Criterion I of 10 CFR Part 50, Appendix B (TN249). NQAP Revision 36 clarifies and describes the organizational elements for the CRN Site (TVA 2018-TN5867). In addition, the staff determined the applicant addressed organizational elements associated with SMR activities, implementing procedures, and management at the CRN Site. The applicant added Appendices K, L, and M of the NQAP to address gaps between RG 1.28, Revisions 3 and 4 (NRC 1985-TN5873, NRC 2010-TN5872). Appendix K identified site-specific organization information. Appendix K and L identified SMR roles and responsibilities at the CRN Site. Appendix M identified TVA commitments for the CRN Site and clarification for the ESP QAP. Appendices K, L, and M also addressed the applicability of 10 CFR Part 52 (TN251). The staff noted the NQAP provided an organizational description that includes an organizational structure, functional responsibilities, levels of authority, and interfaces to establish, execute, and verify NQAP implementation. The applicant also identified and described major delegation of work involved in establishing and implementing the QAP or any part thereof to other organizations. The staff compared the applicant's responses and revised NQAP Revision 36 (TVA 2018-TN5867) to RG 1.28 Revision 4 (NRC 2010-TN5872), and determined that the added appendices adequately addressed the questions in the eRAI-8798 (RAI no. 12), Questions 17.5-01, 17.5-02, 17.5-03.

Based on the above, the staff finds the applicant's QAP meets Criterion I of 10 CFR Part 50, Appendix B (TN249).

17.5.3.2 Quality Assurance Program

The staff reviewed the applicant's NQAP against Criterion II, "Quality Assurance Program" of 10 CFR Part 50, Appendix B (TN249), using the guidance of SRP Section 17.5, Paragraph II.B (NRC 2015-TN5871). Upon the staff's initial review, the NQAP did not specify how the independent assessment of the CRN Site would be implemented. For this reason, the staff issued eRAI-8798 (RAI no.12), Question 17.5-04, requesting that the applicant clarify how

TVA's NQAP ensures effective implementation of the SMR Project QAP objective assessment at the CRN Site.

The applicant responded by letter on April 9, 2018 (TVA 2018-TN5869) that the QAP is regularly reviewed and commits to following RG 1.28, Revision 3 (NRC 1985-TN5873) and American National Standards Institute (ANSI) Standard N45.2-1971 (ANSI 1971-TN6044), which both state, in part, "the program shall provide for the regular review, by management of organizations participating in the program, of the status and adequacy of that part of the quality assurance program for which they have designated responsibility." In addition, the applicant would revise the NQAP to clarify the applicability of independent assessments to the CRN Site and ensure effective implementation of independent assessments at least once each year.

After reviewing TVA's response (TVA 2018-TN5869) to eRAI-8798 (RAI no. 12), Question 17.5-04, and NQAP Revision 36, the staff determined the applicant addressed the independent assessment of the SMR Project QAP for the CRN Site. The staff also noted the NQAP required the documentation of written policies, procedures, and instructions; adequate indoctrination and training of personnel performing activities; and regular management review of the QAP to assess the effectiveness and the adequacy of the scope and implementation of NQAP Revision 36 (TVA 2018-TN5867). Based on the above, the staff finds the applicant's QAP meets Criterion II of 10 CFR Part 50, Appendix B (TN249).

17.5.3.3 Design Control

The staff noted the applicant's NQAP meets Criterion III, "Design Control" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.C (NRC 2015-TN5871). The NQAP design process includes provisions to control design inputs, outputs, changes, interfaces, records, and organizational interfaces with the applicant and its suppliers. These provisions ensure the design inputs (e.g., design bases and the performance, regulatory, quality, and quality verification requirements) are correctly translated into design outputs (e.g., analyses, specifications, drawings, procedures, and instructions).

Based on the above, the staff finds the applicant's QAP meets Criterion III of 10 CFR Part 50, Appendix B (TN249).

17.5.3.4 Procurement Document Control

The staff noted the applicant's NQAP meets Criterion IV, "Procurement Document Control" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.D (NRC 2015-TN5871), for ensuring that procurement documents include or reference applicable regulatory, technical, and QAP requirements. These requirements (such as specifications, codes, standards, tests, inspections, special processes, and 10 CFR Part 21 (TN5874), "Reporting of Defects and Noncompliance") are invoked for procurement of items and services.

Based on the above, the staff finds the applicant's QAP meets Criterion IV of 10 CFR Part 50, Appendix B (TN249).

17.5.3.5 Instructions, Procedures, and Drawings

The staff noted the applicant's NQAP meets Criterion V, "Instruction, Procedure, and Drawings" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.E (NRC 2015-TN5871), to establish the necessary measures and governing procedures to ensure that activities affecting quality are prescribed by, and performed in accordance with, documented instructions, procedures, and drawings. The staff also noted provisions for instructions, procedures, and drawings included appropriate acceptance criteria for determining that important activities have been satisfactorily accomplished.

Based on the above, the staff finds the applicant's QAP meets Criterion V of 10 CFR Part 50, Appendix B (TN249).

17.5.3.6 Document Control

The staff noted the applicant's NQAP meets Criterion VI, "Document Control" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.F (NRC 2015-TN5871), to control the preparation, review, approval, issuance, and changes of documents that specify quality requirements or prescribe measures for controlling activities that affect quality, including organizational interfaces. The NQAP provides measures to ensure that the same organization that performed the original review and approval also reviews and approves changes, unless other organizations are specifically designated.

Based on the above, the staff finds the applicant's QAP meets Criterion VI of 10 CFR Part 50, Appendix B (TN249).

17.5.3.7 Control of Purchased Material, Equipment, and Services

The staff reviewed the applicant's NQAP against Criterion VII, "Control of Purchased Material, Equipment, and Services," of 10 CFR Part 50, Appendix B (TN249), using the guidance of SRP Section 17.5, Paragraph II.G (NRC 2015-TN5871). Upon the staff's initial review, the applicant's NQAP did not ensure (1) ILAC (International Laboratory Accreditation Cooperation) accreditation was a documented process, (2) the acceptance process was for commercial-grade surveys instead of audits, and (3) at receipt inspection, there is objective evidence to validate the accreditation and that the laboratory has certified that it provided the service in accordance with its accredited International Organization for Standardization and the International Electrotechnical Commission (ISO/IEC) 17025:2005 (ISO 2005-TN6098) program. For this reason, the staff issued eRAI-8798 (RAI no. 12), Question 17.5-06, requesting the applicant clarify how conditions in NEI 14-05, "Guidelines for the Use of Accreditation in Lieu of Commercial Grade Surveys for Procurement of Laboratory Calibration and Test Services," were addressed (NRC 2015-TN5875).

The applicant responded by letter on April 9, 2018 (TVA 2018-TN5869) and noted the NQAP would be revised to ensure performance of a documented review of the supplier's accreditation, replace the term "audit" with the term "survey" to be consistent with the guidance provided in NEI 14-05 (NEI 2014-TN5876), and require that validation be performed at receipt inspection.

After reviewing the response to eRAI-8798 (RAI no. 12), Question 17.5-06 and NQAP Revision 36 (TVA 2018-TN5869), the staff determined the applicant has adequately addressed the conditions for using the ILAC accreditation in the NQAP.

Based on the above, the staff finds the applicant's QAP meets Criterion VII of 10 CFR Part 50, Appendix B (TN249).

17.5.3.8 Identification and Control of Materials, Parts, and Components

The staff noted that the applicant's NQAP meets Criterion VIII, "Identification and Control of Materials, Parts, and Components" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.H (NRC 2015-TN5871), for establishing the necessary measures for the identification and control of items such as materials (including consumables and items with limited shelf life), parts, components, and partially fabricated subassemblies. The identification of items is maintained throughout fabrication, erection, installation, and use so the item can be traced to its documentation.

Based on the above, the staff finds the applicant's QAP meets Criterion VIII of 10 CFR Part 50, Appendix B (TN249).

17.5.3.9 Control of Special Processes

Special processes (e.g., welding, heat treating, chemical cleaning, and nondestructive examinations) in accordance with Criterion IX, "Control of Special Processes" of 10 CFR Part 50, Appendix B (TN249), and SRP Section 17.5, Paragraph II.I (NRC 2015-TN5871), are not applicable to ESP activities. Control of special processes will be addressed in the combined license application (COLA). As such, this element was not reviewed or approved by the NRC staff.

17.5.3.10 Inspection

The staff noted the applicant's NQAP meets Criterion X, "Inspection" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.J (NRC 2015-TN5871), to ensure that items, services, and activities that affect safety meet requirements and conform to specifications, instructions, procedures, and design documents. The inspection program establishes requirements for planning inspections, determining applicable acceptance criteria, setting the frequency of inspection, and identifying special tools needed to perform the inspection. Inspectors are properly qualified personnel and independent of those who performed or directly supervised the work.

Based on the above, the staff finds the applicant's QAP meets Criterion X of 10 CFR Part 50, Appendix B (TN249).

17.5.3.11 Test Control

The staff noted the applicant's NQAP meets Criterion XI, "Test Control" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.K (NRC 2015-TN5871), to demonstrate that items subject to the provisions of the NQAP will perform satisfactorily in service, the plant can be operated safely as designed, and the operation of the plant, as a whole, is satisfactory.

Based on the above, the staff finds the applicant's QAP meets Criterion XI of 10 CFR Part 50, Appendix B (TN249).

17.5.3.12 Control of Measuring and Test Equipment

The staff noted the applicant's NQAP meets Criterion XII, "Control of Measuring and Test Equipment," of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.L (NRC 2015-TN5871), for controlling the calibration, maintenance, and use of measuring and test equipment that provides safety information.

Based on the above, the staff finds the applicant's QAP meets Criterion XII of 10 CFR Part 50, Appendix B (TN249).

17.5.3.13 Handling, Storage, and Shipping

The staff noted the applicant's NQAP meets Criterion XIII, "Handling, Storage and Shipping" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.M (NRC 2015-TN5871), for controlling the handling, storage, packaging, shipping, cleaning, and preserving of items to prevent inadvertent damage or loss and to minimize deterioration.

Based on the above, the staff finds the applicant's QAP meets Criterion XIII of 10 CFR Part 50, Appendix B (TN249).

17.5.3.14 Inspection, Test, and Operating Status

Criterion XIV, "Inspection, Test, and Operating Status," of 10 CFR Part 50, Appendix B (TN249) is not applicable to the Clinch River ESPA because TVA is not constructing a nuclear power plant, and therefore, they are not responsible for determining the operability of SSCs. Test and operating status will be addressed in the COLA. As such, this element was not reviewed or approved by the staff.

17.5.3.15 Nonconforming Materials, Parts, or Components

The staff reviewed the applicant's NQAP against Criterion XV, "Nonconforming Materials, Parts, or Components" of 10 CFR Part 50, Appendix B (TN249), and used the guidance of SRP Section 17.5, Paragraph II.O (NRC 2015-TN5871). Upon the staff's initial review, the NQAP did not ensure measures to notify affected organizations of nonconforming materials, parts, or components. For this reason, the staff issued eRAI-8798 (RAI no. 12), Question 17.5-07, requesting that the applicant clarify how the NQAP provides measures to notify affected organizations about nonconforming items.

The applicant responded by letter on April 9, 2018 (TVA 2018-TN5869) and stated the NQAP satisfies the notification of affected organizations about nonconforming items in the NQAP Adverse Conditions section. The applicant indicated it commits to RG 1.28 Revision 3 (NRC 1985-TN5873) and ANSI N45.2-1971 Section 16 (ANSI 1971-TN6044), which both state that "measures shall include as appropriate, procedures for identification, documentation, segregation, disposition, and notification to affected organizations."

After reviewing the applicant's response to eRAI-8798 (RAI no. 12), Question 17.5-07, and NQAP Revision 36 (TVA 2018-TN5869), the staff determined the applicant addressed measures to notify affected organizations of nonconforming items. The NQAP also controls items, including services that do not conform to specified requirements, to prevent inadvertent installation or use.

Based on the above, the staff finds the applicant's QAP meets Criterion XV of 10 CFR Part 50, Appendix B (TN249).

17.5.3.16 Corrective Action

The staff noted the applicant's NQAP meets Criterion XVI, "Corrective Action" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.P (NRC 2015-TN5871), to promptly identify, control, document, classify, and correct conditions adverse to quality. The NQAP requires personnel to identify conditions adverse to quality and identify trends. Significant conditions adverse to quality are documented and reported to responsible management. In the case of suppliers working on safety-related activities or similar situations, the applicant or holder may delegate specific responsibility for the corrective action program, but the applicant or holder maintains responsibility for the program's effectiveness.

In addition, the staff noted the NQAP provides for establishing the necessary measures to implement a program to identify, evaluate, and report defects and noncompliances in accordance with the requirements of 10 CFR 50.55(e) (TN249) and/or 10 CFR Part 21 (TN5874), as applicable.

Based on the above, the staff finds the applicant's QAP meets Criterion XVI of 10 CFR Part 50, Appendix B (TN249).

17.5.3.17 Quality Assurance Records

The staff reviewed the applicant's NQAP against Criterion XVII, "Quality Assurance Records" of 10 CFR Part 50, Appendix B (TN249), and the guidance of SRP Section 17.5, Paragraph II.Q (NRC 2015-TN5871). Upon the staff's initial review, the NQAP did not identify the types of documents that should be included as QA records or demonstrate how the NQAP satisfies controls and measures for electronic records as described in Regulatory Issue Summary (RIS) 2000-18 (NRC 2000-TN6083), "Guidance on Managing Quality Assurance Records in Electronic Media," and Nuclear Information and Records Management Association (NIRMA) (Technical Guides [TGs] 11 [NIRMA 1998-TN6102], 15 [NIRMA 1998-TN6099], 16 [NIRMA 1998-TN6101], and 21 [NIRMA 1998-TN6100]). For this reason, the staff issued eRAI-8798 (RAI no. 12), Questions 17.5-08 and 17.5-09 requesting that the applicant identify the documents that are considered QA records and how the NQAP controls electronic QA records in accordance with RIS 2000-18 (NRC 2000-TN6083) and NIRMA (TG-11, 15, 16, and 21 [NIRMA 1998-TN6102, TN6099, TN6101, TN6100]).

The applicant responded to eRAI-8798 (RAI no. 12), Question 17.5-08 on April 9, 2018, and stated the NQAP would be revised to clarify the types of documents to be included as QA records and address the storage of QA records in electronic media (TVA 2018-TN5869). The revision would clarify that sufficient records would be maintained to furnish evidence of activities affecting quality, as related to the Clinch River ESPA, and comply with applicable ANSI N45.2.9-1974 requirements (ANSI 1974-TN6051) for the ESP. The applicant added Appendix K, Section 5, to the NQAP to clarify that records include, but are not limited to, geotechnical data, topographic and geological maps, plot plans showing locations of major structures and explorations, boring logs and logs of exploratory trenches and excavations, geologic profiles showing excavation limits of structures, geophysical data, photographs of soil samples and rock cores, field and final logs of all borings, program or design plan, qualified investigation

procedures, procurement control records, personnel qualification records, measuring and test equipment control and calibration records, test records, and procedures.

The applicant also responded to eRAI-8798 (RAI no. 12), Question 17.5-09 on April 9, 2018, and stated the NQAP was being revised to address the storage of QA records in electronic media (TVA 2018-TN5869). With respect to electronic media, the revised NQAP would incorporate the requirements of ANSI/ANS-3.2-2012, Section 3.17 (ANSI 2012-TN6060).

After reviewing the responses to eRAI-8798 (RAI no. 12), Questions 17.5-01, 17.5-08, and 17.5-09, as well as the revised NQAP (TVA 2018-TN5867), the staff determined the applicant adequately addressed the QA records with respect to the types of quality documents and electronic media.

Based on the above, the staff finds the applicant's QAP meets Criterion XVII of 10 CFR Part 50, Appendix B (TN249).

17.5.3.18 Quality Assurance Audits

The staff noted that the applicant's NQAP meets Criterion XVIII, "Audits" of 10 CFR Part 50, Appendix B (TN249), and addresses the acceptance criteria in SRP Section 17.5, Paragraph II.R (NRC 2015-TN5871). The NQAP provides for the applicant or holder to conduct periodic internal and external audits. Internal audits determine the adequacy of the program and its implementing procedures. Internal audits are performed with a frequency commensurate with safety significance. An audit of all applicable QAP elements is completed for each functional area within 2 years after the program becomes well established. External audits determine the adequacy of a supplier's or contractor's QAP. Audit results are documented and reviewed. Management responds to all audit findings and initiates corrective actions. In addition, where corrective actions are indicated, documented follow-up of applicable areas through inspections, review, re-audits, or other means is conducted to verify corrective action.

Based on the above, the staff finds the applicant's QAP meets Criterion XVIII of 10 CFR Part 50, Appendix B (TN249).

17.5.3.19 Non-Safety-Related SSC Quality Assurance Control

17.5.3.19.1 Non-Safety-Related SSCs Important to Plant Safety

The staff noted the guidance of SRP Section 17.5, Paragraph II.U (NRC 2015-TN5871), to establish specific program controls for non-safety-related SSCs that are important to plant safety does not apply to ESPAs. Non-safety-related SSC QA control will be addressed in the COLA. As such, this element was not reviewed or approved by the staff.

17.5.3.20 Regulatory Commitments

The staff reviewed the applicant's operational NQAP, which commits to RG 1.28 Revision 3 (which endorses ANSI N.45.2-1971 [ANSI 1971-TN6044]) (NRC 1985-TN5873). Upon initial ESP review, the staff determined the NQAP did not address the applicability, nor did it reference or provide an indication that the NQAP commits to 10 CFR Part 52 (TN251) requirements, as stated above in Section 17.5.3. After reviewing the applicant's response to eRAI-8798 (RAI no. 12), Question 17.5-01, in addition to NQAP Revision 36 (TVA 2018-TN5869), the staff

determined the applicant addressed QA requirements and acceptance criteria, as listed below. The applicant's RG conformance and alternatives are described in NQAP Appendix B, Tables 1 and 2. The NQAP addresses the acceptance criteria in SRP Section 17.5, Paragraph II.V (NRC 2015-TN5871), to establish QAP commitments. The NQAP commits to the following RGs and QA standards for ESP activities:

- The NQAP does not commit to RIS 2000-18 (NRC 2000-TN6083). However, the NQAP commits to the requirements of ANSI/ANS-3.2.2012, Section 3.17 (ANSI 2012-TN6060), as an alternative to meeting the intent of RIS 2000-18 (NRC 2000-TN6083) and the associated NIRMA TGs: NIRMA TG 11-1998 (NIRMA 1998-TN6102), NIRMA TG 15-1998 (NIRMA 1998-TN6099), NIRMA TG 16-1998 (NIRMA 1998-TN6101), and NIRMA TG 21-1998 (NIRMA 1998-TN6100), as described in Section 17.5.3.17 of this report.
- RG 1.26, Revision 4, dated March 2007, "Quality Group Classification and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants" (NRC 2007-TN5880).
- RG 1.28, Revision 4, June 2010, "Quality Assurance Program Criteria (Design and Construction)" (NRC 2010-TN5872), describes a method acceptable to the NRC staff for complying with the provisions of 10 CFR Part 50, Appendix B (TN249), with regard to establishing and implementing the requisite QAP for the design and construction of nuclear power plants. The TVA NQAP commits to RG 1.28 Revision 3 (NRC 1985-TN5873), but includes equivalent alternatives to address gaps between RG 1.28 Revisions 3 and 4, as addressed in NQAP, Section 3.0, Appendix M, for the CRN ESP QAP.
- RG 1.29, "Seismic Design Classification for Nuclear Power Plants," Revision 5, dated July 2016 (NRC 2016-TN5879), is committed to compliance in the TVA NQAP. Exceptions to this RG are addressed in SSAR Chapter 2, "Site Characteristics and Site Parameters."
- In Appendix M of NQAP, Revision 36 (TVA 2018-TN5867), TVA commits to Generic Letter (GL) 89-02, "Actions to Improve the Detection of Counterfeit and Fraudulently Marketed Products" (NRC 1989-TN5882), and GL 91-05, "Licensee Commercial-Grade Procurement and Dedication Programs" (NRC 1991-TN5881), both of which are endorsed by the NRC.
- The following ANSI standards are committed to in the TVA's NQAP Revision 36 (TVA 2018-TN5867) for compliance:
  - ANSI N45.2-1971, "Quality Assurance Program Requirements for Nuclear Power Plants" (ANSI 1971-TN6044)
  - ANSI N45.2.1-1973, "Cleaning of Fluid Systems and Associated Components During Construction Phase of Nuclear Power Plants" (ANSI 1973-TN6046)
  - ANSI N45.2.2-1972, "Packaging, Shipping, Receiving, Storage, and Handling of Items for Nuclear Power Plants (During Construction Phase)" (ANSI 1972-TN6061)
  - ANSI N45.2.3-1973, "Housekeeping during the Construction Phase of Nuclear Power Plants" (ANSI 1973-TN6047)
  - ANSI N45.2.4-1972, "Installation, Inspection, and Testing Requirements for Instrumentation and Electric Equipment During the Construction of Nuclear Power Generating Stations" (ANSI 1972-TN6045)
  - ANSI N45.2.5-1974, "Supplementary Quality Assurance Requirements for Installation, Inspection, and Testing of Structural Concrete and Structural Steel during the Construction Phase of Nuclear Power Plants" (ANSI 1974-TN6050)

- ANSI N45.2.6-1978, “Qualifications of Inspection, Examination, and Testing Personnel for Nuclear Power Plants” (ANSI 1978-TN6056)
- ANSI N45.2.8-1975, “Supplementary Quality Assurance Requirements for Installation, Inspection, and Testing of Mechanical Equipment and Systems for the Construction Phase of Nuclear Power Plants” (ANSI 1975-TN6053)
- ANSI N45.2.9-1974, “Requirements for Collection, Storage, and Maintenance of Quality Assurance Records for Nuclear Power Plants” (ANSI 1974-TN6051)
- ANSI N.45.2.10-1973, “Quality Assurance Terms and Definitions” (ANSI 1973.-TN6048)
- ANSI N.45.2.11-1974, “Quality Assurance Requirements for the Design of Nuclear Power Plants” (ANSI 1974-TN6052)
- ANSI N.45.2.12-1977, “Requirements for Auditing of Quality Assurance Programs for Nuclear Power Plants” (ANSI 1977-TN6055)
- ANSI N.45.2.13-1976, “Quality Assurance Requirements for Control of Procurement of Items and Services for Nuclear Power Plants” (ANSI 1976-TN6054)
- ANSI N45.2.15-1981, “Hoisting, Rigging, and Transporting of Items for Nuclear Power Plants” (ANSI 1981-TN6059)
- ANSI N45.2.20-1979, “Supplementary Quality Assurance Requirements for Subsurface Investigations for Nuclear Power Plants” (ANSI 1979-TN6058)
- ANSI N45.2.23-1978, “Qualification of Quality Assurance Program Audit Personnel for Nuclear Power Plants” (ANSI 1978-TN6057)
- ANSI N18.7-1976/ ANS-3.2, “Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants” (ANSI 1976-TN6043).

17.5.4 Conclusion

The staff used the provisions of 10 CFR Part 50, Appendix B (TN249), and the guidance of SRP Section 17.5 (NRC 2015-TN5871) to evaluate the NQAP. The staff finds the following:

- The NQAP provides adequate guidance for an applicant to describe the authority and responsibility of management and supervisory personnel, performance and verification personnel, and self-assessment personnel.
- The NQAP gives adequate guidance for an applicant to provide for organizations and persons to perform verification and self-assessment functions with the authority and independence to conduct their activities without undue influence from those directly responsible for costs and schedules.
- The NQAP provides adequate guidance for an applicant to apply the NQAP to activities and items that are important to safety.
- The NQAP provides adequate guidance for establishing controls that, when properly implemented, comply with the requirements of 10 CFR Part 52 (TN251); 10 CFR Part 50, Appendix B (TN249); 10 CFR Part 21 (TN5874); 10 CFR 50.55(e) (TN249); the acceptance criteria contained in SRP Section 17.5 (NRC 2015-TN5871); and with the commitments to applicable regulatory guidance.

On the basis of the staff's review of Chapter 17.5 of the CRN Site ESPA and NQAP Revision 36 (TVA 2018-TN5867), the staff concludes the applicant's QAP description for the CRN Site ESPA meets the requirements of 10 CFR Part 50, Appendix B (TN249).

20.0 REVIEW BY THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

The Advisory Committee on Reactor Safeguards (ACRS) completed its review of the application submitted by the Tennessee Valley Authority (TVA) for an early site permit (ESP) for the Clinch River Nuclear (CRN) Site. The ACRS also completed its review of relevant chapters and sections of the U.S. Nuclear Regulatory Commission (NRC) staff's safety evaluation report (SER).

The ACRS ESP subcommittee met with representatives from TVA and the staff on November 15, 2017 for an information briefing on the ESP concept and the staff's anticipated schedule for reviewing the application. On May 15, August 22, October 17 and November 14, 2018, the ACRS subcommittee convened to discuss all chapters of the TVA ESP Site Safety Analysis Report and the relevant advanced SER chapters and sections with no open items prepared by staff. The discussions during these meetings focused on the staff's review of the suitability of the CRN Site for construction and operation of two or more small modular reactors at the site including topics such as the population surrounding the site, external hazards, site physical characteristics, potential radionuclide releases, and emergency preparedness. There were also discussions about staff site visits and audits; conduct of inspections; coordination with other Federal, State, and local agencies; the staff's independent confirmatory analyses where applicable; and the staff's safety findings and conclusions, including any proposed conditions and action items. This final SER (FSER) documents the staff's findings and conclusions.

At the 659th meeting of the ACRS on December 6–7, 2018, the full committee considered the staff's advanced SER with no open items, as well as TVA's ESP application, and issued its final report to the NRC Chairman on January 9, 2019. This report, as well as a response letter from the staff, is included as Appendix E of this FSER.

In its final report of January 9, 2019 (NRC 2019-TN6135), the ACRS made the following conclusions and recommendations:

- Small modular reactors with design characteristics within the plant parameter envelope used by TVA in developing its CRN Site ESP application can be constructed and operated without undue risk to the health and safety of the public.
- The staff's SER of the TVA ESP application should be issued.
- The ESP for the CRN Site should be issued.

21.0 CONCLUSIONS

In accordance with Subpart A, “Early Site Permits,” of Title 10 of the *Code of Federal Regulations* (10 CFR), Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants” (10 CFR Part 52-TN251), the staff of the U.S. Nuclear Regulatory Commission reviewed the early site permit (ESP) application submitted by Tennessee Valley Authority for the Clinch River Nuclear (CRN) Site. Based on the staff’s evaluation documented in this final safety evaluation report, the staff finds the following with respect to the safety aspects[1] of the ESP application:

1. The applicable standards and requirements of the Atomic Energy Act of 1954, as amended (AEA; 42 U.S.C. § 2011 et seq. [TN663]), and the Commission’s regulations have been met,
2. Required notifications to other agencies or bodies have been duly made,
3. There is reasonable assurance that the site is in conformity with the provisions of the AEA and the Commission’s regulations,
4. The applicant is technically qualified to engage in the activities authorized, and,
5. Issuance of the permit will not be inimical to the common defense and security or to the health and safety of the public.

Further, for the reasons set forth in this final safety evaluation report (FSER), the staff concludes that, taking into consideration the applicable requirements of 10 CFR Part 50 (TN249) and its appendices, 10 CFR Part 52 (TN251) and its appendices, and 10 CFR Part 100 (TN282), two or more small modular reactors that have design characteristics that fall within the design parameters for the site, that have site parameters that fall within the site characteristics for the site, and that meet the terms and conditions proposed by the staff in this FSER, can be safely sited on the CRN Site. If issued, the CRN Site ESP may be referenced in an application to construct and operate two or more small modular nuclear power reactors with a maximum thermal power that does not exceed 800 MWt (reactor core) for a single unit or 2,420 MWt (800 MWe) for two or more units at the CRN Site, subject to the terms and conditions of the permit.

[1] An environmental review was also performed of the ESP application, and its evaluation and conclusions are documented in NUREG-2226, “Environmental Impact Statement for an Early Site Permit (ESP) at the Clinch River Nuclear Site, Final Report,” dated April 2019 (NRC 2019-TN6136).

APPENDIX A

PERMIT CONDITIONS, COL ACTION ITEMS, SITE CHARACTERISTICS, AND BOUNDING DESIGN PARAMETERS

A.1 Permit Conditions

<u>Permit Condition</u>: The Commission's regulations at Title 10 of the *Code of Federal Regulations* (CFR) 52.24 (TN251) require an early site permit (ESP) to specify any terms and conditions of the ESP the Commission deems appropriate. A permit condition is not needed when an existing U.S. Nuclear Regulatory Commission (NRC) regulation requires a future regulatory review of a matter to ensure adequate safety during design, construction, or inspection activities for a new plant. The staff proposes that the Commission include six permit conditions, which are set forth in Table A.1, to control various safety matters.

Table A.1. Permit Conditions to Control Various Safety Matters

Permit Condition Numbers	Permit Conditions
1.7 Permit Condition Number (Permit Condition Number) and [FSER Section]	**Chapter 1, Introduction and General Description**
1.7-1 (7) [1.7]	If an applicant for a CP references this ESP, then references in the ESP SSAR to COL, COL applicant, or COL application will include and apply to a CP, CP applicant, and CP application, respectively, unless the context indicates otherwise.
2.2 Permit Condition Numbers (Permit Condition Numbers) and [FSER Sections]	**Section 2.2, Nearby Industrial, Transportation, and Military Facilities – Permit Conditions**
2.2-1 (1) [2.2.3.3.6.1]	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 Clinch River Nuclear (CRN) Site, as the potential site for a general aviation airport. An applicant for a combined license (COL) or construction permit (CP) referencing this ESP shall evaluate this planned airport, wherever it is to be located, for potential aircraft crash impact probability to determine whether or not it is a design basis event. If the aircraft crash is a design basis event, then the applicant shall demonstrate that the plant may nonetheless be safely operated.
2.2-2 (2) [2.2.3.3.6.1]	An applicant for a COL or CP referencing this ESP shall evaluate and demonstrate compliance with NRC regulations regarding the potential effect onsite and offsite toxic chemicals may have on control room habitability. This evaluation shall account for the onsite storage of chemicals (to be identified in the COL or CP application) and the chemicals anhydrous ammonia, chlorine, and nitric acid transported on Interstate Highway I-40, when the concentration of these chemicals exceeds the

Permit Condition Numbers	Permit Conditions
	respective IDLH (Immediately Dangerous to Life and Health) limit at the CRN Site power block area.
2.5 Permit Condition Numbers (Permit Condition Numbers) and [FSER Sections]	**Section 2.5, Geology, Seismology, and Geotechnical Engineering – Permit Conditions**
2.5-1 (3) [2.5.3.4]	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.
2.5-2 (4) [2.5.4.4]	An applicant for a COL or CP that references this ESP shall remove the material above El. 225.9 m (741 ft) NAVD88 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 COL or CP applicant shall also perform additional geotechnical investigations, in accordance with RG 1.132, at the excavation level to identify any potential geologic features that may adversely impact the stability of subsurface materials and foundations.
13.3 Permit Condition Numbers (Permit Condition Numbers) and [FSER Sections]	**Section 13.3, Emergency Planning – Permit Conditions**
13.3-1 (5) [13.3.3.3.3.5]	An applicant for a COL or CP that references this ESP shall provide detailed information in the COL or CP application that demonstrates that the accident release source term information for the selected small modular reactor (SMR) design used in analyses to support the determination of the plume exposure pathway emergency planning zone (EPZ) size is bounded by the non-design-specific plant parameter source term information below in Table 13.3-1, "Plant Parameter Accident Releases for Determining Emergency Planning Zone (EPZ) Size in Support of Emergency Planning Exemptions." Table 13.3-1 Plant Parameter Accident Releases for Determining Emergency Planning Zone (EPZ) Size in Support of Emergency Planning Exemptions Nuclide / 4-Day Total Activity (Ci) / Nuclide / 4-Day Total Activity (Ci) Kr-85 / 3.29E+03 / Ru-106 / 2.68E+00 Kr-85m / 1.94E+03 / Rh-103m / 4.11E+00 Kr-87 / 1.10E+03 / Rh-106 / 2.70E+00 Kr-88 / 3.04E+03 / Nb-95 / 6.45E+01 Xe-133 / 1.74E+05 / Co-58 / 7.88E-05 Xe-135 / 1.49E+04 / Co-60 / 8.74E-04

Table 13.3-1 (as printed within condition 13.3-1)

Nuclide	4-Day Total Activity (Ci)	Nuclide	4-Day Total Activity (Ci)
Kr-85	3.29E+03	Ru-106	2.68E+00
Kr-85m	1.94E+03	Rh-103m	4.11E+00
Kr-87	1.10E+03	Rh-106	2.70E+00
Kr-88	3.04E+03	Nb-95	6.45E+01
Xe-133	1.74E+05	Co-58	7.88E-05
Xe-135	1.49E+04	Co-60	8.74E-04

<table>
<tr><th>Permit Condition Numbers</th><th>Permit Conditions</th></tr>
<tr><td></td><td>
<table>
<tr><td>Xe-135m</td><td>6.95E+02</td><td>Mo-99</td><td>6.16E+01</td></tr>
<tr><td>Cs-134</td><td>1.26E+02</td><td>Tc-99m</td><td>5.80E+01</td></tr>
<tr><td>Cs-136</td><td>2.82E+01</td><td>Nb-97</td><td>3.95E+00</td></tr>
<tr><td>Cs-137</td><td>8.88E+01</td><td>Nb-97m</td><td>4.61E-01</td></tr>
<tr><td>Rb-86</td><td>9.92E-01</td><td>Ce-141</td><td>1.31E+00</td></tr>
<tr><td>Rb-88</td><td>2.59E+03</td><td>Ce-143</td><td>1.09E+00</td></tr>
<tr><td>Ba-139</td><td>1.22E+01</td><td>Ce-144</td><td>1.10E+00</td></tr>
<tr><td>Ba-140</td><td>4.82E+01</td><td>Np-239</td><td>1.10E+01</td></tr>
<tr><td>Sr-89</td><td>2.20E+01</td><td>Pu-238</td><td>7.75E-03</td></tr>
<tr><td>Sr-90</td><td>7.46E+00</td><td>Pu-239</td><td>3.21E-04</td></tr>
<tr><td>Sr-91</td><td>2.05E+01</td><td>Pu-240</td><td>6.48E-04</td></tr>
<tr><td>Sr-92</td><td>1.27E+01</td><td>Pu-241</td><td>1.60E-01</td></tr>
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<tr><td>I-132</td><td>4.35E+02</td><td>Am-241</td><td>1.06E-04</td></tr>
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<tr><td>Sb-129</td><td>1.23E+01</td><td>La-142</td><td>8.65E-01</td></tr>
<tr><td>Te-127</td><td>1.60E+01</td><td>Nd-147</td><td>6.82E+00</td></tr>
<tr><td>Te-127m</td><td>2.86E+00</td><td>Pr-143</td><td>3.10E-01</td></tr>
<tr><td>Te-129</td><td>1.75E+01</td><td>Y-90</td><td>5.05E-01</td></tr>
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<tr><td>Te-131</td><td>1.09E+01</td><td>Y-91m</td><td>9.90E+00</td></tr>
<tr><td>Rh-105</td><td>2.90E+00</td><td>Pr-144</td><td>9.65E-01</td></tr>
<tr><td>Ru-103</td><td>4.13E+00</td><td>Pr-144m</td><td>1.72E-02</td></tr>
<tr><td>Ru-105</td><td>1.55E+00</td><td></td><td></td></tr>
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<tr><td>13.3 - 2 (6)

[13.3.3.5.3.2]</td><td>An applicant for a COL or CP that references this ESP shall update the emergency plan to describe the on-shift personnel assigned to emergency plan implementing functions based on the chosen SMR technology and the number of proposed reactor units.

In addition, if a COL applicant references this ESP, the COL applicant shall propose a license condition for the COL holder to perform the following:

(i) No later than 18 months before the latest date set forth in the schedule submitted in accordance with 10 CFR 52.99(a) for completing the inspections, tests, and analyses in the Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC), the licensee shall have performed a detailed staffing analysis, in accordance with the latest NRC-endorsed revision of Nuclear Energy Institute (NEI) 10-05, “Assessment of On-Shift Emergency Response Organization Staffing and Capabilities.”
(ii) No later than 180 days before the date scheduled for initial fuel loading set forth in the notification submitted in accordance with 10 CFR 52.103(a), the licensee shall have revised the emergency plan to incorporate any changes identified in the staffing analysis that are needed to bring staffing to the required levels.</td></tr>
</table>

Permit Condition Numbers	Permit Conditions
	If a CP applicant references this ESP, the CP applicant shall propose a permit condition for the operating license applicant to: (i) Perform a detailed staffing analysis, in accordance with the latest NRC-endorsed revision of Nuclear Energy Institute (NEI) 10-05, "Assessment of On-Shift Emergency Response Organization Staffing and Capabilities." (ii) Revise the emergency plan to incorporate any changes identified in the staffing analysis that are needed to bring staffing to the required levels.
FSER = Final Safety Evaluation Report	

A.2 COL Action Items

COL Action Items: The COL Action Items set forth in the Final Safety Evaluation Report (FSER) and incorporated herein identify certain matters that shall be addressed in the safety analysis report (SAR) by an applicant for a COL or CP who submits an application referencing the ESP, if granted, for the CRN Site. These items constitute information requirements but do not form the only acceptable set of information in the SAR. An applicant may depart from or omit these items, provided that the departure or omission is identified and justified in the SAR. In addition, these items do not relieve an applicant from any requirement in 10 CFR Parts 50 (TN249) and 52 (TN251) that governs the application. After issuance of a CP or COL, these items are not controlled by NRC requirements unless such items are restated in the preliminary SAR or final SAR, respectively.

The staff identified the COL Action Items listed in Table A.2 to ensure that particular significant issues are tracked and considered during the review of a later COL or CP application referencing the ESP, if granted, for the CRN Site.

Table A.2. COL Action Items

COL Action Item Numbers	COL Action Item
2.3 COL Action Item Numbers and [FSER Sections]	**Section 2.3, Meteorology – COL Action Items**
2.3-1 [2.3.2.3.1.2]	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 [2.3.3.3.1.3]	An applicant for a COL or a CP referencing this ESP should verify that the onsite meteorological measurement system, including the instrument tower, expected at the site prior to operation, is as described in site safety analysis report (SSAR) Section 2.3.3. Any differences in instrumentation, exposure, or siting should be identified and discussed to demonstrate that the

COL Action Item Numbers	COL Action Item
	meteorological measurements program continues to meet the guidance provided in Regulatory Guide (RG) 1.23.
2.3-3 [2.3.3.3.1.3]	An applicant for a COL or a CP referencing this ESP should clarify whether the operational phase of the onsite meteorological measurements program will include wind data averaging on the basis of scalar or vector averages.
2.3-4 [2.3.3.3.1.3]	An applicant for a COL or a CP referencing this ESP should identify and justify the wind speed and direction averaging approach(es) (either vector or scalar) used in the COL or CP application: • for modeling accident-related Control Room and Technical Support Center (TSC) atmospheric dispersion; and • for use during the operational phase to support emergency planning.
2.4 COL Action Item Numbers and [FSER Sections]	**Section 2.4, Hydrology – COL Action Items**
2.4-1 [2.4.2.3.3.2]	An applicant for a COL or CP that references this ESP should design the site grading to provide flooding protection to safety-related structures at the CRN Site based on a comprehensive flood water routing analysis for a local intense precipitation (LIP) event.
2.4-2 [2.4.10.3.1]	An applicant for a COL or CP referencing this this ESP should address whether the local flood elevation exceeds the site grade elevation and whether the local flood elevation justifies flood protection measures to prevent flooding of any safety-related structures, systems and components (SSCs). If so, the applicant should address necessary flooding protection for safety-related SSCs based on the flooding event and associated effects.
2.4-3 [2.4.12.3.8.2]	An applicant for a COL or CP that references this ESP should establish, as part of its plan to minimize contamination in accordance with 10 CFR 20.1406, a baseline for background radionuclide concentrations.
2.4-4 [2.4.13.4.7.2]	An applicant for a COL or CP referencing this ESP should verify that the calculated dose to members of the public from a postulated accidental liquid radionuclide effluent release to the groundwater from a chosen reactor design at the CRN Site is bounded by the dose evaluated in the CRN Site ESP application (ESPA) as reviewed by the NRC staff. The applicant should evaluate discrepancies and justify any changes made to address differences in the source term for the reactor design used to calculate the dose for a COL or CP application.
2.5 COL Action Item Numbers and [FSER Sections]	**Section 2.5, Geology, Seismology, and Geotechnical Engineering – COL Action Items**

COL Action Item Numbers	COL Action Item
2.5-1 [2.5.4.3.1.3]	An applicant for a COL or CP referencing this ESP, upon selection of a final technology and site location, should conduct further evaluation of the shear-fracture zones and weathered fracture zones at the CRN Site.
2.5-2 [2.5.4.3.1.4]	Upon selection of a final technology and site location, an applicant for a COL or CP referencing this ESP, should reevaluate the potential for karstic cavity impacts, within the zone of influence of the foundation under all design loading conditions, and on foundation stabilities for safety-related structures. The evaluation should be performed using a method that can adequately model foundation performance under actual site geologic conditions and specific loading conditions. In the evaluation, detailed information should be provided to address the site subsurface geologic characteristics, foundation dimension and embedment depth, the lateral location of the foundation with respect to the bedding planes and shear-fracture zones, location and dimension of voids, the shear strength at the bedding planes and shear-fracture zones, the in situ stresses around the foundations, and proper subsurface material properties to be used. The analysis should also take into account undetected cavities that could adversely affect foundation performance and include details related to the expected size of such a potential cavity.
2.5-3 [2.5.4.3.1.4]	An applicant for a COL or CP referencing this this ESP should conduct additional surface geophysical surveys during excavation to detect cavities below the foundation elevation that could adversely affect foundation performance. In addition, the applicant should perform confirmatory drilling or borehole testing during excavation to characterize any geophysical anomalies detected. Finally, if needed, the applicant should develop a grouting program based on the information obtained from the geologic mapping, geophysical surveys, and specific analyses, to mitigate the effect of voids or cavities on foundation performance at and below the foundation levels of safety-related structures. If a grouting program is needed, the associated ITAAC should be specified.
2.5-4 [NA]	Previously developed COL Action Item 2.5-4 now covered by Permit Condition 2.5-2 (Permit Condition 4).
2.5-5 [2.5.4.3.2.8]	An applicant for a COL or CP referencing this ESP should perform additional testing to determine rock mass properties and to further characterize the rock shear strength along the bedding planes with discontinuities and fracture zones in areas where the safety-related structures will be located.
2.5-6 [2.5.4.3.5.1]	An applicant for a COL or CP referencing this ESP should provide specific details regarding the lateral and vertical extent of the excavation consistent with the selected reactor technology.
2.5-7 [2.5.4.3.5.2]	An applicant for a COL or CP referencing this ESP should specify excavation procedures and methods that will not have adverse impacts on the integrity of the foundation subsurface materials. The applicant should design proper excavation support, and evaluate the stability of excavation slopes. The applicant should develop a monitoring plan that includes detailed instrumentation and data collection to monitor slope movement and heave of

COL Action Item Numbers	COL Action Item
	subsurface materials due to excavation, changes in pore pressures of soil underneath the foundation, and displacement of the foundation during and after construction.
2.5-8 [2.5.4.3.5.2]	An applicant for a COL or CP referencing this ESP should provide the detailed design of backfill materials including identification of sources and quantity requirements, backfill material property and placement specifications, applicable industry standards, and related ITAAC. The in-place backfill hydraulic characteristics, such as permeability and porosity, should be consistent with those specified in the SSAR. If differences exist, then their effect on the site conceptual model and site characterization, as described in the SSAR, should be evaluated.
2.5-9 [2.5.4.3.6]	An applicant for a COL or CP referencing this ESP should provide the detailed design of dewatering and groundwater control during excavation and construction, including a monitoring plan, and provide an evaluation of the impact of dewatering on the stability of foundations.
2.5-10 [2.5.4.3.6]	An applicant for a COL or CP referencing this ESP should provide the detailed design for foundation protection based on the chemical characteristics of the groundwater and foundation and fills materials at the site consistent with the applicable industrial standards.
2.5-11 [2.5.4.3.7]	An applicant for a COL or CP referencing this ESP should develop seismic wave velocity profiles for the locations where the safety-related structures will be built, based on sufficient detailed site investigation data and with consideration of uncertainties and variability. The applicant should determine the appropriate damping and shear modulus reduction properties for soil and rock for in situ subsurface materials at the CRN Site based on test data and/or justifiable generic curves.
2.5-12 [2.5.4.3.10.1]	An applicant for a COL or CP referencing this ESP should evaluate the foundation bearing capacity for safety-related structures, based on the selected plant structure and foundation designs and actual geologic conditions at the CRN Site under anticipated maximum static and dynamic loadings.
2.5-13 [2.5.4.3.10.2]	An applicant for a COL or CP referencing this ESP should evaluate the foundation settlement and heave for safety-related structures, based on the selected plant structure and foundation designs, and actual geologic conditions at the CRN Site under anticipated excavation depth and maximum static and dynamic loadings.
2.5-14 [2.5.4.3.10.3]	An applicant for a COL or CP referencing this ESP should evaluate the maximum lateral earth pressure and its distribution along foundation and structure walls below ground. The total lateral earth pressure should include pressures contributed from static soil pressure, hydrostatic pressure, surcharge-induced (equipment and adjacent structures) pressure and seismic lateral earth pressure at the CRN Site under anticipated maximum static and dynamic loadings.

COL Action Item Numbers	COL Action Item
2.5-15 [2.5.4.3.11]	An applicant for a COL or CP referencing this ESP should identify and reevaluate geotechnical engineering-related design criteria to meet applicable industrial standards and NRC regulations.
2.5-16 [2.5.4.3.12]	An applicant for a COL or CP referencing this ESP should evaluate subsurface conditions in the influence zone of foundations for safety-related structures when karst or other geologic hazard features are discovered. The applicant should determine remediation methods after evaluating the presence of geologic hazard features based on the results of adequate and more detailed geophysical testing at the site.
2.5-17 (2.5.5.3)	An applicant for a COL or CP that references this ESP should perform a slope stability analysis of any safety-related slopes, including dams and dikes, consistent with the selected reactor technology.
11.2.3 & 11.3.3 COL Action Item Number and [FSER Section]	**Sections 11.2.3 and 11.3.3, Radioactive Waste Management – COL Action Item**
11-1 [11.4.2]	An applicant for a COL or CP referencing this ESP should verify that the calculated doses to members of the public from normal gaseous and liquid effluent releases for a chosen reactor design at the CRN Site are bounded by the doses evaluated in this ESPA as reviewed by the NRC staff. The applicant should evaluate discrepancies and justify any changes made to address differences in the source term for the reactor design used to calculate the doses for a COL or CP application.
13.3 COL Action Item Numbers and [FSER Sections]	**Section 13.3, Emergency Planning – COL Action Items**
13.3-1 [13.3.3.4]	An applicant for a COL or CP that references this ESP should identify the chosen SMR technology for the CRN Site, including the applicable ESP major features emergency plan, or, if appropriate, a new emergency plan for NRC review. In addition, if the accident dose consequences of the chosen SMR technology support the site boundary plume exposure pathway (PEP) EPZ, the applicant will inform the offsite response organizations regarding establishment of the PEP EPZ at the site boundary. The applicant should update the major features emergency plan to reflect the chosen SMR technology, and incorporate it into a complete and integrated emergency plan. In addition, the applicant should provide detailed information that shows the ability of the chosen SMR technology to meet the applicable PEP EPZ, as described in ESPA, Part 2, Section 13.3.3, “Emergency Planning Zones.”
13.3-2 [13.3.3.5.2]	An applicant for a COL or CP that references this ESP should submit to the NRC up-to-date letters of agreement or memoranda of understanding with offsite support organizations, which address the concept of operations in support of their respective emergency response roles associated with the chosen plant design, including hostile actions at the CRN Site, consistent with

COL Action Item Numbers	COL Action Item
	applicable requirements and guidance, including 10 CFR 52.79(a)(22)(i) and (ii) and 10 CFR 50.47(b), (c).
13.3-3 [13.3.3.5.3]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe on-shift emergency response organization staffing in support of the chosen SMR technology for the CRN Site, including the capability for Tennessee Valley Authority's (TVA's) onsite and offsite emergency response organization positions to be staffed and emergency response facilities activated, consistent with the applicable requirements and guidance.
13.3-4 [13.3.3.5.5]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the emergency classification and action level scheme applicable to the chosen SMR technology for the CRN Site, consistent with the applicable requirements and guidance.
13.3-5 [13.3.3.5.6]	An applicant for a COL or CP that references this ESP, including the Part 5B Emergency Plan (2-Mile Emergency Planning Zone [EPZ]), should update the emergency plan to describe the chosen Alert and Notification System (ANS) network(s), which reflects the assessment of the various technologies by TVA and the affected State and local agencies, and meets the applicable requirements and guidance.
13.3-6 [13.3.3.5.7]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the CRN Site Emergency Communications Equipment, including all required communications and data links, associated with the chosen SMR technology, consistent with the applicable regulations and guidance.
13.3-7 [13.3.3.5.8]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location, function, and capabilities of the Joint Information Center (JIC), consistent with the applicable regulations and guidance.
13.3-8 [13.3.3.5.9]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe onsite monitoring systems and equipment, including the installed Radiation Monitoring System, consistent with the applicable regulations and guidance.
13.3-9 [13.3.3.5.9]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe how the criteria in Section 2 of NUREG-0696 and Section 8 of Supplement 1 to NUREG-0737 are met for the TSC, including the emergency classification requiring activation and the time frame for designated personnel to report to the TSC and achieve full functional operation.
13.3-10 [13.3.3.5.9]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location of the Operations Support Center (OSC) and communications capabilities consistent with Section 3.3 of NUREG-0696.

COL Action Item Numbers	COL Action Item
13.3-11 [13.3.3.5.9]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location, function, and capabilities of the Local Recovery Center (LRC). In addition, the applicant should describe how the LRC meets the applicable requirements in Sections IV.E.8.b and IV.E.8.d of Appendix E to 10 CFR Part 50, and the criteria in Sections IV.D and IV.I of NSIR/DPR-ISG-01.
13.3-12 [13.3.3.5.9]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the capability of the Central Emergency Control Center (CECC) to support response to events occurring simultaneously at the CRN Site and at one or more of the other TVA nuclear power reactor sites that are served by the CECC. The CECC description should address, as a minimum, the following considerations, consistent with the applicable regulations and guidance. a. The facility's location and size. b. The prescribed activation time for the facility. c. Whether the facility would be able to fulfill its intended required emergency response functions. d. The anticipated staffing (including response time) and training of licensee emergency response personnel at the facility. e. The facility's communication capabilities and data systems. f. The availability in the facility of the radiation monitoring system and Safety Parameter Display System (SPDS) plant parameter variables, including those identified in NRC RG 1.97, Revision 4, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants" (or other applicable guidance). g. The facility's capacity for accommodating a multi-site event. h. Impact on the NRC and/or State and local response organizations.
13.3-13 [13.3.3.5.10]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the radiation monitoring and other systems and equipment, including potential major release points from the plant, associated with the chosen SMR technology that support accident assessment activities. The emergency plan should also identify the specific monitoring capability for the radiological parameters identified in NRC RG 1.97, Revision 4 (or other applicable guidance), and the dose assessment and projection modeling system.
13.3-14 [13.3.3.5.10]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the new meteorological tower and meteorological monitoring program at the CRN Site, in accordance with NRC RG 1.23, Revision 1, "Meteorological Monitoring Programs for Nuclear Power Plants." The emergency plan should also describe the specific design, instrumentation, and capabilities to provide required meteorological information in support of the new reactor(s) at the CRN Site.
13.3-15 [13.3.3.5.12]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the location of the onsite personnel decontamination facility.

COL Action Item Numbers	COL Action Item
13.3-16 [13.3.3.5.15]	An applicant for a COL or CP that references this ESP should update the emergency plan to describe the frequency for communications testing, and for the conduct of hostile action exercises, consistent with the applicable regulations and guidance.

A.3 Site Characteristics

Site Characteristics: Based on site investigation, exploration, analysis, and testing, the applicant initially proposed a set of site characteristics. These site characteristics are specific physical attributes of the site, whether natural or manmade. Site characteristics, reviewed and approved by the staff, are specified in the ESP for the CRN Site, if granted. Information in a COL application referencing an ESP must be sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP. The staff proposes to include the site characteristics listed in Table A.3 in the ESP, if granted, for the CRN Site.

Table A.3. Site Characteristics to be Included in the ESP

Characteristic/Parameter	Site-Specific Value[(a)]	Description
Geography and Demography		
Exclusion Area Boundary (EAB)	Clinch River Property Boundary	The area surrounding the reactors, in which the reactor licensee has the authority to determine all activities, including exclusion or removal of personnel and property from the area.
Low Population Zone	1 mi from CRN Site center point	The area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken in their behalf in the event of a serious accident.
Population Center Distance	4.8 mi (southeast)	The distance from the site center point to the nearest boundary of a densely populated center containing more than about 25,000 residents.
Meteorology and Hydrology		
Winter Precipitation		
Normal Winter Precipitation Event	21.9 psf	The maximum ground-level weight (lb/ft^2) of the 1) 100-year return snowpack (snow cover), 2) historical snowpack (snow cover), 3) 100-year return 2-day snowfall event, or 4) historical maximum 2-day snowfall event.

Characteristic/Parameter	Site-Specific Value[(a)]	Description
Extreme Frozen Winter Precipitation Event	21.9 psf	The maximum ground-level weight (lb/ft^2) of the 1) 100-year return 2-day snowfall event or 2) historical maximum 2-day snowfall event.
Extreme Liquid Winter Precipitation Event (48-hour Probable Maximum Winter Precipitation (PMWP))	23.5 in	The extreme liquid winter precipitation event is defined as the theoretically greatest ground-level depth of precipitation (in inches of water) for a 48-hour period that is physically possible over a 25.9 square kilometer (10 square mile) area at a particular geographical location during those months with the historically highest snowpacks.
Potential for Frazil Ice in Ultimate Heat Sink (UHS) Water Storage Facility	NA	Potential for accumulated ice formation in the UHS Water Storage Facility in a turbulent flow condition.
Maximum Rainfall Rate	18.8 in/hr 6 in/5-minutes	PMP for 1-hour and for 5-minute durations at the site estimated from Hydro-Meteorological Report HMR-52.
(SRI/CEII) Maximum Flood (or Tsunami)	[[redacted]] ft NGVD29 ([[redacted]] ft NAVD88) –Still water [[redacted]] ft – wind-wave [[redacted]] ft NGVD29 ([[redacted]] ft NAVD88) –Combined	Predicted maximum flood level (including wave run-up) from external events, not including local PMP.
Maximum Ground Water	816.1 ft NAVD88	Maximum groundwater level under deep foundation structures in power block area.
Basic Wind Speed	96.3 mph for a 3-second gust	Wind velocity at 33 ft above ground for Exposure Category C associated with a 100-year return period in the site area.
Historical Maximum Wind Speed	87 mph for a 3-second gust 73 mph fastest mile	The resulting windspeed for nominal 3-second peak-gust values at a height of 33 ft in flat open terrain.
Design-Basis Hurricane Windspeed	130 mph for a 3-second gust	Wind velocity at 33 ft above ground associated with the most severe hurricane wind that has been historically observed in the site region.
Tornado		
Maximum Pressure Drop	1.2 psi	Decrease in ambient pressure from normal atmospheric pressure at the site due to passage of a tornado having a probability of occurrence of 10^{-7} per year.

Characteristic/Parameter	Site-Specific Value[(a)]	Description
Maximum Rotational Speed	184 mph	Rotation component of maximum wind speed at the site due to passage of a tornado having a probability of occurrence of 10^{-7} per year.
Maximum Translational Speed	46 mph	Translation component of maximum wind speed at the site due to the movement across the ground of a tornado having a probability of occurrence of 10^{-7} per year.
Maximum Wind Speed	230 mph	Sum of the maximum rotational and translational wind speed components at the site due to passage of a tornado having a probability of occurrence of 10^{-7} per year.
Radius of Maximum Rotational Speed	150 ft	Distance from the center of the tornado at which the maximum rotational wind speed occurs at site due to passage of a tornado having a probability of occurrence of 10^{-7} per year.
Rate of Pressure Drop	0.5 psi/s	Maximum rate of pressure drop at site due to passage of a tornado having a probability of occurrence of 10^{-7} per year.
Site Characteristic Ambient Air Temperatures		
Site characteristic wet bulb and dry bulb temperatures associated with the listed exceedance values and the 100-year return period.		
Maximum Dry Bulb Temperature with Maximum Wet Bulb Temperature		
The maximum dry-bulb temperature that has existed at the site for 2 hours or more combined with the maximum wet-bulb temperature that exists in that population of dry-bulb temperatures.		
95% Annual Exceedance	30°F Dry Bulb	
5% Annual Exceedance	85°F Dry Bulb 71.8°F Coincident Wet Bulb	
2% Annual Exceedance	90°F Dry Bulb 73.7°F Coincident Wet Bulb	
1% Annual Exceedance	92°F Dry Bulb 74.2°F Coincident Wet Bulb	
0.4% Annual Exceedance	95°F Dry Bulb 74.9°F Coincident Wet Bulb	
0% Annual Exceedance	105°F Dry Bulb 74.6°F Coincident Wet Bulb	
100-Year Return Period	107°F Dry Bulb 73.1°F Coincident Wet Bulb	

Characteristic/Parameter	Site-Specific Value[(a)]	Description
Maximum Non-Coincident Wet Bulb Temperature		
The maximum historic wet-bulb temperature recorded for 2 or more hours.		
2% Annual Exceedance	75.7°F	
1% Annual Exceedance	76.7°F	
0.4% Annual Exceedance	77.6°F	
0% Annual Exceedance	81.7°F	
100-Year Return Period	83.6°F	
Minimum Dry Bulb Temperature		
2% Annual Exceedance	25°F	
1% Annual Exceedance	21°F	
0.4% Annual Exceedance	16°F	
0% Annual Exceedance	-9°F	
100-Year Return Period	-9.9°F	
Atmospheric Dispersion (X/Q) (Accident)		
0-2 hr @ EAB	4.96×10^{-3} s/m^3	Atmospheric dispersion coefficients used in the design safety analyses to estimate dose consequences of accident airborne releases.
0-8 hr @ LPZ	3.10×10^{-4} s/m^3	
8-24 hr @ LPZ	2.26×10^{-4} s/m^3	
1-4 day @ LPZ	1.14×10^{-4} s/m^3	
4-30 day @ LPZ	4.30×10^{-5} s/m^3	
Atmospheric Dispersion (X/Q) (Annual Average)	SSAR Rev. 2 Table 2.3.5-10	Atmospheric dispersion coefficient used in the safety analysis for the dose consequences of normal airborne releases.
Gaseous Releases Dose Consequences		
Normal	10 CFR 20, App. B 10 CFR 50, App. I	Estimated design radiological dose consequences due to gaseous releases from normal operation of the plant.
Post-Accident	10 CFR 52.17(a)(1)(ix)	Estimated design radiological dose consequences due to gaseous releases from postulated accidents.
Minimum Distance from Release Point to EAB	1100 ft	Minimum lateral distance from the effluent release boundary to the EAB.
Liquid Releases Dose Consequences		
Normal	10 CFR 20, App. B 10 CFR 50, App. I	Estimated design radiological dose consequences due to liquid effluent releases from normal operation of the plant.

Characteristic/Parameter	Site-Specific Value[(a)]	Description
Post-Accident	10 CFR 20, App. B DC/COL-ISG-013	Estimated design radiological dose consequences due to liquid effluent releases from postulated accidents.
Geology, Seismology, and Geotechnical Engineering		
Ground Motion Response Spectra	SSAR Rev. 2 Figure 2.5.2-78	The design response spectra used to establish a plant's seismic design.
Capable Tectonic Structures or Sources	None	The assumption made in a plant design about the presence of capable faults or earthquake sources in the vicinity of the plant site (e.g., no fault displacement potential within the investigative area).
Soil Properties		
Liquefaction	None	Liquefaction potential at the site.
Minimum Bearing Capacity (Static)	110 ksf	Allowable load-bearing capacity of layer supporting plant structures.
Minimum Shear Wave Velocity	4650 fps	Propagation velocity of shear waves through foundation materials.
Dynamic Bearing Capacity	110 ksf	Capacity of the foundation soil/rock to resist loads imposed by the structures in the event of an earthquake.
Minimum Soil Angle of Internal Friction	36°	Minimum value of the internal friction angle of foundation soils, fill soils, or excavation slopes that would provide a safe design of the plant through soil structure interaction analyses including sliding along the base.
(a) Values shown are for a single unit, but would be the same value for each additional unit.		

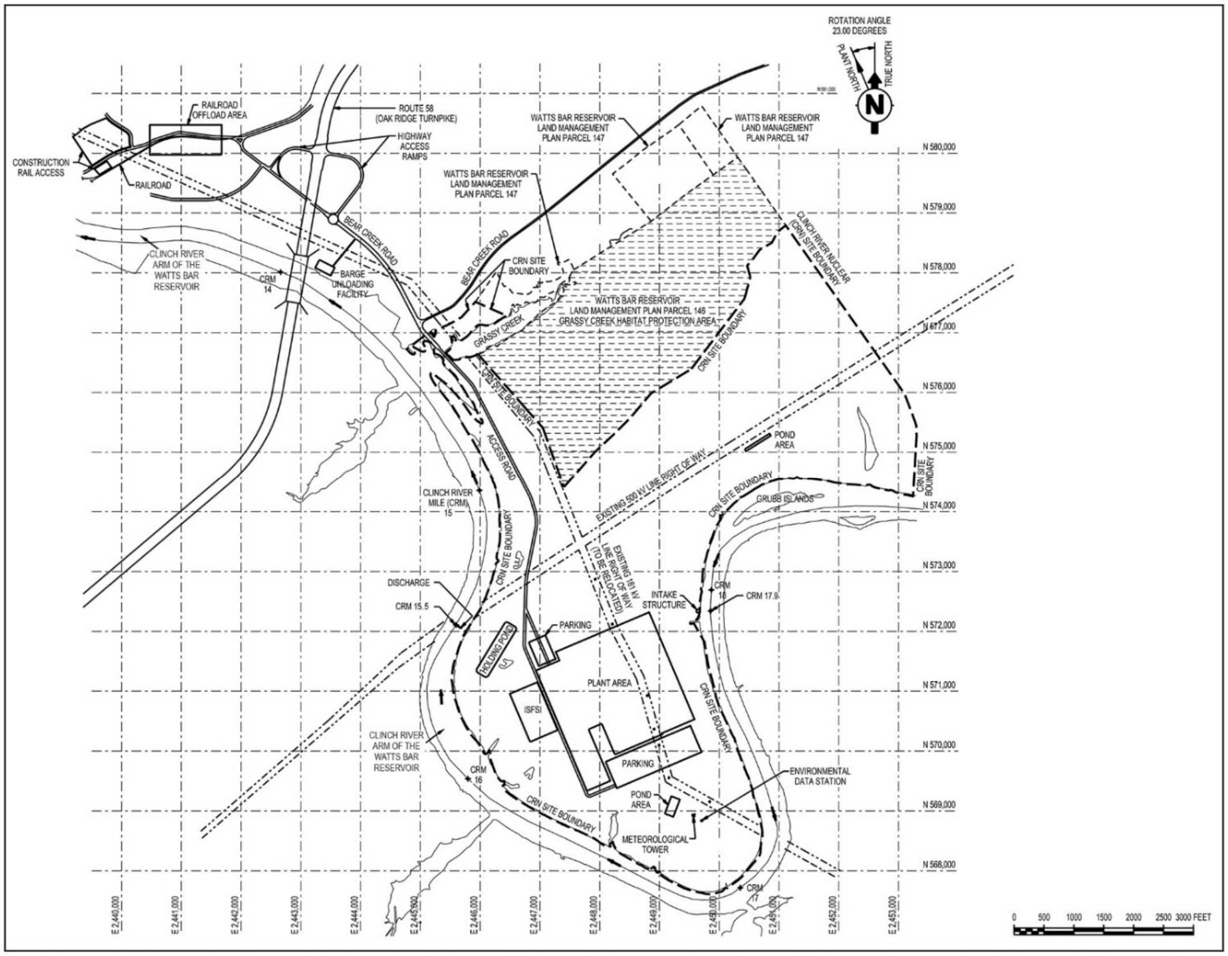

Figure A-1. CRN Site Boundary (Reproduced from SSAR Revision 1, Figure 1.2-1)

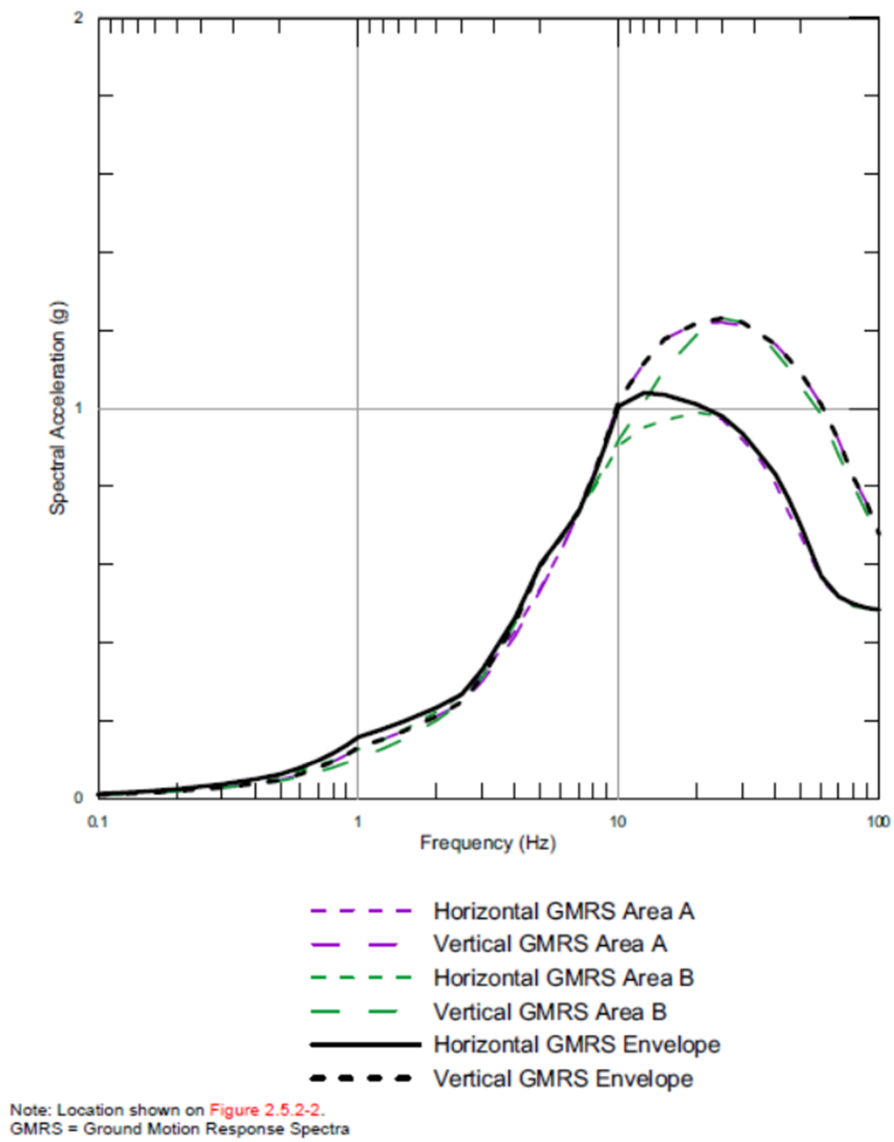

Figure A-2. Plots of the Horizontal and Vertical Ground Motion Response Spectrum (GMRS) (Reproduced from SSAR Revision 1, Figure 2.5.2-78)

A.4 Bounding Design Parameters

Bounding Design Parameters: The bounding design parameters are postulated features of a reactor or reactors that could be built at a proposed site that are specified to support the NRC staff's review of an ESPA. Because the NRC staff is relying on certain design parameters specified in the ESPA to reach its conclusions about site suitability, these bounding design parameters would be included in the ESP that might be issued for the CRN Site. A COL or CP application referencing the ESP, if granted, must contain information sufficient to demonstrate that the actual characteristics of the design chosen by the COL or CP applicant falls within the bounding design parameters specified in the ESP, as listed in Table A.4.

Table A.4. Bounding Design Parameters Specified in the ESP

Characteristic/ Parameter	Bounding Value[(a)]	Description
Structure Height	160 ft	The height from finished grade to the top of the tallest power block structure, excluding stacks and cooling towers.
Structure Foundation Embedment	138 ft	The depth from finished grade to the bottom of the basemat for the most deeply embedded power block structure.
Plant Megawatts Thermal	800 MWt (reactor core) (805 MWt including reactor coolant pump) [2,420 MWt]	The maximum thermal power generated by one unit and the maximum thermal power for the site.
Minimum Site Grade	821 ft NAVD88	Minimum finished ground elevation in the power block area.
Condenser/Heat Exchanger Design Duty	[5,593 MBTU/hr]	Design value for the waste heat rejected to the circulating water system across the condensers.
Gaseous Releases		
Source Term (Accident)	Refer to SSAR Table 2.0-3	Bounding design basis accident atmospheric release by post-accident interval.
Source Term (Normal)	Refer to SSAR Table 2.0-4	Annual activity, by radionuclide, contained in routine plant airborne effluent streams.
Release Point Elevation		
Accident	Ground level	The elevation above finished grade of the release point for releases due to an accident.
Normal	Ground level	The elevation above finished grade of the release point for normal effluent releases.
Liquid Releases		
Accidental Release	Refer to SSAR Table 2.0-5	The assumed activity, by radionuclide, contained in accidental liquid radwaste release.
Source Term (Normal)	Refer to SSAR Table 2.0-6	Annual activity, by isotope, contained in routine plant liquid effluent streams.

(a) Values shown are for a single unit, but would be the same value for each additional unit. Bracketed numbers represent the value for multiple units at the site.

APPENDIX B

CHRONOLOGY OF AN EARLY SITE PERMIT APPLICATION FOR THE CLINCH RIVER NUCLEAR SITE

This appendix lists correspondence between the Tennessee Valley Authority (TVA) and the U.S. Nuclear Regulatory Commission (NRC), and other correspondence related to the NRC staff's review, regarding the Clinch River Nuclear Site early site permit (ESP) application, with the exception of legal filings related to any associated hearing proceedings. The listed correspondence also includes the associated NRC Agencywide Documents Access and Management System accession numbers. Correspondence received during the scoping period of the Environmental Impact Statement (EIS) is outlined in the Scoping Summary Report, dated October 30, 2017, and can be found at Accession No. ML17242A069 (NRC 2017-TN5343). The Scoping Summary Report is a summary of correspondence received from stakeholders and documents NRC staff responses to comments detailed in stakeholder's correspondence. Correspondence received during the Draft EIS comment period is outlined in Appendix E of the Final EIS, dated April 3, 2019, and can be found at Accession No. ML19073A109 (NRC 2019-TN6136). Appendix E of the Final EIS is summary of correspondence received from stakeholders and documents NRC staff responses to comments regarding the Draft EIS.

October 23, 2013	NRC Memorandum: Trip Report Pre-Application Visit to Clinch River Small Modular Reactor Site, Oak Ridge, Tennessee, and Meeting with U.S. Army Corps of Engineers, Nashville District, Eastern Section, in Lenoir City, Tennessee. (Accession No. ML13296A087)
March 20, 2015	NRC Memorandum: Summary of Trip to TVA's Clinch River Site on October 7-8, 2014, for a Site Tour and a Review of the Current Status of the Environmental Report for TVA's Early Site Permit Application Submittal. (Package Accession No. ML14329A151).
April 30, 2015	Letter to NRC from J.W. Shea, TVA, Regarding Onsite Reference Portal. (Accession No. ML15124A655)
July 15, 2015	Letter from the NRC to J.W. Shea, TVA, Regarding the Clinch River Small Modular Reactor Project ESP Application Online Reference Portal. (Accession No. ML15149A397)
July 17, 2015	Letter from the NRC to Daniel Stout, TVA, Regarding the Clinch River Early Site Permit Pre-Application Readiness Assessment. (Accession No. ML15190A225)
October 26, 2015	NRC Memorandum: Observations from the Environmental Readiness Assessment Activities for a Future Early Site Permit Application for the Clinch River Nuclear Site. (Package Accession No. ML15251A697)
May 12, 2016	Letter to NRC from J.W. Shea, TVA, Submitting Application for Early Site Permit for Clinch River Nuclear Site (Rev 0). (Accession No. ML16139A752)

May 12, 2016	Early Site Permit Application (Rev 0) for Clinch River Nuclear Site at https://www.nrc.gov/reactors/new-reactors/esp/clinch-river.html#application
June 10, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Meteorological Data in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16168A212)
June 10, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Evacuation Time Estimate Report in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16166A054)
June 17, 2016	Letter from NRC to J.W. Shea, TVA, Acknowledging Receipt of the Early Site Permit Application For the Clinch River Nuclear Site and Associated Federal Register Notice. (Accession No. ML16153A282)
June 23, 2016	*Federal Register* Notice - NRC Receipt of TVA Early Site Permit Application. (81 FR 40929)
June 23, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Calculation Input and Output Files in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16180A307)
July 6, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Siting Study in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16188A075)
July 21, 2016	E-mail from NRC to Dan Stout, TVA, Regarding Draft Requests for Supplemental Information (RSIs) and Observations Identified During Acceptance Review of the Early Site Permit Application for the Clinch River Nuclear Site. (Accession No. ML19011A128)
July 28, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Atmospheric Dispersion Calculation Input and Output Files in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16216A109)
July 28, 2016	Letter to NRC from J.W. Shea, TVA Regarding Submittal of Hydrology Calculation Input and Output Files in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16216A115 – not publicly available)
August 10, 2016	NRC Memorandum: Notice of Forthcoming Public Meeting with Tennessee Valley Authority to Discuss Various Topics Related to Supplemental Information for the Early Site Permit Application for the Clinch River Nuclear Site. (Accession No. ML16222A333)
August 11, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Schedule for Submittals of Supplemental Information. (Accession No. ML16224B143)

August 19, 2016	Letter from NRC to J.W. Shea, TVA, Regarding Tennessee Valley Authority Request and Schedule for Submittal of Supplemental Information in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16225A667)
August 31, 2016	Notice of Forthcoming Public Meeting with Tennessee Valley Authority to Discuss Various Topics Related to Supplemental Information for the Early Site Permit (ESP) Application for the Clinch River Nuclear Site. (Accession No. ML16252A375)
September 15, 2016	Handouts from Public Meeting of Sep 15, 2016: Environmental Alternatives Supplemental Items. (Accession No. ML16252A182)
September 30, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Hydrology Calculation Input Files in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16280A065 – not publicly available)
September 30, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Groundwater Calculation Input and Output Files in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16280A066)
October 21, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to Geologic Characterization Information, Surface Deformation, and Stability of Subsurface Materials and Foundation in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16302A176)
October 27, 2016	Letter from NRC to Daniel Stout Regarding Plan for Document Audit of Tennessee Valley Authority's Supplemental Information to Support the Early Site Permit Environmental Report. (Accession No. ML16285A388)
October 28, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to Vibratory Ground Motion in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16302A445)
December 2, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Information on Cumulative Radiological Health Impacts in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16340A259)
December 2, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Regarding Radiation Protection and Accident Consequences in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16340A258)
December 2, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Supplemental Information Regarding Meteorological Information in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16340A256)

December 8, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Regarding Hydrology in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML16344A085)
December 8, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Information on Alternate Cooling Water Systems in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16344A061)
December 12, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Cultural Reports and Programmatic Agreement in Support of Early Site Permit Application for Clinch River Nuclear Site. (Package Accession No. ML17284A306)
December 13, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Information on Terrestrial Ecology in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16348A552)
December 15, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Site Selection Information in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16350A429)
December 15, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Additional Supplemental Information Related to Stability of Subsurface Materials and Foundation in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16350A420)
December 16, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Aquatic Ecology Information in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16356A485)
December 27, 2016	Letter to NRC from J.W. Shea, TVA, Regarding Environmental Protection Plan Information in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML16363A378)
January 5, 2017	Letter from NRC to J.W. Shea, TVA, Regarding the Acceptance Review Results for an Early Site Permit Application for Clinch River Nuclear Site. (Package Accession No. ML16356A226)
January 5, 2017	NRC Memorandum: Notice of Acceptance for Docketing of an Application for an Early Site Permit for the Clinch River Nuclear Site Near Oak Ridge, Tennessee. (Accession No. ML16356A215)
January 6, 2017	NRC Memorandum: Acceptance Review Results for the Clinch River Early Site Permit Application. (Accession No. ML17005A180)
January 9, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Cultural Resource Reports in Support of Early Site Permit Application for Clinch River Nuclear Site. (Package Accession No. ML17298A058)

January 12, 2017	*Federal Register* Notice - Early Site Permit Application; Acceptance for Docketing. (82 FR 3812)
January 31, 2017	Notice of Forthcoming Meeting between the U.S. NRC and Tennessee Valley Authority to Discuss Topics Associated with Sections 2.1, 2.2, and 2.3 in Part 2 (SSAR) of TVA's Early Site Permit Application. (Accession No. ML17031A388)
February 8, 2017	Letter to NRC from Scott Breor, U.S. Department of Homeland Security, Regarding Confirmation of Clinch River Consultation. (Accession No. ML17041A009)
February 10, 2017	E-mail from NRC, to Ray Schiele, TVA, Regarding Additional topic for Monday (2/13/17) public call. (Accession No. ML17041A344)
February 11, 2017	NRC Memorandum: Summary Report for the Audit Related to the Tennessee Valley Authority's Supplemental Information to Support the Early Site Permit Environmental Report. (Accession No. ML17011A193)
February 13, 2017	NRC-TVA Publicly-Noticed Meeting (2/13/2017) Topics for Discussion: Clinch River Nuclear (CRN) ESP SSAR, Chapter 2, Sections 2.1, 2.2 and 2.3. (Accession No. ML17040A271)
February 13, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Additional topics for Monday (2/13/17) public call. (Accession No. ML17044A265)
February 21, 2017	NRC-TVA Publicly-Noticed Meeting (2/21/2017) Topics for Discussion: Clinch River Nuclear (CRN) ESP SSAR, Chapter 2 Figures 2.5.1 and 2.5.3. (Accession No. ML17046A505)
February 21, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Draft Transportation info needs (Environmental Audit). (Accession No. ML17052A091)
February 21, 2017	NRC Memorandum: Public Meeting Summary to Discuss Clarifications of Figures in Section 2.5.2 and 2.5.3 in Part 2, Site Safety Analysis Report of TVA's Early Site Permit Application. (Accession No. ML17066A350)
February 25, 2017	NRC Memorandum: Summary of Meeting Between the US. NRC and TVA to discuss topics associated with Section 2.1, 2.2 and 2.3 in Part 2 of the Site Safety Analysis Report of the Tennessee Valley Authority's Early Site Permit Application for the Clinch River Nuclear Site. (Accession No. ML17054D545)
March 1, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Calculation Input and Output Files in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17065A269)
March 10, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Tribal Consultation Letter in Support of Early Site Permit Application. (Accession No. ML17072A224)

March 17, 2017	Letter from NRC to J.W. Shea, TVA, Regarding the Clinch River Nuclear Site Early Site Permit Application Review Schedule. (Accession No. ML17069A104)
March 27, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to Control Room Habitability in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17086A496)
March 30, 2017	Letter from NRC to Emily Steele, Kingston Public Library, Regarding Maintenance of Reference Materials at the Kingston Public Library Related to the Environmental Review of the Tennessee Valley Authority Early Site Permit Application at the Clinch River Nuclear Site. (Accession No. ML17061A426)
March 30, 2017	Letter from NRC to Kathy McNeilly, Oak Ridge Public Library, Regarding Maintenance of Reference Materials at the Oak Ridge Public Library Related to the Environmental Review of the Tennessee Valley Authority Early Site Permit Application at the Clinch River Nuclear Site. (Accession No. ML17061A427)
April 3, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to Site Safety Analysis Report Figures in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17094A242)
April 4, 2017	Letter from NRC to J.W. Shea, TVA, Regarding Tennessee Valley Authority - Application for an Early Site Permit for the Clinch River Nuclear Site; the Notice of Hearing, Opportunity to Petition for Leave to Intervene, and Associated Federal Register Notice. (Package Accession No. ML17061A396)
April 4, 2017	*Federal Register* Notice - Notice of Hearing and Opportunity to Petition for Leave to Intervene; Order Imposing Procedures. (82 FR 16436)
April 7, 2017	Notice of Forthcoming Meeting Between The U.S. Nuclear Regulatory Commission and Tennessee Valley Authority To Discuss Topics Associated With TVA's Early Site Permit Application For The Clinch River Nuclear Site. (Accession No. ML17097A447)
April 7, 2017	Letter from NRC to J.W. Shea, TVA, Regarding Notice of Intent to Prepare an Environmental Impact Statement and Conduct Scoping Related to an Early Site Permit for the Clinch River Nuclear Site. (Package Accession No. ML17068A241)
April 11, 2017	NRC Memorandum: April 17-28, 2017, Audit of Clinch River Nuclear Site Early Permit Application – Hydrology and Health Physics Analyses. (Accession No. ML17069A045)

April 12, 2017	Letter from NRC to Tammy Turley, USACE Nashville District, Regarding Invitation to Participate as a Cooperating Agency in Preparation of an Environmental Impact Statement for the Tennessee Valley Authority Early Site Permit Application at the Clinch River Nuclear Site, Roane County, Tennessee. (Accession No. ML17065A237)
April 13, 2017	*Federal Register* Notice - Intent to Prepare Environmental Impact Statement and Conduct Scoping Process; Public Meeting and Request for Comment. (82 FR 17885)
April 17, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to the Exclusion Area Boundary and Population Distribution Around the Clinch River Nuclear Site in Support of the Early Site Permit Application. (Accession No. ML17107A080)
April 19, 2017	Plan for Areas Covered in Section 2.5 of the Site Safety Analysis Report, Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17108A822)
April 20, 2017	Letter from NRC to Edwina Butler-Wolfe, Absentee Shawnee Tribe, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17041A081)
April 20, 2017	Letter from NRC to Ryan Morrow, Thlopthlocco Tribal Town, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A682)
April 20, 2017	Letter from NRC to Gary Batton, Choctaw Nation of Oklahoma, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17041A086)
April 20, 2017	Letter from NRC to Stephanie A. Bryan, Poarch Band of Creek Indians, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A676)
April 20, 2017	Letter from NRC to Jo Ann Battise, Alabama-Coushatta Tribe of Texas, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17041A082)

April 20, 2017	Letter from NRC to Patrick Lambert, Eastern Band of Cherokee Indians of North Carolina, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17017A123)
April 20, 2017	Letter from NRC to Bill John Baker, Cherokee Nation, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17041A085)
April 20, 2017	Letter from NRC to Tarpie Yargee, Alabama-Quassarte Tribal Town, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17041A084)
April 20, 2017	Letter from NRC to B. Cheryl Smith, Jena Band of Choctaw Indians, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee . (Accession No. ML17047A407)
April 20, 2017	Letter from NRC to Bill Anoatubby, Chickasaw Nation, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A681)
April 20, 2017	Letter from NRC to John Berrey, Quapaw Tribe of Oklahoma, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A677)
April 20, 2017	Letter from NRC to Marcellus W. Osceola, Jr., Seminole Tribe of Florida, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A679)
April 20, 2017	Letter from NRC to Joe Bunch, United Keetoowah Band of Cherokee Indians, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A683)
April 20, 2017	Letter from NRC to Lovelin Poncho, Coushatta Tribe of Louisiana, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A405)

April 20, 2017	Letter from NRC to E. Patrick McIntyre, Jr., Tennessee Historical Commission, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17061A428)
April 20, 2017	Letter from NRC to Phyliss J. Anderson, Mississippi Band of Choctaw Indians, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A409)
April 20, 2017	Letter from NRC to Mary Jennings, U.S. Fish and Wildlife Service, Regarding Request For Participation In The Environmental Scoping Process And A List Of Protected Species Within The Area Under Evaluation For The Proposed Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17069A249)
April 20, 2017	Letter from NRC to James Floyd, Muscogee (Creek) Nation of Oklahoma, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A675)
April 20, 2017	Letter from NRC to Leonard M. Harjo, Seminole Nation of Oklahoma, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee . (Accession No. ML17047A678)
April 20, 2017	Letter from NRC to Glenna J. Wallace, Eastern Shawnee Tribe of Oklahoma, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A406)
April 20, 2017	Letter from NRC to Ron Sparkman, Shawnee Tribe of Oklahoma, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A680)
April 20, 2017	Letter from NRC to Bill Pearson, U.S. Fish and Wildlife Service, Alabama Ecological Services Field Office, Regarding Request For Participation In The Environmental Scoping Process And A List Of Protected Species Within The Area Under Evaluation For The Proposed Clinch River Early Site Permit Application Review. (Accession No. ML17088A264)

April 20, 2017	Letter from NRC to Reid Nelson, Advisory Council on Historic Preservation, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17065A239)
April 20, 2017	Letter from NRC to Jeremiah Hobia, Kialegee Tribal Town, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17047A408)
April 21, 2017	Letter to NRC from Mary Jennings, U.S. Fish and Wildlife Service, Regarding FWS#2017-CPA-0711. Notice of Intent for the Nuclear Regulatory Commission to Prepare an Environmental Impact Statement and Conduct a Scoping Process for the Clinch River Nuclear Site Located in Roane County, Tennessee. (Accession No. ML17145A505)
April 28, 2017	Notice of Public Meeting to Discuss the Environmental Scoping Process for the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17118A330)
May 2, 2017	Letter from Tammy Turley, USACE Nashville District, to NRC, regarding Invitation to Participate as a Cooperating Agency in Preparation of an Environmental Impact Statement for the Tennessee Valley Authority Early Site Permit Application at the Clinch River Nuclear Site, Roane County, Tennessee. (Accession No. ML17205A413)
May 5, 2017	Letter to NRC from Mary Jennings, U.S. Fish and Wildlife Service, Regarding FWS# 2017-I-0473. U.S. Nuclear Regulatory Commission - Requests for Participation in the Environmental Scoping Process and List of Federally Protected Species Within the Area Under Evaluation for the Proposed Clinch River Nuclear Site Located in Oak Ridge, Roane County, Tennessee. (Accession No. ML17205A341)
May 7, 2017	Plan for Environmental Audit Related to the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17088A728)
May 8, 2017	Handouts from Audit of May 8, 2017: Clinch River Nuclear Seismic/Geotechnical Audit Information Packet. (Accession No. ML17108A822)
May 11, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to the Accidental Release of Liquid Effluents in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17143A417)
May 12, 2017	Letter to NRC from Elizabeth Toombs, Cherokee Nation, Regarding Clinch River Nuclear Site, Roane County, TN – Cherokee Nation Section 106. (Accession No. ML17145A580)

May 23, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Data Request in Support of NRC's Safety Review of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17143A441)
May 25, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding CRNS ESP Application RAI-1-8761 [Emergency Planning]. (Accession No. ML17145A584)
May 30, 2017	NRC Memorandum: Public Meeting Summary to Discuss Topics Associated with TVA's Early Site Permit Application for the Clinch River Nuclear Site. (Accession No. ML17164A312)
May 30, 2017	NRC-TVA Publicly-Noticed Meeting (5/30/2017) Topics for Discussion: Clinch River Nuclear (CRN) ESP SSAR – Quality Assurance Program. (Accession No. ML17145A337)
May 30, 2017	Letter to NRC from Larry Long, U.S. Environmental Protection Agency, Regarding Informal Pre-permit Clinch River Nuclear Site. (Accession No. ML17157B742)
June 5, 2017	Letter to NRC from J.W. Shea, TVA Regarding Submittal of Supplemental Information Associated with Hydrologic Engineering in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17157B212 – not publicly available)
June 5, 2017	Letter to NRC from Daniel Rangle, Choctaw Nation of Oklahoma, Regarding Initiation of Section 106 and Scoping Process for the Environmental Review of the Early Site Permit Application for Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML17157B749)
June 7, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to the Hydrologic Engineering in Support of the Clinch River Nuclear Site Early Site Permit Application – Groundwater. (Accession No. ML17158B342)
June 12, 2017	Letter to NRC from Jonathan Hoyes, Federal Emergency Management Agency, Regarding Federal Emergency Management Agency Review of An Early Site Permit Application for the Tennessee Valley Authority Clinch River Nuclear Site. (Accession No. ML17164A206)
June 12, 2017	Letter to NRC from Kendra Abkowitz, Tennessee Department of Environment and Conservation, Regarding TDEC NEPA Review/Comments Complete. (Accession No. ML17170A310)
June 15, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Regarding the Impacts of Non-Radiological Traffic Accidents in Support of the Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17167A155)

June 15, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Hydrology Calculation Input Files in Response to the Hydrology Audit of Plant Early Site Permit Application. (Accession No. ML17171A335 – not publicly available)
June 15, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information Regarding Emergency Planning in Support of the Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17166A455)
June 16, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Resubmittal of Supplemental Information Regarding Radiation Protection and Accident Consequences in Support of the Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17167A150)
June 28, 2017	Letter to NRC from Karen Pritchett, United Keetoowah Band of Cherokee Indians, Regarding Clinch River Nuclear Site, Roane County, Tennessee. (Accession No. ML17206A450)
June 20, 2017	NRC Memorandum: Summary of Public Scoping Meeting Related To The Early Site Permit Application Review Of The Clinch River Nuclear Site. (Package Accession No. ML17163A352)
June 21, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Section 2.5.2, Vibratory Ground Motion, RAI Number 3, eRAI-8893. (Accession No. ML17206A613)
June 26, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to Plant Parameter Envelope Source Terms in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17178A330)
June 26, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Site Safety Analysis Report Figure Digital Format Data in Response to the Safety Review of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17192A318)
July 3, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Associated with Site Safety Analysis Report Section 2.5 in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17186A113)
July 7, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to the Environmental Audit in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17206A091)
July 18, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to the Environmental Audit in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17200C887)

July 18, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Associated with Hydrologic Engineering in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17206A090 – not publicly available)
July 19, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information RAI Number 3, eRAI-8893, Regarding Vibratory Ground Motion in Support of Early Site Permit Application for Clinch River Nuclear Site Early Site. (Accession No. ML17201F323)
July 20, 2017	Letter from NRC to Mary Jennings, U.S. Fish and Wildlife Service, Regarding FWS# 2017-I-0473. U.S. Nuclear Regulatory Commission (NRC) – Updated List of Federally Threatened and Endangered Species that Potentially Occur near the Proposed Clinch River Small Modular Nuclear Reactor Facility in Oak Ridge, Roane County, Tennessee. (Accession No. ML17205A342)
July 25, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Section 2.1.3, Population Distribution, RAI Number 4, eRAI-8857. (Accession No. ML17206A623)
July 26, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Information Related to the Early Site Permit Application for the Clinch River Nuclear Site Operational Quality Assurance Program. (Accession No. ML17208A162)
July 28, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Part 6 of TVA Application, Exemptions and Departures, EP Exemptions. (Accession No. ML17209A401)
August 1, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Section 2.5.1, Basic Geologic and Seismic Information (RAI Number 5, eRAI-8991). (Accession No. ML17213A971)
August 1, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to the Environmental Audit in Support of Early Site Permit Application for Clinch River Nuclear Site. (Package Accession No. ML17234A002)
August 2, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Section 2.1.3, Population Distribution, RAI Number 4, eRAI-8857. (Accession No. ML17214A447)
August 2, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Section 2.5.2, Vibratory Ground Motion, RAI Number 3, eRAI-8893. (Accession No. ML17214A448)
August 2, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Section 2.5.4, Stability of Subsurface Materials and Foundations (RAI Number 6, eRAI-9035). (Accession No. ML17214A446)

August 8, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to Emergency Planning Correspondence Between Tennessee Emergency Management Agency and Tennessee Valley Authority in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17220A139)
August 14, 2017	NRC-TVA Clinch River Public Meeting 08/14/2017 Topics for Discussion. (Accession No. ML17221A618)
August 14, 2017	NRC Memorandum: Meeting between the U.S. Nuclear Regulatory Commission and Tennessee Valley Authority to Discuss Topics Associated With TVA's Early Site Permit Application for the Clinch River Nuclear Site [Application Figures and Graphic Information System files]. (Accession No. ML18010A258)
August 21, 2017	E-mail from Mike Barbour, Auburn University, to James Becker, PNNL, Regarding Map Package for AL NHP. (Package Accession No. ML18022A463).
August 21, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Evacuation Time Estimates in Section 13.03 of TVA Application. (Accession No. ML17233A359)
August 21, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to the Environmental Audit in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17233A298)
August 24, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information Number 4, eRAI-8857, Regarding Population Distribution in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17236A249)
August 24, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information Related to Emergency Planning Exemption Requests in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17237A175)
August 25, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining Section 02.03.03 - Onsite Meteorological Measurements. (Accession No. ML17237A195)
August 25, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Supplemental Information Related to Groundwater Hydrology in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17237C084)
August 30, 2017	Topics for TVA Public Meeting for Clinch River. (Accession No. ML17242A158)

August 30, 2017	Meeting Summary between the U.S. Nuclear Regulatory Commission (NRC) and Tennessee Valley Authority (TVA) to Discuss Topics Associated With TVA's Early Site Permit Application for the Clinch River Nuclear Site [Cultural Resources and Transportation]. (Accession No. ML17352A028)
September 5, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Supplemental Information Related to Environmental Report Figures in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18010A067)
September 6, 2017	E-mail from Pat Black, Tennessee Wildlife Resource Agency, to James Becker, PNNL, Regarding Watts Bar Reservoir Creel Survey Report. (Package Accession No. ML18022A346).
September 6, 2017	E-mail from Gerry Middleton, Tennessee Department of Environment and Conservation, to James Becker, PNNL, Regarding Bat Data Report 2013, 2014, and 2015. (Package Accession No. ML18019A036)
September 7, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Coincident Wet-Bulb Data and Spreadsheet Files in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17257A174)
September 11, 2017	NRC Memorandum: Summary Report for the May 8-9, 2017, Geology, Seismology, and Geotechnical Engineering Information Audit (Section 2.5 of the Site Safety Analysis Report), Tennessee Valley Authority, Early Site Permit Application, Clinch River Nuclear Site. (Accession No. ML17223A428)
September 11, 2017	E-mail from Stephanie Williams, Tennessee Department of Environment and Conservation, to James Becker, PNNL, Regarding Map Package for TN NHP. (Package Accession No. ML18026A552)
September 13, 2017	E-mail from James Becker, PNNL, to Ian Horn, Kentucky State Nature Preserves Commission, Regarding KY NHP Review of Transmission Line Segment for Clinch River SMR ESP Project in Tennessee. (Accession No. ML18059A130)
September 14, 2017	Letter from NRC to Jonathan Hoyes, Federal Emergency Management Agency, Regarding Response to Federal Emergency Management Agency Review of an Early Site Permit Application for the Tennessee Valley Authority Clinch River Nuclear Site. (Accession No. ML17192A105)
September 15, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information Related to the Evacuation Time Estimates in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17261A066)

September 15, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information Number 5, Questions 02.05.01-01 and 02.05.01-02, Regarding Basis Geologic and Seismic Information and RAI Number 6, Questions 02.05.04-01 and 02.05.04-02, Regarding Stability of Subsurface Materials and Foundations in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17261A062)
September 18, 2017	E-mail from Kitty McCracken, Oak Ridge National Laboratory, to James Becker, PNNL, Regarding Fish Data for Ish Creek, Oak Ridge, Tennessee. (Package Accession No. ML18016A334)
September 19, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Section: 13.06.03 – Physical Security. (Accession No. ML17262B229)
September 24, 2017	E-mail from Anna Yellin, Georgia Department of Natural Resources, to James Becker, PNNL, Regarding the Environmental Review. (Package Accession No. ML18012A478)
September 25, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information RAI Number 9, eRAI-8972, Regarding Onsite Meteorological Measurements Programs in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17268A391)
September 29, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information Number 5, Questions 02.05.01-03 and 02.05.01-05, Regarding Basis Geologic and Seismic Information in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17275A215)
October 2, 2017	E-mail from Ian Horn, Kentucky State Nature Preserves Commission, to James Becker, PNNL, Regarding KY NHP Review of Transmission Line Segment for Clinch River SMR ESP Project in Tennessee. (Package Accession No. ML18012A656)
October 10, 2017	Letter to NRC, from J.W. Shea, TVA, Regarding Submittal of Supplemental Information Related to Groundwater Hydrology in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17286A615)
October 11, 2017	NRC-TVA Public Meeting on October 11, 2017 - Topics For Discussion: Clarification of TVA Responses (TVA Letter CNL-17-099) to NRC RAI 5 (eRAI-8991), RAI 6 (eRAI-9035), and TVA Responses (TVA Letter CNL-17-127) to RAI 9 (eRAI-8972) for the Clinch Nuclear Site Early Site Permit Application Review. (Accession No. ML17278A673)
October 18, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Request for TVA Text Used to Support the NRC-TVA Public Meeting on October 11, 2017. (Accession No. ML17291B067)

October 19, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information Number 2 Regarding Physical Security in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17295A000)
October 19, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information RAI Number 5, Questions 02.05.01-04 and 02.05.01-06, Regarding Basis Geologic and Seismic Information in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17295A001)
October 26, 2017	Environmental Impact Statement Scoping Process Summary Report Clinch River Nuclear Site Early Site Permit Application. (Package Accession No. ML17242A061)
November 3, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of TVA Discussions Provided During October 11, 2017 Public Meeting in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17307A310)
November 3, 2017	E-mail from Brian Flock, Tennessee Wildlife Resource Agency, to James Becker, PNNL, Regarding Clinch River Small Modular Reactor Project- 2 Figures. (Accession No. ML18064A895)
November 8, 2017	E-mail from Neil Giffen, Oak Ridge National Laboratory, to James Becker, PNNL, Regarding Questions About a Former Area of “Very High Biological Significance” on the Clinch River Site. (Package Accession No. ML18022A742)
November 9, 2017	E-mail from NRC to Ray Schiele, TVA, Regarding Issuance of RAI Pertaining to Part 6 of the Clinch River Nuclear Site ESP Application – Exemptions and Departures (RAI Number 10, eRAI-9206). (Accession No. ML17325A735)
November 11, 2017	NRC-TVA Clinch River ESP Public Meeting 11/6/2016 Topics for Discussion: Clinch River Nuclear (CRN) ESP Environmental Report, Section 2.3.1. (Accession No. ML17304A856)
November 13, 2017	Meeting Summary between the U.S. Nuclear Regulatory Commission (NRC) and Tennessee Valley Authority (TVA) to Discuss Topics Associated With TVA's Early Site Permit Application for the Clinch River Nuclear Site [ER References and Site Safety Hydrology]. (Accession No. ML18010A322)
November 13, 2017	NRC Memorandum: November 15, 2017, Audit of Clinch River Nuclear Site Early Site Permit Application – Part 6 – Exemptions and Departures, Emergency Planning Assumptions. (Accession No. ML17311A908)
November 14, 2017	NRC-TVA Public Meeting (November 14, 2017) Topics for Discussion: Clinch River Nuclear (CRN) ESP SSAR, Chapter 2 Section 2.3. (Accession No. ML17317A100)

November 17, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Environmental Report References in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML17334A038)
November 28, 2017	Letter to NRC from J.W. Shea, TVA, Regarding Clarification of Supplementation Information Associated with Hydrologic Engineering in Support of the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML17333A789)
December 7, 2017	E-mail from Neil Giffen, Oak Ridge National Laboratory, to James Becker, PNNL, Regarding Question About a Former Area of "Very High Biological Significance" on the Clinch River Site. (Accession No. ML18010A883).
December 15, 2017	Letter to NRC from J.W. Shea, TVA, Submitting Application for Early Site Permit for Clinch River Nuclear Site (Rev 1). (Accession No. ML18005A067)
December 15, 2017	Early Site Permit Application for Clinch River Nuclear Site at https://www.nrc.gov/reactors/new-reactors/esp/clinch-river.html#application
January 9, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Watts Bar Interagency Agreement. (Accession No. ML18038B156)
January 9, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding Draft CRN ESP Environmental Audit Report. (Accession No. ML18038B165)
January 11, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding ER Audit Report Review. (Accession No. ML18038B164)
January 11, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding DRAFT Clinch River Environmental Audit Report – TVA Comments. (Accession No. ML18038B163)
January 11, 2018	NRC Memorandum: Summary Report for the Full Scope Environmental Audit for the Clinch River Nuclear Site Early Site Permit Application. (Package Accession No. ML17226A020)
January 19, 2018	E-mail from NRC to Theodore Isham, Seminole Nation of Oklahoma, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Package Accession No. ML18031A950)
January 19, 2018	E-mail from NRC to Samantha Robison, Alabama-Quassarte Tribal Town, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18046A410)
January 19, 2018	E-mail from NRC to Bryant Celestine, Alabama-Coushatta Tribe of Texas, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Package Accession No. ML18058B560)

January 20, 2018	E-mail from Theodore Isham, Seminole Nation of Oklahoma, to NRC, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18046A412)
January 22, 2018	E-mail from Karen Brunso, Chickasaw Nation, to NRC, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18031A976)
January 22, 2018	E-mail from NRC to Victoria Menchaca, Seminole Tribe of Florida, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18059A157)
January 22, 2018	Letter to NRC from J.W. Shea, TVA, Submitting Responses to Request for Additional Information Related to Emergency Planning Exemption Requests in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18022A917)
January 24, 2018	Letter to NRC from Michael Chesney, Federal Emergency Management Agency, Regarding Federal Emergency Management Agency Review of an Early Site Permit Application for the Tennessee Valley Authority Clinch River Nuclear Site. (Accession No. ML18031B055)
January 25, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Environmental Report References in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18036A346)
January 26, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding Visiting Talking Points. (Accession No. ML18038B173)
January 25, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Revised Safety Analysis Report Figure 2.5.1-34 in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18029A451)
January 29, 2018	E-mail from NRC to Terry Clouthier, Thlopthlocco Tribal Town, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18040A439)
February 7, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Updated Schedule for ACRS Meeting. (Accession No. ML18064A196)
February 9, 2018	E-mail from NRC to Daniel Ragle, Choctaw Nation of Oklahoma, Regarding Clinch River Nuclear Site, Early Site Permit Application, Environmental Audit Summary Report. (Accession No. ML18044A843)
February 9, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Draft RAI Pertaining to Section 17.5, Quality Assurance Program Description (RAI Number 12, eRAI-8798). (Accession No. ML18064A205)
February 12, 2018	E-mail to NRC from Ray, Schiele, TVA, Regarding Draft NRC ACRS Review Schedule. (Accession No. ML18064A215)

February 13, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Clinch River: Met Question on Vector WD and Scalar WS. (Accession No. ML18064A055)
February 14, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding Clinch River: Met Question on Vector WD and Scalar WS. (Accession No. ML18064A056)
February 16, 2018	E-mail from NRC to Carolyn White, Poarch Band of Creek Indians, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18051A746)
February 19, 2018	Letter to NRC from Terry Clouthier, Thlopthlocco Tribal Town, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18051A738)
February 20, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Replacement Pages for Response to Request for Additional Information Related to Emergency Planning Exemption Requests in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18052A085)
February 23, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Revised Draft RAI Pertaining to Section 17.5, Quality Assurance Program Description (RAI Number 12, eRAI-8798). (Accession No. ML18064A217)
February 26, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Addendum to: Clinch River: Met Question on Vector WD and Scalar WS. (Accession No. ML18064A053)
March 5, 2018	E-mail from NRC to Theodore Isham, Seminole Nation of Oklahoma, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18064A222)
March 5, 2018	E-mail from NRC to Ray Schiele, Regarding Met: Feedback on Sections 2.0 and 2.3.1 Rev 1 SSAR. (Accession No. ML18096B703)
March 9, 2018	E-mail from NRC to Ray Schiele, Regarding Discussion of Phone Call on March 8, 2018. (Accession No. ML18068A070)
March 9, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Response to Portion of Request for Additional Information Related to Emergency Planning Exemption Requests in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18068A732)
March 9, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding CRNS ESP Final QA01 eRAI-8798. (Accession No. ML18096B685)
March 13, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Permission to Use Melton Hill Dam Image. (Accession No. ML18096B710)
March 15, 2018	Letter from NRC to J.W. Shea, TVA, Regarding Quality Assurance Program Implementation Inspection of Clinch River Nuclear Site – Early Site Permit Application. (Accession No. ML18066A737)

March 16, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Revised Site Safety Analysis Report Subsection 2.4.3.2, “Probable Maximum Precipitation,” in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18075A314)
March 23, 2018	NRC Memorandum: Summary Report for the Hydrology and Health Physics Safety Audit (Section 2.4, 11.2 and 11.3 of the Site Safety Analysis Report) for the Clinch River Nuclear Early Site Permit Application. (Accession No. ML19059A370)
March 26, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Potential Errors in ER Table 1.2-2. (Accession No. ML18096A014)
March 26, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding Potential Errors in ER Table 1.2-2. (Accession No. ML18096A012)
March 30, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Response to Portion of Request for Additional Information Related to Emergency Planning Exemption Requests in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18089A605)
April 4, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding QA Inspection. (Accession No. ML18096B677)
April 6, 2018	NRC Memorandum: April 12, 2018, Audit of Clinch River Nuclear Site Early Permit Application – Part 6, “Exemptions and Departures, Emergency Planning Exemptions.” (Accession No. ML18095A083)
April 9, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Response to NRC Request for Additional Information 12 in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18100A916)
April 9, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Voluntary Submittal Comparing Offsite Atmospheric Dispersion Using Vector and Scalar Wind Direction in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18100A950)
April 12, 2018	E-mail to NRC from Dan Stout, TVA, Regarding Proprietary Information – Clinch River ESP SE Sections 2.1, 2.2, 3.5.1.6 and 15.0.3 transmitted to ACRS. (Accession No. ML18127B724)
April 12, 2018	NRC Memorandum: Clinch River Nuclear Early Site Permit Application Safety Evaluations with No Open Items for Section 2.1, “Geography and Demography,” and Section 2.2., “Nearby Industrial, Transportation and Military Facilities,” Section 3.5.1.6, “Aircraft Hazards,” and Section 15.0.3, “Radiological Consequences of Design Basis Accidents.” (Accession No. ML18102A611).

April 12, 2018	Letter from NRC to J.W. Shea, TVA Regarding Clinch River Nuclear Early Site Permit Application Safety Evaluations with No Open Items for Section 2.1, “Geography and Demography,” and Section 2.2., “Nearby Industrial, Transportation and Military Facilities,” Section 3.5.1.6, “Aircraft Hazards,” and Section 15.0.3, “Radiological Consequences of Design Basis Accidents.” (Accession No. ML18102A612).
April 20, 2018	Letter from NRC to B. Cheryl Smith, Jena Band of Choctaw Indians, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A193)
April 20, 2018	Letter from NRC to Bill Anoatubby, Chickasaw Nation, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A186)
April 20, 2018	Letter from NRC to Bill John Baker and THPO, Cherokee Nation, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A184)
April 20, 2018	Letter from NRC to Bill Pearson, U.S. Fish and Wildlife Service, Alabama Ecological Services Field Office, Regarding Notification of the Issuance of the Draft Environmental Impact Statement and Biological Assessment for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18092B607)
April 20, 2018	Letter from NRC to David Sickey, Coushatta Tribe of Louisiana, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A194)
April 20, 2018	Letter from NRC to Edwina Butler-Wolfe, Absentee Shawnee Tribe, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A181)
April 20, 2018	Letter from NRC to E. Patrick McIntyre, Jr., Tennessee Historical Commission, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18092B609)

April 20, 2018	Letter from NRC to Glenna J. Wallace, Eastern Shawnee Tribe of Oklahoma, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A188)
April 20, 2018	Letter from NRC to Gregory Chilcoat, Seminole Nation of Oklahoma, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A197)
April 20, 2018	Letter from NRC to James Floyd, Muscogee (Creek) Nation of Oklahoma, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A190)
April 20, 2018	Letter from NRC to Jeremiah Hobia, Kialegee Tribal Town, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A189)
April 20, 2018	Letter from NRC to Jo Ann Battise, Alabama-Coushatta Tribe of Texas, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A182)
April 20, 2018	Letter from NRC to Joe Bunch, United Keetoowah Band of Cherokee Indians, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18092B125)
April 20, 2018	Letter from NRC to J.W. Shear, TVA, Regarding Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee and Associated Federal Register Notice. (Accession No. ML18086B699)
April 20, 2018	Letter from NRC to Larry Long, U.S. Environmental Protection Agency, Region 4, Regarding Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18106B115)

April 20, 2018	Letter from NRC to Marcellus W. Osceola Jr., Seminole Tribe of Florida, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A196)
April 20, 2018	Letter from NRC to Mary Jennings, U.S. Fish and Wildlife Service, Tennessee Ecological Service Field Office, Regarding Notification of the Issuance of the Draft Environmental Impact Statement and Biological Assessment for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18092B598)
April 20, 2018	Letter from NRC to Nelson Harjo, Alabama-Quassarte Tribal Town, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A183)
April 20, 2018	Letter from NRC to Reid Nelson, Advisory Council on Historic Preservation, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18092B415
April 20, 2018	Letter from NRC to Richard Sneed, Eastern Band of Cherokee Indians, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A187)
April 20, 2018	Letter from NRC to Ron Sparkman, Shawnee Tribe of Oklahoma, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A195)
April 20, 2018	Letter from NRC to Ryan Morrow, Thlopthlocco Tribal Town, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A192)
April 20, 2018	Letter from NRC to Stephanie A. Bryan, Poarch Band of Creek Indians, Regarding Section 106 Consultation and Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18171A191)
April 24, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding SER 2.1, 3.5, 15.0 Comments. (Accession No. ML18127A805)

April 25, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding NQAP Rev 36. (Accession No. ML18127A792)
April 25, 2018	Letter from NRC to Emily Steele, Kingston Public Library, Regarding Maintenance of Reference Materials at the Kingston Public Library Related to the Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18113A519)
April 25, 2018	Letter from NRC to Kathy McNeilly, Oak Ridge Public Library, Regarding Maintenance of Reference Materials at the Oak Ridge Public Library Related to the Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18113A520)
April 26, 2018	E-mail to NRC from Kevin Casey, TVA, Regarding Access Information for NRC June CRN Site Visit. (Accession No. ML18127A784)
April 26, 2018	*Federal Register* Notice – NRC Draft Environmental Impact Statement; Public Meetings and Request for Comment. (83 FR 18354)
April 26, 2018	Environmental Impact Statement for an Early Site Permit (ESP) at the Clinch River Nuclear Site: Draft Report for Comment at https://www.nrc.gov/reactors/new-reactors/esp/clinch-river.html#deis
April 27, 2018	*Federal Register* Notice – Environmental Protection Agency Environmental Impact Statement Notice of Availability. (83 FR 18554)
April 27, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Clinch River ESP Phase C SE Sections 2.1, 2.2, 3.5.1.6, and 15.0.3. (Accession No. ML18127A776)
April 27, 2018	Notification of the Issuance of the Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site, Roane County, Tennessee. (Accession No. ML18117A488)
April 27, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Submittal of Revised Site Safety Analysis Report Subsection 2.4.2.2, “Flood Design Considerations,” and Subsection 2.4.3.5, “Probable Maximum Flood Flow,” and Figure 2.4.3-3 in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18121A446)
April 27, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Supplemental Information Related to Emergency Planning Exemption Requests in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18117A291)

April 27, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Comments on Safety Evaluations for Section 2.1, "Geography and Demography," 2.2, "Nearby Industrial, Transportation, and Military Facilities," 3.5.1.6, "Aircraft Hazards," and 15.0.3, "Accident Analysis," in Support of Early Site Permit Applications for Clinch River Nuclear Site. (Accession No. ML18121A444)
April 27, 2018	E-mail from NRC to Kevin Casey, TVA, Regarding Access Information for NRC June CRN Site Visit. (Accession No. ML18127A745)
April 27, 2018	E-mail to NRC from Kevin Casey, TVA, Regarding Access Information for NRC June CRN Site Visit. (Accession No. ML18127A736)
April 30, 2018	E-mail from NRC to Ray Schiele, Regarding TVA Comments on SE Sections 2.1, 2.2, 3.5.1.6, and 15.0.3 - Corrected. (Accession No. ML18127A725)
May 3, 2018	NRC Memorandum: May 7, 2018, Through May 11, 2018, Audit of Clinch River Nuclear Site Early Site Permit Application – Comparing Offsite Atmospheric Dispersion Using Vector and Scalar Wind Direction. (Accession No. ML18122A219)
May 4, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Update to Site Safety Analysis Report Section 17.5, "Quality Assurance," in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18124A116)
May 8, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Nuclear Quality Assurance Plan, TVA-NQA-PLN89-A, Revision 35 and 36. (Accession No. ML18129A317)
May 8, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Draft ACRS Agenda Clinch River ESP 20180515. (Accession No. ML18159A240)
May 8, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding Draft ACRS Agenda Clinch River ESP 20180515. (Accession No. ML18159A238)
May 8, 2018	E-mail to NRC from Kevin Casey, TVA, Regarding NRC Environmental CRN Visit. (Accession No. ML18159A236)
May 10, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Designated Federal Official for ACRS Meetings: Quynh Nguyen. (Accession No. ML18159A235)
May 15, 2018	Notice of Public Meeting to Discuss the Draft Environmental Impact Statement for the Clinch River Nuclear Site Early Site Permit Application. (Accession No. ML18155A543)
May 16, 2018	Letter from E. Patrick McIntyre, Tennessee Historical Commission, to NRC, Regarding Comments on the DEIS for the Clinch River Nuclear Site ESP. (Accession No. ML18194A388)

May 18, 2018	E-mail from NRC to Kevin Casey, TVA, Regarding Change in Site Visit Attendees – Philip Meyer in Tamsen Dozier's Place. (Accession No. ML18159A233)
May 18, 2018	E-mail to NRC from Philip Meyer, PNNL, Regarding Change in Site Visit Attendees – Philip Meyer in Tamsen Dozier's Place. (Accession No. ML18159A232)
May 22, 2018	NRC Memorandum: Summary Report for the Regulatory Audit of Clinch River Nuclear Early Site Permit Application – Part 6 Exemptions and Departures, Emergency Planning Exemptions. (Accession No. ML18122A344)
May 22, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding Clinch River Audit Summary of Part 6 Exemptions and Departures Emergency Planning. (Accession No. ML18159A408)
May 29, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding NRC Inspection April 16- April 20, 2018. (Accession No. ML18159A220)
May 29, 2018	E-mail to NRC from Kevin Casey, TVA, Regarding June 6 NRC Clinch River Site Visit. (Accession No. ML18159A231)
May 30, 2018	*Federal Register* Notice – NRC Draft Environmental Impact Statement; Public Meetings and Request for Comment: Correction. (83 FR 24832)
May 31, 2018	E-mail from NRC to Ray Schiele, TVA, Regarding June 6 NRC Clinch River Site Visit. (Accession No. ML18159A218)
June 1, 2018	Letter from NRC to J.W. Shea, TVA, Regarding Nuclear Regulatory Commission Inspection of the Quality Assurance Program Implementation for Clinch River Nuclear Site Early Site Permit Application, Report No. 0500047/2018-201. (Accession No. ML18143B478)
June 14, 2018	Letter from Carol J. Monell, Environmental Protection Agency, Region 4, Regarding Draft Environmental Impact (DEIS) for the Clinch River Nuclear Site and the Tennessee Valley Authority's Application for an Early Site Permit, CEQ No.: 20180071. (Accession No. ML18194A030)
June 19, 2018	E-mail to NRC from Carla Edmondson, TVA, Regarding August 17 Recurring Meeting. (Accession No. ML18183A604)
June 25, 2018	E-mail from NRC to Jeff Perry, TVA, Regarding Reading Room Access Request. (Accession No. ML18183A605)
June 29, 2018	E-mail to NRC from Daniel Stout, TVA, Regarding TVA Response to NRC Request for Comments on CRN ESP DEIS. (Accession No. ML18180A386)

July 6, 2018	E-mail to NRC from Erin Thompson, Absentee Shawnee Tribe of Oklahoma, Regarding Early Site Permit at the Clinch River Nuclear Site in Oak Ridge, Roane County, Tennessee. (Accession No. ML18264A326)
July 9, 2018	NRC Memorandum: Summary Report for the Second Regulatory Audit for Clinch River Nuclear Site Early Site Permit Application – Part 6 Exemptions and Departures, Emergency Planning Exemptions. (Accession No. ML18177A107)
July 9, 2018	Letter to NRC from Joyce Stanley, Department of the Interior, Regarding Comments and Recommendations for the Draft Environmental Impact Statement for an Early Site Permit at the Clinch River Nuclear Site in Oak Ridge, Roane County, TN – Docket # NRC 2016-0119. (Accession No. ML18191B354)
July 11, 2018	E-mail to NRC from Kendra Abkowitz, Tennessee Department of Environment and Conservation, Regarding TDEC Comment Letter on NRC Early Site Permit for CRN Site Draft EIS. (Accession No. ML18192C176)
July 11, 2018	E-mail to NRC from Theodore Isham, Seminole Nation of Oklahoma, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18194A380)
July 13, 2018	Letter to NRC from Elizabeth Toombs, Cherokee Nation, Regarding Draft Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site. (Accession No. ML18199A044)
July 13, 2018	E-mail to NRC from Linda Langley, Coushatta Tribe of Louisiana, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18264A325)
July 13, 2018	Letter to NRC from Terry Clouthier, Thlopthlocco Tribal Town, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18196A260)
July 20, 2018	NRC Memorandum: Early Site Permit Application for the Clinch River Nuclear Site – Safety Evaluation with No Open Items for Chapter 13, Section 13.3 “Emergency Planning.” (Accession No. ML18186A558)
July 20, 2018	Letter from NRC to J.W. Shea, TVA, Regarding Early Site Permit Application for the Clinch River Nuclear Site – Safety Evaluation with No Open Items for Chapter 13, Section 13.3 “Emergency Planning.” (Accession No. ML18186A557)
August 2, 2018	NRC Memorandum: Summary of Public Meeting to Discuss the Draft Environmental Impact Statement for an Early Site Permit for the Clinch River Nuclear Site. (Package Accession No. ML18206A693)
August 6, 2018	NRC-TVA Publicly-Noticed Meeting (8/6/2018) Topics for Discussion: Clinch River Nuclear (CRN) ESP DEIS. (Accession No. ML18212A356)

August 8, 2018	Meeting Summary from Staff's Examination of Geological Features at TVA's Clinch River Nuclear Site During a 30-31 January 2018 NRC Management Site Visit. (Accession No. ML18220A777)
August 15, 2018	E-mail to NRC from Ray Schiele, TVA, Regarding E-mail Address. (Accession No. ML18243A159)
August 15, 2018	E-mail to NRC from Raymond Schiele, TVA, Regarding Withdrawal of DEIS Comments. (Accession No. M18243A159)
August 15, 2018	NRC-TVA Publicly-Noticed Meeting (August 15, 2018) Historic and Cultural Topics for Discussion: Clinch River Nuclear (CRN) EPS DEIS. (Accession No. ML18220B385)
August 15, 2018	Meeting Summary between the NRC and Tennessee Valley Authority to Discuss Topics Associated with Comments on the Draft Environmental Impact Statement for an Early Site Permit at the Clinch River Nuclear Site [Cultural Resources]. (Accession No. ML18239A254)
August 22, 2018	Advisory Committee on Reactor Safeguards (ACRS) Meeting of the ACRS Subcommittee on Regulatory Policies and Practices. (Accession No. ML18215A273)
September 6, 2018	NRC-TVA Publicly-Noticed Meeting Topics for Discussion: Clinch River Nuclear (CRN) ESP Draft Environmental Impact Statement Request for Additional Information Clarification. (Accession No. ML18249A393)
September 7, 2018	Letter to NRC, from J.W. Shea, TVA, Regarding Status of Clinch River Breeder Reactor Project Wells. (Accession No. ML18253A095)
September 10, 2018	E-mail from NRC to Daniel Stout, TVA, Regarding CRNS ESP Final RAI Env-1 eRAI 9602 (re-issue). (Accession No. ML18253A285)
September 10, 2018	Meeting Summary between the NRC and Tennessee Valley Authority to Provide Clarification Regarding NRC's Request for Additional Information (RAI) Env-1, eRAI-9602. (Accession No. ML18261A046)
September 14, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Clinch River Nuclear Early Site Permit Application Safety Evaluation with No Open Items for Section 17.5, "Quality Assurance Program Description." (Accession No. ML18242A151)
September 21, 2018	E-mail from NRC to Theodore Isham, Seminole Nation of Oklahoma, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18264A327)
September 25, 2018	E-mail from NRC to Elizabeth Toombs, Cherokee Nation, Regarding Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18268A357)

October 5, 2018	Letter to NRC from J.W. Shea, TVA, Regarding Response to Request for Additional Information, eRAI 9602, Related to EIS Postulated Accidents in Support of Early Site Permit Application for Clinch River Nuclear Site. (Accession No. ML18282A227)
October 23, 2018	Meeting Summary of Nonpublic Meeting between TVA and NRC to discuss Tribal NHPA Section 106 concerns. (Accession No. ML18332A421)
November 13, 2018	Letter from NRC to Elizabeth Toombs, Cherokee Nation, Regarding Response to Comments from the Cherokee Nation on the Draft Environmental Impact Statement for an Early Site Permit at the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18267A314)
November 13, 2018	Letter from NRC to E. Patrick McIntyre, Tennessee Historical Commission, Regarding Documentation of Completion of U.S. Nuclear Regulatory Commission's National Historic Preservation Act Section 106 Consultation for the Early Site Permit for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18267A315)
November 13, 2018	Letter from NRC to Terry Clouthier, Thlopthlocco Tribal Town, Regarding Response to Comments from the Thlopthlocco Tribal Town on the Draft Environmental Impact Statement for an Early Site Permit at the Clinch River Nuclear Site in Roane County, Tennessee (THPO File Number 2018-67). (Accession No. ML18267A316)
November 13, 2018	Letter from NRC to Theodore Isham, Seminole Nation of Oklahoma, Regarding Response to Comments from the Seminole Nation of Oklahoma on the Draft Environmental Impact Statement for an Early Site Permit at the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML18267A267)
January 8, 2019	E-mail from NRC to Dustin Boles, U.S. Fish and Wildlife Service, Regarding Consultations Under Section 7 of the ESA. (Accession No. ML19008A307)
January 9, 2019	Letter to NRC from Michael Corrandini, Advisory Committee on Reactor Safeguards, Regarding Early Site Permit – Clinch River Nuclear Site. (Accession No. ML19009A286)
January 18, 2019	Letter to NRC from J.W. Shea, TVA, Regarding Resubmittal of Application for Early Site Permit for Clinch River Nuclear Site (Rev 2). (Accession No. ML19030A485)
January 28, 2019	E-mail from Dustin Boles, U.S. Fish and Wildlife Service, to NRC, Regarding Clinch River Early Site Permit Environmental Review - Consultations under Section 7 of ESA. (Accession No. ML19028A275)

February 4, 2019	Letter from NRC to Michael Corrandini, Advisory Committee on Reactor Safeguards, Regarding Early Site Permit – Clinch River Nuclear Site. (Accession No. ML19022A306)
March 1, 2019	NRC-TVA Publicly-Noticed Meeting (3/1/2019) Topics for Discussion: Changes in Revisions 2 of Clinch River Nuclear (CRN) Site Early Site Permit Application, Part 2 – Site Safety Analysis, Chapter 2; and Part 8 – Enclosures, Plates 2a through 2d. (Accession No. ML19056A548)
March 1, 2019	Meeting Summary of Topics Associated with Part 2, Site Safety Analysis Report of Tennessee Valley Authority's Early Site Permit Application. (Accession No. ML19063B421)
March 8, 2019	Letter from NRC to J.W. Shea, TVA, Regarding Safety Evaluation with No Open Items for Section 13.6 "Physical Security." (Accession No. ML19029A109)
March 18, 2019	Letter to NRC from Joshua Frost, U.S. Army Corps of Engineers, Regarding the Environmental Impact Statement for the Early Site Permit associated with the Clinch River Nuclear Site. (Accession No. ML19080A090)
March 25, 2019	Letter to NRC from J.W. Shea, Regarding Response to Request for Supplemental Information Regarding Changes Made in Revision 2 of the Application for Early Site Permit for Clinch River Nuclear Site. (Accession No. ML19084A244)
April 3, 2019	Final Environmental Impact Statement and Reader's Guide (Package Accession No. ML19087A266)
April 3, 2019	Letter from NRC to J.W. Shea, Regarding Tracking Table for Public Webpage Clinch River Nuclear Site ESP Review. (Accession No. ML19092A418)
April 3, 2019	*Federal Register* Notice - Environmental Impact Statement Issuance. (84 FR 13975)
April 3, 2019	E-mail from NRC to Ray Schiele, TVA, Regarding Clinch River ESP Phase B SE, Section 13.6. (Accession No. ML17291A112)
April 3, 2019	Letter from NRC to David Sickey, Coushatta Tribe of Louisiana, Notification of the Issuance of the Final Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML19053A648)
April 3, 2019	Letter from NRC to Marcellus W. Osceola, Jr., Seminole Tribe of Florida, Notification of the Issuance of the Final Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML19056A165)

April 3, 2019	Letter from NRC to Larry Long, U.S. Environmental Protection Agency, Region 4, Notification of the Issuance of the Final Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML19046A184)
April 3, 2019	Letter from NRC to Bill John Baker, Cherokee Nation, Notification of the Issuance of the Final Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML19053A646)
April 3, 2019	Letter from NRC to Patrick McIntyre, Tennessee Historical Commission, Notification of the Issuance of the Final Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML19053A649)
April 3, 2019	Letter from NRC to Ryan Morrow, Thlopthlocco Tribal Town, Notification of the Issuance of the Final Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML19056A167)
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April 3, 2019	Letter from NRC to Stephanie A. Bryan, Poarch Band of Creek Indians, Notification of the Issuance of the Final Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML19056A169)
April 3, 2019	Letter from NRC to Mary Jennings, U.S. Fish and Wildlife Service, Notification of the Issuance of the Final Environmental Impact Statement for the Early Site Permit Application for the Clinch River Nuclear Site in Roane County, Tennessee. (Accession No. ML19053A750)
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May 24, 2019	Letter from NRC to Scott Breor, Department of Homeland Security (DHS), Request for DHS Determination on DHS-NRC Consultation on the Early Site Permit Application for the Clinch River Nuclear Site. (Accession No. ML19143A203)
May 30, 2019	Email Response to NRC from Felix Pomponi, Department of Homeland Security (DHS), Regarding DHS Determination to Conduct DHS-NRC Consultation on a Future Combined License Application Received by NRC for the Clinch River Nuclear Site. (Accession No. ML19157A345)

APPENDIX C

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APPENDIX D

PRINCIPAL CONTRIBUTORS

Name	Responsibility
Barss, Daniel	Emergency Planning
Bauer, Laurel	Geology
Briethaupt, Stephen	Hydrology
Brown, David	Meteorology
Candelario, Luissette	Geotechnical Engineering
Cheng, Yuan	Hydrology
Clement, Richard	Radioactive Waste Management
Diec, David	Physical Security
Fetter, Allen	Project Management
Giacinto, Joseph	Hydrology
Green, Sharon	Document Editing, Formatting, Styling
Hart, Michelle	Accident Analysis and Radiological Consequences (for Emergency Planning)
Heeszel, David	Seismology
Keim, Andrea	Quality Assurance Inspection
Keith, Felicia	Document Administrative Processing
Mazaika, Michael	Meteorology
Musico, Bruce	Emergency Planning
Quinlan, Kevin	Meteorology
Rodriguez, Ricardo	Geotechnical Engineering
Savwoir, Nick	Quality Assurance Program
Stieve, Alice	Geology
Stirewalt, Gerry	Geology
Sutton, Mallecia	Project Management
Tammara, Seshagiri	Geography-Demography, Site Hazards, Aircraft Hazards, Accident Analysis and Radiological Consequences
Thompson, Jenise	Geology
Wang, Weijun	Geotechnical Engineering
White, Jason	Meteorology

Contractors	Technical Area
Pacific Northwest National Laboratory	Hydrology, FSER Document Management

APPENDIX E

REPORT BY THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS AND RESPONSE LETTER FROM NRC STAFF

E.1 ACRS Review of Relevant SER Chapters and Sections

The relevant chapters and sections of this FSER have undergone a final review by the Advisory Committee on Reactor Safeguards (ACRS), and the results of the committee's review are provided in their final letter report below (ACRS 2019 - ML19009A286).

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

January 9, 2019

The Honorable Kristine L. Svinicki
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
SUBJECT: EARLY SITE PERMIT – CLINCH RIVER NUCLEAR SITE
Dear Chairman Svinicki:

During the 659th meeting of the Advisory Committee on Reactor Safeguards (ACRS), December 6-7, 2018, we completed our review of the early site permit application submitted by the Tennessee Valley Authority (TVA) for two or more small modular reactors (SMRs) at its Clinch River Nuclear (CRN) Site, and the NRC staff's safety evaluation report. Our Regulatory Policies and Practices Subcommittee received an informational briefing on this topic on November 15, 2017, and also reviewed this matter at its meetings on May 15, August 22, October 17, and November 14, 2018. During our reviews, we had the benefit of discussions with the staff and representatives of TVA. We also had the benefit of the referenced documents. Our reviews of the application and the safety evaluation report were conducted to fulfill the requirements of 10 CFR 52.23, which states that the ACRS shall report on those portions of an early site permit application that concern safety.

CONCLUSION AND RECOMMENDATIONS

1. Small modular reactors with design characteristics within the plant parameter envelope used by TVA in developing its Clinch River Nuclear Site early site permit application can be constructed and operated without undue risk to the health and safety of the public.

2. The staff's safety evaluation report of the TVA early site permit application should be issued. The staff accepted TVA's plume exposure pathway emergency planning zone sizing methodology; two *major features* emergency plans (one plan for a site boundary plume exposure pathway emergency planning zone and a second plan for an approximate 2-mile radius plume exposure pathway emergency planning zone); and associated exemption requests. The safety evaluation report also identified a number of items that are treated either as permit conditions or as action items that must be addressed at the operating license stage.

3. The early site permit for the Clinch River Nuclear Site should be issued.

BACKGROUND

An early site permit is the Commission's approval of the safety and environmental suitability for a proposed site to support future construction and operation of one or more nuclear power plants. TVA's submittal addresses site suitability issues, environmental protection issues, and plans for coping with emergencies, independent of the review of a specific nuclear power plant design. Before a plant can be constructed, either under a combined license or a construction permit, a specific reactor technology for the site must be reviewed and approved by the NRC.

TVA filed an early site permit application for its CRN Site in May 2016 and the NRC accepted and docketed the application in December 2016. The TVA application was based on a plant parameter envelope (PPE) approach as a surrogate for a specific plant design. Using inputs from four prospective vendors (NuScale, Holtec, BWX Technologies, and Westinghouse) of light-water reactor-derivative SMR designs, TVA determined bounding values for construction and operation of two or more SMRs at the CRN Site with a total nuclear generating capacity up to 2420 MWt and 800 MWe (up to 800 MWt for a single unit or module). This approach allows TVA flexibility, while also potentially reducing licensing risk.

DISCUSSION

<u>Proposed Site, Population, and Hazards Analyses</u>

The proposed CRN Site encompasses 935 acres of land, bordered by the Department of Energy's Oak Ridge Reservation to the north and east, and by the Clinch River Arm of the Watts Bar Reservoir to the east, south, and west. Located within the City of Oak Ridge, Roane County, Tennessee, it is 6.8 miles east of Kingston, 9.2 miles east-southeast of Harriman, 8.8 miles northwest of Lenoir City, and 25.6 miles west-southwest of Knoxville, Tennessee. The land is owned by the U.S. Government and is managed by TVA as an agent of the federal government.

The exclusion area boundary is delineated by the boundaries of the CRN Property bordered by the Oak Ridge Reservation and the Clinch River. There are no residences, commercial activities, or traversing public roads and active railways within the exclusion area boundary. The low population zone is a one-mile radius from the center point of the site. Population

density predictions for a 50-mile radius around the site are estimated at start of construction (2021), commencement of operations (2027), and through end of plant life (2067) to be well below siting guidelines (i.e., less than 500 people per square mile). The staff found the site information provided to be acceptable and meets the requirements of 10 CFR 100.20.

In general, potential hazards and accidents from nearby industrial, transportation, military, and aircraft operations were analyzed and were demonstrated to be well below frequency cut-offs and/or accidental dose guidelines. The staff in its evaluation of hazards set two permit conditions: one regarding main control room habitability for nearby transport of anhydrous ammonia and chlorine; and a second for the possible construction of a commercial airport in the nearby vicinity (about 6 miles from the site).

Site Characteristics

The CRN Site is well characterized in terms of geology, seismology, meteorology, and hydrology, and benefits from past site characterization (e.g., field meteorology measurements, borings, and excavation work) performed when the site was the location of the proposed, later cancelled, Clinch River Breeder Reactor Project. The staff conducted site visits and audits, performed independent confirmatory calculations, and conducted thorough evaluations and reviews of each of these areas in the application. The staff concluded that the CRN Site characteristics meet the requirements of 10 CFR Part 100, "Reactor Site Criteria" and 10 CFR Part 20, "Standards for Protection Against Radiation." Subject to the safety evaluation report action items and permit conditions, there is reasonable assurance that approved reactor designs falling within the PPE design parameters for the CRN Site characteristics can be operated without undue risk to public health and safety.

Potential Radionuclide Releases

Radioactive Waste Management

TVA developed conservative PPE parameters for normal liquid and gaseous effluent release source terms for use in calculating offsite doses and used the LADTAP-II and GASPAR-II codes, respectively, to conduct exposure pathway dose analyses using site-specific hydrology and meteorology. The staff found that these analyses meet the design objectives of 10 CFR Part 50, Appendix I, environmental standards of 40 CFR Part 190, and dose limits of 10 CFR 20.1301. They concluded that reactor designs falling within the envelope of the PPE normal effluent release source terms and associated offsite doses are without undue risk to public health and safety. The staff issued an action item to verify that calculated doses to the public from normal effluent releases for the chosen reactor design are bounded by the doses evaluated in the early site permit. We concur with the staff's conclusions.

Accident Analyses

To evaluate offsite post-accident doses TVA selected the vendor-supplied design basis accident analyses with the highest post-accident doses for the site-specific dose analysis, and based the PPE source term on light-water reactor fuel representative of the SMR designs under consideration, assuming a single unit or module up to 800 MWt. Using site-specific short-term atmospheric dispersion factors (χ/Q methodology), TVA scaled the vendor-supplied doses and dispersion factors to obtain doses at the exclusion area boundary and low population zone boundaries. TVA was able to demonstrate that the surrogate plant would meet the

requirements of 10 CFR 50.34(a)(1) and 52.17(a)(1): an individual at any point on the exclusion area boundary for any 2-hour period following the onset of fission product release would not receive a radiation dose in excess of 25 rem total effective dose equivalent (TEDE); and an individual located at any point on the outer boundary of the low population zone exposed to the radioactive cloud from the postulated fission product release (during the entire period of its passage) would not receive a radiation dose in excess of 25 rem TEDE.

Consequences for bounding large-break loss-of-coolant accidents in SMRs are expected to be less than for large light-water reactors. TVA performed a comparison to similar analyses for the AP1000 plant (Vogtle 3 & 4 early site permit application) by scaling its thermal power by 0.235 (800MWt/3400 MWt). The scaled AP1000 dose result was 25% greater than the PPE surrogate for the worst 2-hour period, and roughly equivalent for a 30-day period, providing confidence in its analyses. The staff review found the analytical results adequate and acceptable in meeting the requirements of 10 CFR 50.34(a)(1) and 52.17(a)(1), and the PPE source term used not unreasonable in comparison to the AP1000 design. We concur with the staff's accident analysis assessment.

Emergency Preparedness

TVA proposed a risk-informed, dose-based, consequence-oriented methodology to determine the plume exposure pathway (PEP) emergency planning zone (EPZ). This would be consistent with the dose-savings approach developed in NUREG-0396 and used to meet the dose criteria of the Environmental Protection Agency (EPA) early-phase protective action guides (PAGs), (i.e., protection from doses above the 1 rem TEDE limit). The dose savings criteria of NUREG-0396 for determining the PEP EPZ are: 1) the EPZ should encompass those areas in which projected dose from design basis accidents could exceed the PAG; 2) the EPZ should encompass those areas in which the consequences of less severe core melt accidents could exceed the PAG; and 3) the EPZ should be of sufficient size to provide for substantial reduction in early severe health effects in event of more severe core melt accidents (i.e., the conditional probability of exceeding 200 rem whole body dose outside the PEP EPZ is less than 1×10^{-3}).

For the first two criteria, an applicant would analyze design basis accidents and appropriate accident scenarios with a mean core damage frequency greater than 1×10^{-6} per reactor-year, determine source terms, calculate dose consequences, and compare results to the EPA early-phase PAG. For substantial reduction in early health effects, an applicant would use a core damage frequency of greater than 1×10^{-7} per reactor-year to select severe accident scenarios, then repeat the above process to calculate a distance at which the conditional probability to exceed 200 rem exceeds 1×10^{-3}.

Based on the above approach, and taking into consideration design information from the four SMRs, TVA developed two *major features*[a] emergency plans: one with the site boundary as the EPZ and a second with an approximate 2-mile radius EPZ. An evacuation time estimate study was also conducted for the 2-mile radius EPZ. The evacuation time estimate did not identify any physical characteristics unique to the site that would pose a significant impediment to development of future emergency plans.

At least one SMR design is expected to meet the dose criteria for the site boundary EPZ; all four are expected to meet the dose criteria for a 2-mile EPZ. TVA also developed a bounding, non-design-specific, composite, accident release source term for the PPE with a 25% added margin.

[a] 10 CFR 50.47(a)(1)(iv)

Analyses demonstrate that the PEP EPZ criteria are met. The isotopic total release activity over 96 hours resulted in a TEDE of about 0.9 rem at the site boundary. Although we concur that the 96-hour time period was correctly implemented with the example calculations, it is important to select the most severe 96-hour period for the specific design.

TVA is seeking exemption requests to deviate from the 10-mile PEP EPZ [10 CFR 50.33(g) and 50.47(c)(2)], and from certain emergency planning requirements. To support their exemptions request, TVA cited anticipated enhanced safety features of the SMR designs considered: smaller radionuclide inventory and source terms, reduced likelihood of accidents, slower accident progression rates, and features to minimize or mitigate accident consequences.

TVA would then present a complete and integrated emergency plan with the combined license or construction permit application, based on the selected SMR technology and estimated dose consequences, resulting in either an EPZ at the site boundary, the approximate 2-mile radius, or an appropriately scaled EPZ. The ingestion pathway EPZ for the CRN Site would also be described in the application.

The staff concluded that: TVA's PEP EPZ sizing methodology is acceptable because it is consistent with analyses that form the technical basis of the current 10-mile PEP EPZ and maintains the same level of protection (i.e., dose savings); the two *major features* emergency plans are acceptable; and the exemption requests are acceptable and will not present an undue risk to public health and safety. We concur with these staff conclusions.

SUMMARY

The TVA early site permit application and the staff's review demonstrated suitability of the CRN Site considering topics including surrounding population, external hazards, site physical characteristics, potential radionuclide releases, and emergency preparedness. This application is unique in its approach to emergency planning in that it proposes a risk-informed, dose-based, consequence-oriented methodology to determine the appropriate PEP EPZ. We note that this is in parallel to proposed rulemaking on emergency preparedness for small modular reactors and other new technologies, which we agreed with in our recent October 19, 2018 letter on this subject.

The TVA early site permit application benefits from the proposed use of advanced light-water reactor-derivative SMR designs that are expected to exhibit both lower accident frequencies and consequences than the current fleet of large light-water reactors; the large body of knowledge associated with light-water reactor technology, particularly regarding source terms; and extensive light-water reactor operating and licensing experience. TVA's approach to emergency planning in providing dose savings is consistent with that used in developing NUREG-0396 and the staff's proposed current rulemaking on the matter. The early site permit for the Clinch River Nuclear Site should be issued.

Sincerely,
/RA/
Michael L. Corradini
Chairman

REFERENCES

1. Tennessee Valley Authority, "Clinch River Nuclear Site Early Site Permit Application," May 12, 2016 (ML16139A752, ML16144A033, ML16144A074, ML16144A145, ML16144A150, ML16144A151).

2. U.S. Nuclear Regulatory Commission, Selected Chapters from the Final Safety Evaluation Report presented to the ACRS from May 2018 to November 2018, "Clinch River Nuclear Early Site Permit Application Safety Evaluations with No Open Items," (ML18102B203, ML17289B148, ML18288A360, ML17289B252, ML17289B253, ML17289B254, ML17289B255, ML18102B150, ML17289A625, ML17291A052, ML18102B149, ML17291A547).

3. U.S. Nuclear Regulatory Commission, "Acceptance Review Results for an Early Site Permit Application for Clinch River Nuclear Site," January 5, 2017 (ML16356A226).

4. U.S. Nuclear Regulatory Commission, NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear power Plants," December 1978 (ML051390356).

5. U.S. Environmental Protection Agency, EPA-400/R-17/001, "PAG Manual: Protective Action Guidelines and Planning Guidance for Radiological Incidents," January 2017 (ML17044A073).

6. Nuclear Energy Institute, NEI 10-01, "Industry Guidelines for Developing a Plant Parameter Envelope in support of an Early Site Permit," Revision 0, March 2010 (ML101050329).

E.2 NRC Staff Response Letter to the ACRS Final Letter Report

The staff's response letter to the ACRS final letter report is provided below (NRC 2019 – ML19022A306).

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 4, 2019

Dr. Michael L. Corradini, Chairman
Advisory Committee on Reactor Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: EARLY SITE PERMIT—CLINCH RIVER NUCLEAR SITE

Dear Dr. Corradini:

On behalf of the U.S. Nuclear Regulatory Commission (NRC) staff, I would like to thank you for the letter from the Advisory Committee on Reactor Safeguards (ACRS) dated January 9, 2019 (Agencywide Documents Access and Management System Accession No. ML19009A286), on the early site permit (ESP) application submitted by the Tennessee Valley Authority (TVA) for the Clinch River Nuclear (CRN) Site. Your letter came after the ACRS's 659th meeting on December 6–7, 2018, during which the ACRS completed its review of the ESP application and the NRC staff's safety evaluation report (SER).

The ACRS letter included the following conclusions and recommendations:

- Small modular reactors with design characteristics within the plant parameter envelope used by TVA in developing its CRN Site ESP application can be constructed and operated without undue risk to the health and safety of the public.
- The staff's SER of the TVA ESP application should be issued.
- The ESP for the CRN Site should be issued.

The staff appreciates the Committee's efforts and agrees with its conclusions and recommendations.

The staff would like to clarify one statement made in the ACRS letter. As discussed during the meeting, TVA proposed a risk-informed, dose-based, consequence-oriented methodology to determine the plume exposure pathway (PEP) emergency planning zone (EPZ). TVA's methodology uses a dose-savings approach consistent with NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants," issued December 1978, and the dose criteria of the U.S. Environmental Protection Agency's early-phase protective action guides. The ACRS

letter dated January 9, 2019, stated, “At least one SMR design is expected to meet the dose criteria for the site boundary EPZ; all four are expected to meet the dose criteria for a 2-mile EPZ.” To clarify, although this is TVA’s stated expectation, the NRC staff has not verified this conclusion because it is outside the scope of the ESP review. A combined license applicant that references the ESP will use the PEP EPZ size methodology with plant-specific information to determine the appropriate PEP EPZ size and emergency plan for the site. Any applicant referencing the ESP must also satisfy the permit conditions described in Section 13.3 of the SER.

The staff appreciates the thorough review of the ESP application for the CRN Site by the ACRS. We look forward to future meetings with the ACRS.

Sincerely,
/RA/
Frederick D. Brown, Director
Office of New Reactors

Docket No.: 52-047
cc: Chairman Svinicki
Commissioner Baran
Commissioner Burns
Commissioner Caputo
Commissioner Wright
SECY